MICROPROCESSORS
AND
PERIPHERALS

DATA BOOK

NEC

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GENERAL INFORMATION 1

Section 1 – General Information

Introduction

NEC offers a wide variety of microprocessors and support products for you to choose from. This volume COVERS microprocessor, standard peripherals and intelligent peripheral controller products. These products are offered in a variety processes (NMOS and CMOS) and in a variety of package types. This extraordinary selection of products provides the systems designer with a wide assortment of design alternatives with products that truly fit your data processing, communications, instrumentation, industrial, and telecommunications needs.

The NEC microcomputer data book is divided into the following sections.

1. General Information. This section includes ordering information and product selection guides.

2. Quality and Reliability. The NEC concepts of designed-in quality and total quality control as a company-wide activity are discussed here.

3. CMOS Microprocessors. This section covers NEC's 8-bit, 16-bit and 32-bit lines of CMOS microprocessors. Included is NEC's proprietary V-Series of advanced CMOS microprocessors and co-processors.

4. NMOS Microprocessors. This section covers NEC's 8-bit, 16-bit lines of NMOS microprocessors.

5. Intelligent Peripheral Controllers. This section covers NEC's line of Magnetic Media, Communication and Graphic Controllers. Included are floppy disk, hard disk, disk support chips, serial controllers, LAN controller, and GPIB controller.

6. CMOS System Support Products. This section covers NEC's line of CMOS System Support Products. These products are CMOS versions of most of the NMOS System Support Products. They have been specially designed for low cost, low power system needs.

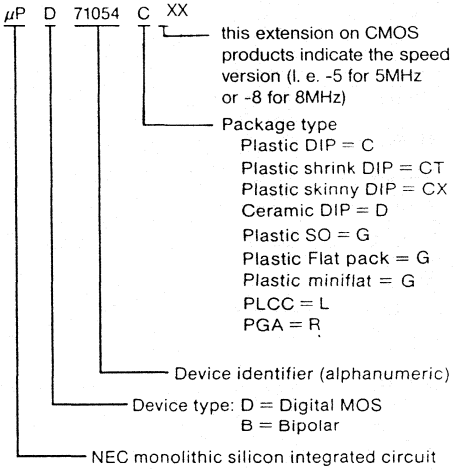
7. NMOS System Support Products. This section covers NEC's line of 8085/8088/8086 NMOS and Bipolar system support chips.

8. Packaging. This section provides dimensioned package drawings and a cross-reference from package type to device numbers.

Ordering Information

Part numbers for ordering microcomputer products are listed on the first page of each data sheet. NEC's part numbers consist of four elements as shown in the example that follows.

Part Numbering System



CMOS Microprocessor Selection Guide

Device	Description	Data Bits	Clock (MHz)	Supply Voltage (V)	Power Dissipation		Package	Pins
					Active (mA)	Standby (mA)		
μPD70008C	Microprocessor (CMOS Z80)	8	4	+5	30	.5	Plastic DIP	40
μPD70008AC-4	Microprocessor (CMOS Z80)	8	4	+5	30	.4	Plastic DIP	40
μPD70008AC-6	Microprocessor (CMOS Z80)	8	6	+5	30	.4	Plastic DIP	40
μPD70008AG-4	Microprocessor (CMOS Z80)	8	4	+5	30	.4	Plastic Miniflat	44
μPD70008AG-6	Microprocessor (CMOS Z80)	8	6	+5	30	.4	Plastic Miniflat	44
μPD70008AL-6	Microprocessor (CMOS Z80)	8	6	+5	30	.4	PLCC	44
μPD70108C-5	Microprocessor	8/16	5	+5	45	6	Plastic DIP	40
μPD70108C-8	Microprocessor	8/16	8	+5	45	6	Plastic DIP	40
μPD70108D-5	Microprocessor	8/16	5	+5	45	6	Ceramic DIP	40
μPD70108D-8	Microprocessor	8/16	8	+5	45	6	Ceramic DIP	40
μPD70108D-10	Microprocessor	8/16	10	+5	45	6	Ceramic DIP	40
μPD70108G-5	Microprocessor	8/16	5	+5	45	6	Plastic Flat pack	
μPD70108G-8	Microprocessor	8/16	8	+5	45	6	Plastic Flat pack	
μPD70108L-5	Microprocessor	8/16	5	+5	45	6	PLCC	44
μPD70108L-8	Microprocessor	8/16	8	+5	45	6	PLCC	44
μPD70116C-5	Microprocessor	16	5	+5	45	6	Plastic DIP	40
μPD70116C-8	Microprocessor	16	8	+5	45	6	Plastic DIP	40
μPD70116D-5	Microprocessor	16	5	+5	45	6	Ceramic DIP	40
μPD70116D-8	Microprocessor	16	8	+5	45	6	Ceramic DIP	40
μPD70116D-10	Microprocessor	16	10	+5	45	6	Ceramic DIP	40
μPD70116G-5	Microprocessor	16	5	+5	45	6	Plastic Flat pack	
μPD70116G-8	Microprocessor	16	8	+5	45	6	Plastic Flat pack	
μPD70116L-5	Microprocessor	16	5	+5	45	6	PLCC	44
μPD70116L-8	Microprocessor	16	8	+5	45	6	PLCC	44
μPD70208R-8	Microprocessor	8/16	8	+5	50	10	PGA	68
μPD70208L-8	Microprocessor	8/16	8	+5	50	10	PLCC (Note 1)	68
μPD70208G-8	Microprocessor	8/16	8	+5	50	10	Plastic Miniflat	80
μPD70216R-8	Microprocessor	16/16	8	+5	50	10	PGA	68
μPD70216L-8	Microprocessor	16/16	8	+5	50	10	PLCC (Note 1)	68
μPD70216G-8	Microprocessor	16/16	8	+5	50	10	Plastic Miniflat	80
μPD70616R	Microprocessor	16/32	16	+5	((Not 1))	(Note 1)	PGA (Note 1)	68
μPD72191D	Floating Point Processor	16/32/ 64/80	8	+5	(Note 1)	(Note 1)	Ceramic DIP	40

1. Available first quarter 1987.

NMOS and HMOS Microprocessor Selection Guide

Device	Description	Data Bits	Clock (MHz)	Supply Voltage (V)	Power Dissipation		Package	Pins
					Active (mA)	Standby (mA)		
μPD780C	NMOS Microprocessor	8	2.5	+5	150	—	Plastic DIP	40
μPD780C-1	NMOS Microprocessor	8	4	+5	200	—	Plastic DIP	40
μPD780C-2	NMOS Microprocessor	8	6	+5	200	—	Plastic DIP	40
μPD8085AC-2	NMOS Microprocessor	8	5	+5	170	—	Plastic DIP	40
μPD8085AHC	HMOS Microprocessor	8	3	+5	135	—	Plastic DIP	40
μPD8085AHC-2	HMOS Microprocessor	8	5	+5	135	—	Plastic DIP	40
μPD8086D	HMOS Microprocessor	16	5	+5	340	—	Cerdip	40
μPD8086D-2	HMOS Microprocessor	16	8	+5	350	—	Cerdip	40
μPD8088D	HMOS Microprocessor	8	5	+5	340	—	Cerdip	40
μPD8088D-2	HMOS Microprocessor	8	8	+5	350	—	Cerdip	40

Intelligent Peripheral Controller Selection Guide

Device	Description	Data Bits	Clock (MHz)	Supply Voltage (V)	Power Dissipation		Package	Pins
					Active (mA)	Standby (mA)		
Magnetic Media Controllers								
μPD765AC	NMOS Single/ Double Density FDC	8	8	+5	150	—	Plastic DIP	40
μPD765AC-2	NMOS Single/ Double Density FDC	8	8	+5	150	—	Plastic DIP	40
μPD7265C	NMOS Single/ Double Density FDC	8	8	+5	150	—	Plastic DIP	40
μPD7265C-2	NMOS Single/ Double Density FDC	8	8	+5	150	—	Plastic DIP	40
μPD72065C	CMOS Single/ Double Density FDC	8	8	+5	10	.5	Plastic DIP	40
μPD72065G	CMOS Single/ Double Density FDC	8	8	+5	10	.5	Plastic Flat pack	52
μPD72065L	CMOS Single/ Double Density FDC	8	8	+5	10	.5	PLCC	44
μPD72066C	CMOS Single/ Double Density FDC	8	8	+5	10	.5	Plastic DIP	40
μPD72066G	CMOS Single/ Double Density FDC	8	8	+5	10	.5	Plastic Flat pack	52
μPD72066L	CMOS Single/ Double Density FDC	8	8	+5	10	.5	PLCC	44
μPB9201C	Bipolar Floppy Disk Interface	—	16	+5	270	—	Plastic DIP	40
μPD71065G	CMOS Analog Phase-Locked Loop	—	19.2	+5	25	—	Plastic SO	28
μPD71066CT	CMOS Analog Phase-Locked Loop	—	19.2	+5	25	—	Plastic Shrink DIP	30
μPD7260D	NMOS Hard/Floppy Disk Controller	8	12	+5	320	—	Ceramic DIP	40
μPD7261AD	NMOS Hard Disk Controller	8	12	+5	320	—	Ceramic DIP	40
μPD7261BD-18	NMOS Hard Disk Controller	8	18	+5	320	—	Ceramic DIP	40
μPD9306AC	CMOS Hard Disk Interface	—	10	+5	30	—	Plastic DIP	28
μPD7262D	NMOS ESDI Controller	8	18	+5	320	—	Ceramic DIP	40

Image Progressing

Device	Description	Data Blitz	Clock (MHz)	Supply Voltage (V)	Power Dissipation		Package	Pins
					Active (mA)	Standby (mA)		
μPD728D	NMOS Image Pipelined Processor	16	5	+5	500	–	Ceramci DIP	40
μPD9305R	CMOS IPP Support Chip	8/16	10	+5	100	–	PGA	132

Intelligent Peripheral Controller Selection Guide (cont)

Device	Description	Data Bits	Clock (MHz)	Supply Voltage (V)	Power Dissipation Active (mA)	Power Dissipation Standby (mA)	Package	Pins
Communications Controllers								
μPD7201AC	NMOS MPS Communications Controller	8	4	+5	230	—	Plastic DIP	40
μPD7201AD	NMOS MPS Communications Controller	8	4	+5	230	—	Ceramic DIP	40
μPD72001C	CMOS MPS Communications Controller	8	8	+5	40	2	Plastic DIP	40
μPD72001L	CMOS MPS Communications Controller	8	8	+5	40	2	PLCC	44
μPD72105C	CMOS Omninet Local Network Controller	8	8	+5	40	2	Plastic DIP	48
μPD72105L	CMOS Omninet Local Network Controller	8	8	+5	40	2	PLCC	52
μPD7210C	NMOS Intelligent GPIB Controller for Listener, Talker, Controller	8	8	+5	180	—	Plastic DIP	40
Graphics Controllers								
μPD7220AD	NMOS Graphics Display Controller	8	6	+5	270	—	Ceramic DIP	40
μPD7220AD-1	NMOS Graphics Display Controller	8	7	+5	270	—	Ceramic DIP	40
μPD7220AD-2	NMOS Graphics Display Controller	8	8	+5	270	—	Ceramic DIP	40
μPD7225G-00	LCD 7/14 Segment Controller/Driver	8 (serial)	0.2	2.7-5.5	0.1	–	Plastic Flat, Bent Leads	52
μPD7225G-01	LCD 7/14 Segment Controller/Driver	8 (serial)	0.2	2.7-5.5	0.1	–	Plastic Flat, Straight Leads	52
μPD7227G-11	LCD 8 x 40 Dot Matrix Controller/Driver	8 (serial)	1.1	5	0.1	–	Plastic Flat, Straight Leads	64
μPD7227G-12	LCD 8 X 40 Dot Matrix Controller/Driver	8 (serial)	1.0	5	0.1	–	Plastic Flat, Bent Leads	64
μPD7228G-12	LCD 8 x 50/ 16 x 42 Dot Matrix Controller/Driver	8 (serial) 4 (parallel)	1.1	5	0.2	–	Plastic Flat, Bent Leads	80
μPD7228AG-12	LCD 8 x 50/ 16 x 42 Dot Matrix Controller/Driver with 12.5 V for VLCD	8 (serial) 4 (parallel)	1.1	5	0.2	0.02	Plastic Flat Bent Leads	80
μPD7229G-12	LCD 8 x 50/ 16 x 42 Dot Matrix Controller Driver with Customized Character Set	8 (serial) 4 (parallel)	1.1	5	0.2	0.02	Plastic Flat Bent Leads	80

CMOS System Support Product Selection Guide

Device	Description	Data Bits	Clock (MHz)	Supply Voltage (V)	Power Dissipation		Package	Pins
					Active (mA)	Standby (mA)		
μPD71011C	Clock Pulse Generator/Driver	—	20	4.5 to 5.5	30	—	Plastic DIP	18
μPD71011G	Clock Pulse Generator/Driver	—	20	4.5 to 5.5	30	—	Plastic SO	20
μPD71051C	Serial Control Unit	8	8	4.5 to 5.5	10	.05	Plastic DIP	28
μPD71051G	Serial Control Unit	8	8	4.5 to 5.5	10	.05	Plastic Miniflat	44
μPD71051L	Serial Control Unit	8	8	4.5 to 5.5	10	.05	PLCC	28
μPD71054C	Programmable Timer/Counter	8	8	4.5 to 5.5	30	.05	Plastic DIP	24
μPD71054G	Programmable Timer/Counter	8	8	4.5 to 5.5	30	.05	Plastic Miniflat	44
μPD71054L	Programmable Timer/Counter	8	8	4.5 to 5.5	30	.05	PLCC	28
μPD71055C	Parallel Interface Unit	8	8	4.5 to 5.5	15	.05	Plastic DIP	40
μPD71055G	Parallel Interface Unit	8	8	4.5 to 5.5	15	.05	Plastic Miniflat	44
μPD71055L	Parallel Interface Unit	8	8	4.5 to 5.5	15	.05	PLCC	44
μPD71059C	Interrupt Control Unit	8	8	4.5 to 5.5	9	.05	Plastic DIP	28
μPD71059G	Interrupt Control Unit	8	8	4.5 to 5.5	9	.05	Plastic Miniflat	44
μPD71059L	Interrupt Control Unit	8	8	4.5 to 5.5	9	.05	PLCC	28
μPD71071C	DMA Controller	8/16	8	4.5 to 5.5	30	.01	Plastic DIP	48
μPD71071D	DMA Controller	8/16	8	4.5 to 5.5	30	.01	Ceramic DIP	48
μPD71071G	DMA Controller	8/16	8	4.5 to 5.5	30	.01	Plastic Flat pack	52
μPD71071L	DMA Controller	8/16	8	4.5 to 5.5	30	.01	PLCC	52
μPD71082C	Transparent Latch	8	8	4.5 to 5.5	20	.08	Plastic DIP	20
μPD71082G	Transparent Latch	8	8	4.5 to 5.5	20	.08	Plastic SO	20
μPD71083C	Transparent Latch	8	8	4.5 to 5.5	20	.08	Plastic DIP Inverted	20
μPD71083G	Transparent Latch	8	8	4.5 to 5.5	20	.08	Plastic SO	20
μPD71084C	Clock Pulse Generator/Driver	—	25	4.5 to 5.5	30	—	Plastic DIP	18
μPD71084G	Clock Pulse Generator/Driver	—	25	4.5 to 5.5	30	—	Plastic SO	20
μPD71086C	Bus Buffer/Driver	8	8	4.5 to 5.5	40	.08	Plastic DIP	20
μPD71086G	Bus Buffer/Driver	8	8	4.5 to 5.5	40	.08	Plastic SO	20
μPD71087C	Bus Buffer/Driver	8	8	4.5 to 5.5	40	.08	Plastic DIP Inverted	20
μPD71087G	Bus Buffer/Driver	8	8	4.5 to 5.5	40	.08	Plastic SO	20
μPD71088C	System Bus Controller	—	8	4.5 to 5.5	20	.08	Plastic DIP	20
μPD71088G	System Bus Controller	—	8	4.5 to 5.5	20	.08	Plastic SO	20
μPD82C43C	Input/Output Expander	—	5	4.5 to 5.5	40	—	Plastic DIP	24
μPD82C43G	Input/Output Expander	—	5	4.5 to 5.5	40	—	Plastic SO	24

NMOS System Support Product Selection Guide

Device	Description	Data Bits	Clock (MHz)	Supply Voltage (V)	Power Dissipation		Package	Pins
					Active (mA)	Standby (mA)		
μPD8155C	256 x 8 RAM with I/O Ports and Timer	8	3	4.5 to 5.5	180	—	Plastic DIP	40
μPD8155C-2	256 x 8 RAM with I/O Ports and Timer	8	5	4.5 to 5.5	180	—	Plastic DIP	40
μPD8155HC	256 x 8 RAM with I/O Ports and Timer	8	3	4.5 to 5.5	180	—	Plastic DIP	40
μPD8155HC-2	256 x 8 RAM with I/O Ports and Timer	8	5	4.5 to 5.5	180	—	Plastic DIP	40
μPD8156C	256 x 8 RAM with I/O Ports and Timer	8	3	4.5 to 5.5	180	—	Plastic DIP	40
μPD8156C-2	256 x 8 RAM with I/O Ports and Timer	8	5	4.5 to 5.5	180	—	Plastic DIP	40
μPD8156HC	256 x 8 RAM with I/O Ports and Timer	8	3	4.5 to 5.5	180	—	Plastic DIP	40
μPD8156HC-2	256 x 8 RAM with I/O Ports and Timer	8	5	4.5 to 5.5	180	—	Plastic DIP	40
μPD8216C	Parallel Bidirectional Bus Driver	4	—	4.5 to 5.5	130	—	Plastic DIP	16
μPB8216C	Parallel Bidirectional Bus Driver	4	—	4.5 to 5.5	130	—	Plastic DIP	16
μPB8226C	Parallel Bidirectional Bus Driver	4	—	4.5 to 5.5	120	—	Plastic DIP	16
μPD8237AC-5	Programmable DMA Controller	8	5	4.5 to 5.5	150	—	Plastic DIP	40
μPD8243C	Input/Output Expander	—	5	4.5 to 5.5	20	—	Plastic DIP	24
μPD8243HC	HMOS Input/Output Expander	—	5	4.5 to 5.5	20	—	Plastic DIP	24
μPD8251AC	Programmable Communication Interface	8	3/5	4.5 to 5.5	100	—	Plastic DIP	28
μPD8251AFC	Programmable Communication Interface	8	3/5	4.5 to 5.5	100	—	Plastic DIP	28
μPD8253C-2	Programmable Internal Timer	8	5	4.5 to 5.5	140	—	Plastic DIP	24

NMOS System Support Product Selection Guide (cont)

Device	Description	Data Bits	Clock (MHz)	Supply Voltage (V)	Power Dissipation		Package	Pins
					Active (mA)	Standby (mA)		
μPD8259AC-2	Programmable Interrupt Controller	8	5	4.5 to 5.5	85	—	Plastic DIP	28
μPD8279C-2	Programmable Keyboard/Display Interface	—	5	4.5 to 5.5	120	—	Plastic DIP	40
μPB8282C	Octal Latch	8	8	4.5 to 5.5	160	—	Plastic DIP	20
μPB8283C	Octal Latch	8	8	4.5 to 5.5	160	—	Plastic DIP	20
μPB8284AD	Clock Generator/ Driver	—	24	4.5 to 5.5	140	—	Cerdip	18
μPB8286C	Octal Bus Transceiver	8	8	4.5 to 5.5	160	—	Plastic DIP	20
μPB8287C	Octal Bus Transceiver	8	8	4.5 to 5.5	130	—	Plastic DIP	20
μPB8288D	CPU System Bus Controller	—	10	4.5 to 5.5	230	—	Cerdip	20
μPB8289D	Bus Arbiter	—	8	4.5 to 5.5	165	—	Cerdip	20

μPD70208/216 Hardware Development Tool Selection Guide

Device	Description
IE-70108-S	In circuit emulator for μPD70108 (with V20 pod)
IE-70116-S	In-circuit emulator for μPD70116 (with V30 pod)
IE-70108-001	Optional pod unit for μPD70108
IE-70116-001	Optional pod unit for μPD70116
IE-70208-S008	In-circuit emulator for μPD70208 (with V40 pod)
IE-70216-S008	In-circuit emulator for μPD70216 (with V50 pod)
IE-70208-1008	Optional pod unit for μPD70208 emulation
IE-70216-1008	Optional pod unit for μPD70216 emulation
IE-70216-1508	Converts IE-70108/70116-S to IE-70208/70216-S008

μPD70108/116/208/216 Software Relocatable Assembler Development Tool Selection Guide

Device	Host	Operating System
RAC86-08SS-70116	APC	CP/M-86*
RAC86-I5DD-70116	IBM-XT	CP/M-86
RAPCD-I5DD-70116	IBM-XT	PC-DOS*
RASPD-I5DD-70116	PCD (Siemens)	MS-DOS*
RAIS3-08SD-70116	Intel MDS	ISIS3*
RAUNX-0T16-70116	VAX	ULTRIX*
RAVMS-0T16-70116	VAX	VMS*

PG1000 PROM Programmer Selection Guide

Device	Host	Operating System
CCC86-08SS-70116	APC	CP/M-86
CCC86-I5DD-70116	IBM-XT	CP/M-86
CCCPCD-I5DD-70116	IBM-XT	PC-DOS
CCSPD-I5DD-70116	PCD (Siemens)	MS-DOS
CCIS3-08SD-70116	Intel MDS	ISIS3
CCUNX-0T16-70116	VAX	ULTRIX
CCVMS-0T16-70116	VAX	VMS

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QUALITY AND RELIABILITY 2

Section 2 – Quality and Reliability

Introduction

As large-scale integration reaches a higher level of density, reliability of devices mposes a profound impact on system reliability. And as device reliability becomes a major factor, test methods to assure acceptable reliability become more complicated. Simply performing a reliability test according to a conventional method cannot satisfy he demanding requirements for higher reliability. At these new, higher levels of LSI density, it is increasingly difficult to activate all the elements in the internal circuits. A different philosophy and methodology is needed for reliability assurance. Moreover, as integration density increases, the degradation of internal elements in an LSI device is seldom detected by measuring characteristics across external terminals.

In order to improve and guarantee a certain level of reliability for large-scale integrated circuits, it is essential to build quality and reliability into the product. Then, the conventional reliability tests are followed to ensure that the product demonstrates an acceptable level of reliability.

NEC has introduced the concept of total quality control (TQC) across its entire semiconductor product line. By adopting TQC, NEC can build quality into the product and thus assure higher reliability. The concept and methodology of total quality control are company-wide activities involving workers, engineers, quality control staffs, and all levels of management.

NEC has also introduced a prescreening method into the production line that helps eliminate potentially defective units. The combination of building quality in and screening projected early failures out has resulted in superior quality and excellent reliability.

Technology Description

Most large-scale integrated circuits utilize high-density, MOS technology. State-of-the-art high performance has been achieved by introducing fine-line generation techniques. By reducing physical parameters, circuit density and performance increase while active circuit power dissipaton decreases. The data presented here shows that this advanced technology yields products as reliable as those from previous technologies.

Reliability Testing

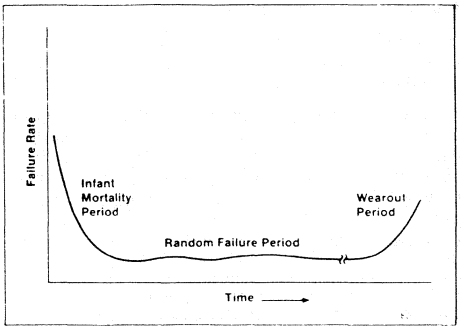
Reliability is defined as the characteristics of an item expressed by the probability that it will perform a required function under stated conditions for a stated period of time. This involves the concept of probability, definition of required function(s), and the critical time used in defining the reliability.

Definition of a required function, by implication, treats the definition of a failure. Failure is defined as the termination of the ability of a device to perform its required function. Furthermore, a device is said to have failed if it shows inability to perform within quaranteed parameters as given in an electrical specification.

Discussion of reliability and failure can be approached in two ways: with respect to systems or to individual devices. The accumulation of normal device failure rates constitutes the expected failure rate of the system hardware. Important considerations here are the constant failure period, the early failure (infant mortality) period, and overall reliability level. With regard to individual devices, areas of prime interest include specific failure mechanisms, failures in accelerated tests, and screening tests.

Some of these failure considerations pertain to both systems and devices. The probability of no failures in a system is the product of the probability of no failure in each of its components. The failure rate of system hardware is then the sum of the failure rates of the components used to construct the system.

Figure 1. Reliability Life (Bathtub) Curve



Life Distribution

The fundamental principles of reliability engineering predict that the failure rate of a group of devices will follow the well-known bathtub curve in figure 1. The curve is divided into three regions: infant mortality, random failures, and wearout failures.

Infant mortality, as the name implies, represents the early-life failures of devices. These failures are usually associated with one or more manufacturing defects.

After some period of time, the failure rate reaches a low value. This is the random failure portion of the curve, representing the useful portion of the life of a device. During this random failure period, there is a decline in the failure rate due to the depletion of potential random failures from the general population.

The wearout failures occur at the end of the device's useful life. They are characterized by a rapidly rising failure rate over time as devices wear out both physically and electrically.

Thus, for devices that have very-long life expectancies compared to those of systems, the areas of concern will be the infant mortality and the random failure portions of the population.

The system failure rates are related to the collective device failure rates. In a given system, after elimination of the early failures, the system will be left to the failure rate of its components. In order to make proper projections of the failure rate in the operating environment, time-to-failure must be accelerated in tests in a predictable way.

Failure Distribution at NEC

Integrated circuits returned to NEC from the field underwent extensive failure analysis at NEC's Integrated Circuit Division.

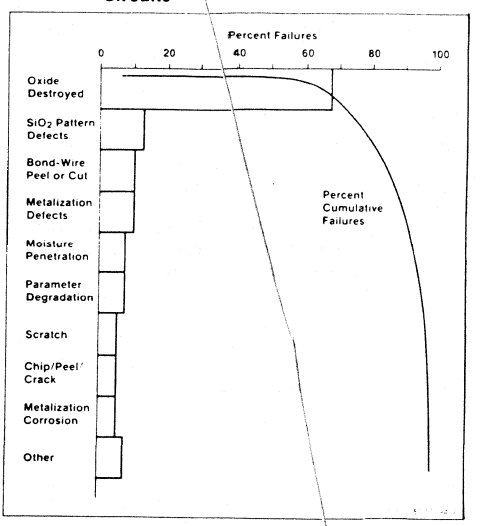
First, approximately 50 percent of the field returns were found to be damaged either from improper handling or misuse of the devices. These units were eliminated from the analysis. The remaining failed units were classified by their failure mechanisms as depicted in figure 2. These failures were then related to the major integrated circuit failure mechanisms and to their origins in a particular manufacturing step.

As shown in figure 2, the first four failure mechanisms accounted for more than 90 percent of total failures. As a result, NEC improved processes and material to reduce these failures. Additionally, NEC introduced screening procedures to detect and eliminate defective devices.

Temperature, humidity, and bias tests are used for testing the moisture resistance of plastic encapsulated integrated circuits. NEC developed a special process to improve the plastic encapsulation material. As a result, moisture-related—thus packaging-related—failures have been drastically reduced.

As a preventive measure, NEC has introduced a special screening procedure embedded in the production line. A burn-in at an elevated temperature is performed for 100 percent of the lots. This burn-in effectively removes the potentially defective units. In addition, improvement of the plastic encapsulation material has lowered the failures in a high-temperature and high-humidity environment.

Figure 2. Failure Distribution of MOS Integrated Circuits



Accelerated Reliability Testing

As an example, assume that an electronic system contains 1000 integrated circuits and can tolerate 1 percent system failures per month. The failure rate per component is:

$$\frac{0.01 \text{ Failures}}{720\text{K Device Hours}} = 13.888 \times 10^{-9} \text{ Failures/Hour or } 13.8888 \text{ FITs}$$

where FIT = Failure units per 10^9 device hours

To demonstrate this failure rate, note that 13.8888 FITs corresponds to one failure in about 7000 devices during an operating test of 10,000 hours. It is quickly apparent that a test condition is required to accelerate the time-to-failure in a predictable and understandable way. The implicit requirement for the accelerated stress test is that the relationship between the accelerated stress testing condition and the condition of actual use be known.

A most common time-to-failure relationship involves the effect of temperature, which accelerates many physiochemical reactions leading to device failure. Other environmental conditions are voltage, current, humidity, vibration, or some combination of these. Table 1 lists the reliability assurance tests performed at NEC for integrated circuits.

Table 1. Monthly NEC Reliability Tests

Test	MIL-STD-883 Method	Test Conditions
Life Test		
High-temperature, operating	1005A, D	T_A = 100 to 125 °C for 1000 hours
High-temperature, storage	1008C	T_A = 150 °C for 1000 hours
High-temperature, high-humidity test	—	T_A = 85 °C at 85% RH for 1000 hours
Pressure cooker test	—	T_A = 125 °C at 2.3 atm for 168 hours
Environmental Test		
Soldering heat test	2031 (MIL-STD-750)	T = 260 °C for 10 s without flux
Temperature cycle	1010C	T = −65 to +150 °C for 10 cycles
Thermal shock	1011A	T = 0 to 100 °C for 15 cycles
Lead fatigue	2004B2	at 250 gm: 3 leads, 3 bends
Solderability	2003	T = 230 °C for 5 s with flux

Temperature Effect. The effect of temperature that concerns us is that which responds to the Arrhenius relationship. This relates the reaction rate to temperature.

$$R = R_o \exp(-E_a/kT)$$

where R_o = Constant
E_a = Activation energy in eV
k = Boltzmann's constant = 8.617×10^{-5} eV/K
T = Absolute temperature in kelvin (K)

The significance of this relationship is that the failure mechanisms of semiconductor devices are directly applicable to it. A linear relationship between failure mechanism and time is assumed.

Activation Energy. Associated with each failure mechanism is an activation energy value. Table 2 lists some of the more common failure mechanisms and the associated activation energy of each.

Table 2. Activation Energy and Detection of Failure Mechanisms

Failure Mechanism	Activation Energy	Detection
Oxide defect	0.3 eV	High-temperature operating life test
Silicon defect	0.3 eV	
Ionic contamination	1.0-1.35 eV	
Electromigration	0.4-0.8 eV	
Charge injection	1.3 eV	
Gold-aluminum interface	0.8 eV	
Metal corrosion	0.7 eV	High-humidity operating life test

High-Temperature Operating Life Test. This test is used to accelerate failure mechanisms by operating the devices at an elevated temperature of 125 °C. The data obtained is translated to a lower temperature by using the Arrhenius relationship.

High-Temperature and High-Humidity Test. Semiconductor integrated circuits are highly sensitive to the general accelerating effect of humidity in causing electrolytic corrosion between biased lines. The high-temperature and high-humidity test is performed to detect failure mechanisms that are accelerated by these conditions. This test is effective in accelerating leakage-related failures and drifts in device parameters due to process instability.

High-Temperature Storage Test. Another common test is the high-temperature storage test in which devices are subjected to elevated temperatures with no applied bias. This test is used to detect mechanical problems and process instability.

Environmental Test. Other environmental tests are performed to detect problems related to the package, material, susceptibility to extremes in environment, and problems related to usage of the devices.

Failure Rate Calculation and Prediction

Analysis of integrated circuit failure rates can serve many useful purposes. For example, the early-life failure rate helps establish a warranty period, while the mature-life failure rate aids in estimating repair costs, spare parts stock requirements, or product downtime. Accurate prediction of failure rates can also be used for process control.

The following sections describe the failure rate calculation and prediction methods used by NEC's Integrated Circuit Division.

The Arrhenius Model

Most integrated circuit failure mechanisms depend to some degree on temperature. This relationship can be represented by the Arrhenius model, which includes the effects of temperature and activation energy of the failure mechanisms.

As applied to accelerated life testing of integrated circuits, the Arrhenius model assumes that degradation of a performance parameter is linear with time. Temperature dependence is taken to be the exponential function that defines the probability of occurrence. The relationship of failure rate to temperature is expressed as:

$$F_1 = F_2 \exp[(E_a/k) \times (1/T_1 - 1/T_2)]$$

Where: F_2 = Failure rate at T_2
F_1 = Failure rate at T_1
E_a = Activation energy in eV
k = Boltzmann's constant
T = Operating junction temperature in kelvin (K)

The equation explains the thermal dependence of integrated circuit failure rates and is used for derating the resulting failure rate to a more realistic temperature.

Acceleration Factor

The acceleration factor is the factor by which the failure rate can be accelerated by increased temperature. This factor is derived from the Arrhenius failure rate expression, resulting in the following form.

$$A = F_1/F_2 = \exp[(E_a/k) \times (1/T_1 - 1/T_2)]$$

where A = Acceleration factor
F_2 = Failure rate at T_2
F_1 = Failure rate at T_1

In calculating the field reliability of an integrated circuit, it is necessary to calculate the junction temperature. In general, the junction temperature will depend on the ambient temperature, cooling, package type, operating cycle time, and power dissipation of the circuit itself. In these terms, the junction temperature (T_J) is expressed as:

$$T_J = T_A + P_d A_f \theta_{JA}$$

where T_J = Junction temperature
T_A = Ambient temperature
P_d = Power dissipation
A_f = Air flow factor
θ_{JA} = Package thermal resistance

Table 3 lists derating factors of various failure mechanisms. This table is generated assuming that an accelerated test is performed at a junction temperature of 125°C. The result is then derated to 55°C junction temperature. The acceleration factor may then be obtained by taking the inverse of the derating factor.

Table 3. Derating Factors of Failure Mechanisms

Failure Mechanisms	Activation Energy, eV	Derating Factor
Oxide defect	0.3	0.1546
Silicon defect	0.3	0.1546
Ionic contamination	1.0	0.001984
Electromigration	0.4	0.08307
Charge injection	1.3	0.0003067
Metal corrosion	0.7	0.01315
Gold-aluminum interface	0.8	0.006886

The acceleration of failure mechanisms in a high-humidity and high-temperature environment must be expressed as a function not only of temperature but also of humidity.

According to the reliability test statistics, the acceleration factor in such an environment can best be approximated with Peck's model as follows.

$$A = \exp[(E_a/k) \times (1/T_1 - 1/T_2)] \times (H_2/H_1)^{4.5}$$

where E_a = Activation energy
k = Boltzmann's constant
T = Junction temperature
H = Relative humidity

For example, the acceleration factor for high-humidity and high-temperature or pressure cooker tests ranges from 100 to 1000 times that of the normal operating environment.

Failure Rate Calculation

As an example, suppose that product samples are submitted to a 1000-hour life test at 125°C junction temperature and two failures are encountered: one oxide and one metalization defect. The sample size is 885 units.

Thus, the oxide failure rate is 0.11 percent per 1000 hours and the metalization failure rate is 0.11 percent per 1000 hours. Therefore, the total failure rate at 125°C sums to 0.22 percent per 1000 hours at 1K hours.

Failure Rate Prediction

To derate these failure rates to a normal operating environment, use the derating factors listed in table 3.

Oxide failures = 0.11 x 0.1546 = 0.01701% per 1K hrs
Metal failures = 0.11 x 0.01315 = 0.00145% per 1K hrs
Total failures = 0.01846% per 1K hrs

Note that the example above is a snapshot of the high-temperature life test performed on a particular lot. It is not accumulated data that can be used to represent overall reliability. This conservative illustration, however, shows that the failure rate in a normal operating environment is approximately one-twelfth the failure rate in a higher-temperature environment.

The failure rate prediction takes different activation energies into account whenever the causes of failures are known through performing failure analysis. In some cases, however, an activation energy is assumed in order to accomplish a quick first-order approximation. To yield a conservative estimate of failure rates, NEC assumes an average activation energy of 0.7 eV whenever the exact failure mechanism is not known.

Reliability Test Results

Before introducing new technologies or products, NEC's internal reliability goals must be attained. Several categories of testing are used in the internal qualification program to assure that product reliability meets NEC's reliability goals. Once the product is qualified, its reliability level is regularly monitored in a monthly reliability test.

NEC's Goals on Failure Rates

NEC's approach to achieving high reliability is to build quality into the product, as opposed to merely screening out defective units. The use of distributed control methods embedded in the production line, in conjunction with conventional screening methods, results in the highest reliability at the lowest cost.

NEC's maximum failure rate goals for infant mortality and long-term device operation are listed in table 4.

Table 4. Infant Mortality and Long-Term Failure Rates

Type	Failure Rate Percent/1000 Hours
Infant mortality	0.10 max
Long-term	
1.2M device hours average	0.02 max
3.0M device hours average	0.01 max

Infant Mortality Failure Rate

The infant mortality goal for each product group is set at 0.10 percent maximum. When a failure rate exceeds this level, there is prompt remedial action.

Long-Term Failure Rate

The long-term failure rate goal is based on the following conditions:

- A minimum of 1.2 million device hours at 125°C is accumulated to resolve 0.02 percent per 1000 hours at 55°C with a 60-percent confidence level.
- A minimum of 3 million device hours at 125°C is accumulated to resolve 0.01 percent per 1000 hours at 55°C with a 60-percent confidence level.

Infant Mortality Failure Screening

It is logical to assume the integrated circuit that fails at one temperature would also fail at another temperature, except it would fail sooner at a higher temperature. As can be expected, the failure rate is a function of activation energy. Establishing infant mortality screening, therefore, requires knowledge of the likely failure mechanisms and their associated activation energy.

The most likely mechanisms associated with infant mortality failures are generally manufacturing defects and process anomalies. These generally consist of contamination, cracked chips, wire bond shorts, or bad wire bonds. Since these describe a number of possible mechanisms, any one of which might predominate at a given time, the activation energy for infant mortality might be expected to vary considerably.

The effectiveness of a screening condition, preferably at some stress level in order to shorten the time, varies greatly with the failure mechanism being screened for. Another factor is the economics of the screening process introduced into the production line. Optimal conditions and duration of a screening process will be a compromise of these two factors.

For example, failures due to ionic contamination have an activation energy of approximately 1.0 eV. Therefore, a 15-hour stress at 125 °C junction temperature would be the equivalent of approximately 90 days of operation at a junction temperature of 55 °C. On the other hand, failures due to oxide defects have an activation energy of approximately 0.3 eV, and a 15-hour stress at 125 °C junction temperature would be the equivalent of approximately one week's operation at 55 °C junction temperature. As indicated by this, the condition and duration of infant mortality screening would be a strong function of the allowable component failures, hence the system failure, in the field.

Empirical data, gathered over more than a year at NEC, indicates that early failure does occur after less than 4 hours of stress at 125 °C ambient temperature. This fact is supported by the life test of the same lot, where the failure rate shows random distribution, as opposed to a decreasing failure rate that then runs into the random failure region.

NEC has adopted the initial infant mortality burn-in at 125 °C as a standard production screening procedure. As a result, the field reliability of NEC devices is an order of magnitude higher than the goals set for NEC's integrated circuit products.

Life Tests

The most significant difference between NEC's products and those of other integrated circuit manufacturers is that NEC's have been prescreened for their infant mortality defects. The products delivered to customers are operating at the beginning of the random failure region of the life curve. The life test data also reflects this fact, as will be shown.

The failure mechanism distribution from field failures, as previously shown in figure 2, also contains a very low percentage due to infant mortality. The majority of failures are long-term life failures, and these can be eliminated by stringent process control. Usually, these failure mechanisms have low activation energy associated with them.

Another significant improvement devised by NEC is plastic encapsulation and passivation. As a result, NEC products show excellent reliability in both high-humidity and high-temperature environments. Following is life test data accumulated over more than a year for large-scale integrated circuits.

High-Temperature Operating Life Test

This test is used to accelerate failure mechanisms by operating the devices at an elevated temperature. For large-scale integrated circuits, the failure rate is 0.242 percent per 1000 hours at 125 °C. This is equivalent to 0.0071 percent per 1000 hours in an operating environment of 55 °C (table 5).

Table 5. High-Temperature Operating Life Test

Number of Samples	Number of Failures at				
	48 hrs	96 hrs	168 hrs	500 hrs	1K hrs
3317	0	0	1	4	3
Total number of failures at 1K hrs	= 8				
Failure rate at 1K hrs at 125 °C	= 0.242% per 1K hrs				
Projected failure rate at 1K hrs at 55 °C	= 0.007% per 1K hrs				

High-Temperature and High-Humidity Life Test

This test is used to accelerate failure mechanisms by operating the devices at high temperature and high humidity. Leakage-related failures and device parameter drift are accelerated by this test. For these large-scale integrated circuits, the failure rate is 0.091 percent per 1000 hours. This is equivalent to 0.0027 percent per 1000 hours in an operating environment of 55 °C. The test conditions are T_A = 85 °C and relative humidity (RH) = 80% (table 6).

Table 6. High-Temperature and High-Humidity Life Test

Number of Samples	Number of Failures at 48 hrs	96 hrs	168 hrs	500 hrs	1K hrs
2190	0	0	0	0	2
Total number of failures at 1K hrs	= 2				
Failure rate at 1K hrs at 85°C/80% RH	= 0.091% per 1K hrs				
Projected failure rate at 1K hrs at 55°C/60% RH	= 0.003% per 1K hrs				

High-Temperature Storage Life Test

This test is effective in accelerating the failure mechanisms related to mechanical reliability problems and process instability. For these LSI devices, the failure rate is 0.207 percent per 1000 hours at 125°C. This is equivalent to 0.0061 percent per 1000 hours in an operating environment of 55°C (table 7).

Table 7. High-Temperature Storage Life Test

Number of Samples	Number of Failures at 48 hrs	96 hrs	168 hrs	500 hrs	1K hrs
2410	0	0	0	1	4
Total number of failures at 1K hrs	= 5				
Failure rate at 1K hrs at 125°C	= 0.207% per 1K hrs				
Projected failure rate at 1K hrs at 55°C	= 0.006% per 1K hrs				

Pressure Cooker Test

This test is effective in accelerating failure mechanisms related to metalization corrosion due to moisture. The failure rate is 0.52 percent per 1000 hours at T_A = 125°C and 2.3 atm at 100 percent humidity. This is equivalent to 0.0013 percent per 1000 hours at 55°C and an environment of 60 percent humidity (table 8).

Table 8. Pressure Cooker Test

Number of Samples	Number of Failures at 48 hrs	96 hrs	168 hrs	500 hrs	1K hrs
1718	0	4	5	No test performed	
Total number of failures at 168 hrs	= 9				
Failure rate at 125°C	= 0.54% per 1K hrs				
Projected failure rate at 55°C	= 0.001% per 1K hrs				

Life Test Data Summary

Table 9 summarizes the life test results and projected failure rates in the normal operating environment. The failure rate shows random distribution as opposed to a decreasing failure rate. This is a result of infant mortality screening.

Table 9. Life Test Data

Test Time	Number of Samples	Number of Failures at 96 hrs	168 hrs	500 hrs	1K hrs	Total Number of Failures
High-temperature life test	3317	0	1	4	3	8
High-humidity life test	2190	0	0	0	2	2
High-temperature storage life test	2410	0	0	1	4	5
Pressure cooker test	1718	4	5	No test performed		9
Total	9635	4	6	5	9	24

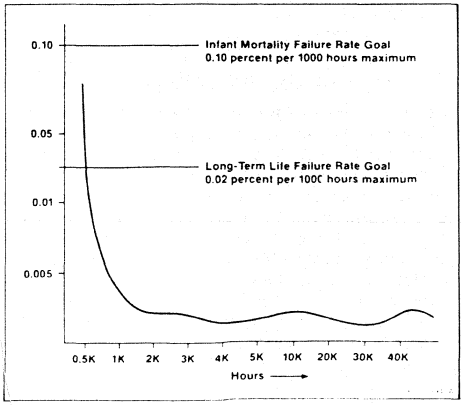
The projected failure rate in the normal operating environment is calculated assuming that the average activation energy is 0.7 eV.

Figure 3 shows the life distribution of NEC integrated circuits as a form of the bathtub curve.

This life test data shows improvements of approximately an order of magnitude better than NEC's goal. The hours of operation are equivalent to the normal operating environment. Wear-out failures, which had been the main target for reliability improvement, have also been significantly reduced. This result comes mainly from process improvements and stringent manufacturing process control.

NEC's main goal has been to improve reliability with respect to infant mortality and long-term life failures. This can be achieved by introducing an effective screening method for infant mortality and building quality into the product.

Figure 3. Plot of Life Test Results



Thermal Stress Tests

Temperature cycling and thermal shock test the thermal compatibility of material and metal used to make integrated circuits. Table 10 lists the reliability test results of thermal stress tests.

Table 10. Thermal Stress Tests

Test Item	Number of Samples	Number of Failures
Soldering heat test T_A = 260°C for 10 seconds	1891	0
Temperature cycle T_A = −65 to +150°C, 10 cycles	1891	0
Thermal shock test T_A = 0 to +100°C, 15 cycles	1891	0

Mechanical Stress Tests

In addition to the device life test, NEC performs mechanical stress tests to detect reliability problems related to the package, material, and device susceptibility to an extreme environment. Table 11 lists mechanical stress test results.

Table 11. Mechanical Stress Tests

Test Item	Number of Samples	Number of Failures
Mechanical shock test at 15 kg, 3 axis	315	0
Vibration test at 100 Hz to 2 kHz, 20 g	315	0
Constant acceleration at 20 kg, 3 axis	315	0
Lead fatigue test at 240 grams	538	0
Solderability test at 230°C for 5 seconds	638	0

Built-In Quality and Reliability

As large-scale integration reaches even higher levels of density, simple quality inspections cannot assure adequate levels of product quality and reliability. In order to ensure the reliability of state-of-the-art VLSI, NEC has adopted another approach. Highest reliability and superior quality of a device can only be achieved by building these characteristics into the product at each process step. NEC, therefore, has introduced the notion of total quality control (TQC) into its entire semiconductor production line. Quality control is distributed into each process step and then summed to form a consolidated system.

Approaches to Total Quality Control

First, the quality control function is embedded into each process. This method enables early detection of possible causes of failure and immediate feedback.

Second, the reliability and quality assurance policy is an integral part of the entire organization. This enables a companywide quality control activity. At NEC, everyone in the company is involved with the concept and methodology of total quality control.

Third, there is an ongoing research and development effort to set even higher standards of device quality and reliability.

Fourth, extensive failure analysis is performed periodically and corrective actions are taken as preventive measures. Process control is based on statistical data gathered from this analysis.

The goal is to maintain the superior product quality and reliability that has become synonymous with the NEC name. The new standard is continuously upgraded and the iterative process continues.

Implementation of Distributed Quality Control

Building quality into a product requires early detection of possible causes of failure at each process step. Then, immediate feedback to remove the causes is a must. A fixed station quality inspection is often lacking in immediate feedback. It is, therefore, necessary to distribute quality control functions to each process step, including the conceptual stage. NEC has implemented a distributed quality control function at each step of the process. Following is a breakdown of the significant steps:

- Product development phase
- Wafer processing
- Chip mounting and packaging
- Electrical testing and thermal aging
- Incoming material inspection

Product Development Phase. The product development phase includes conception of a product, review of the device proposal, organization and physical element design, engineering evaluation, and finally, transfer of the product to manufacturing. Quality and reliability are considered at every step. More significantly, at the design review stage and prior to product transfer, the quality and reliability requirements have to be examined and determined to be satisfactory. This often adds 2 to 3 months to the product development cycle. Building in high reliability, however, cannot be sacrificed.

Wafer Processing Stage Inspection. The in-process quality inspections that occur at the wafer fabrication stage are listed in table 12.

Table 12. Wafer Processing Inspection

Process	Inspection Item
Wafer	Resistivity, dimension, and appearance, (lot sampling inspection)
Mask	
Photolithography	Alignment and etching (100% inspection)
Cleaning	
Diffusion and oxidation	Oxide thickness, sheet resistivity (lot sampling inspection)
Metalization and passivation	Thickness, V_{th}, C-V characteristics (lot sampling)
Wafer sort and scribe	Dc parameters (100% inspection)
Die sort	100% visual inspection

Chip Mounting and Packaging. The in-process quality inspections done at the chip mounting and packaging stage are listed in table 13.

Table 13. Chip Mounting and Packaging Inspection

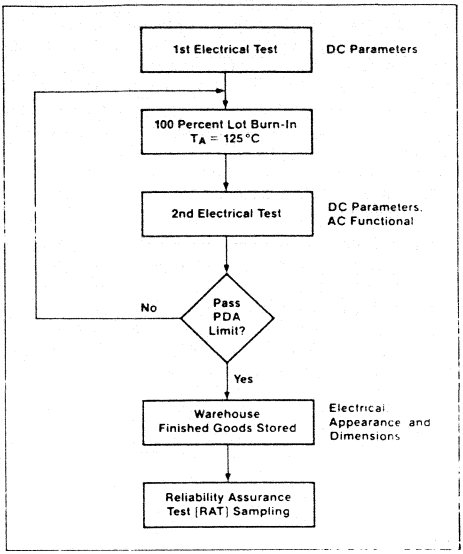
Process	Inspection Item
Die	Incoming material Inspection
Die attach	Appearance (lot sampling inspection)
Wire bonding	Bond strength, appearance (lot sampling)
Packaging	100% appearance inspection
Fine leak*	Lot sampling
Gross leak*	100% inspection

*For ceramic package devices only.

Electrical Testing and Screening. Electrical testing and infant mortality screening are performed at this stage. A flowchart of the process is depicted in figure 4.

At the first electrical test, dc parameters are tested according to the electrical specifications on 100% of each lot. This is a prescreening prior to the infant mortality test. At the second electrical test, ac functional tests as well as dc parameter tests are performed on 100% of the subjected lot. If the percentage of defective units exceeds the limit, the lot is subjected to an additional burn-in. During this time, the defective units are undergoing a failure analysis, the results of which are then fed back into the process for corrective action.

Figure 4. Electrical Testing and Screening



Incoming Material Inspection. Prior to warehouse storage, lots are subjected to an incoming inspection according to the following sampling plan.

- Electrical test: Dc parameters LTPD 3%
  Functional test LTPD 3%
- Appearance LTPD 3%

Reliability Assurance Test

Samples are continually taken from the warehouse and subjected to monthly reliability tests as discussed previously. They are taken from similar process groups so that it can be assumed that any device is representative of the reliability of the group.

In-Process Screening

Perhaps the most significant preventive measure that NEC has implemented is the introduction of 100% burn-in as an integral part of the standard production process. Most of the potential infant failures are effectively screened from every lot, thereby improving reliability. Assuming average activation energy of 0.7 eV, burn-in at $T_A = 125°C$ for 4 hours is equivalent to a week's operation in a normal operating environment. This appears to be ample time for accelerating the time-to-failure mechanisms for early failures.

Process automation, as previously mentioned, has also contributed a great deal toward improving reliability. Since its introduction, assembly related failure mechanisms have been substantially reduced. And, in combination with in-process screening and materials improvement, it has helped establish quality and reliability above NEC's initial goals.

Summary and Conclusion

As has been discussed, building quality and reliability into products is the most efficient way to ensure product reliability. NEC's approach of distributing quality control functions to process steps, then forming a consolidated quality control system, has produced superior quality and excellent reliability.

Prescreening, introduced as an integral part of large-scale integrated circuit protection, has been a major factor in improving reliability. The most recent year's production clearly demonstrates continuation of NEC's high reliability and the effectiveness of this method.

Reliability assurance tests (RATs), performed monthly, have ensured high outgoing quality levels. The combination of building quality into products, effective prescreening of potential failures, and the reliability assurance test has established a singularly high standard of quality and reliability for NEC's large-scale integrated circuits.

With a companywide quality control program, NEC is committed to building superior quality and highest reliability into all its products. Through continuous research and development activities, extensive failure analysis, and process improvements, a higher standard of quality and reliability will continuously be set and maintained.

NEC

CMOS MICROPROCESSORS 3

Section 3 – CMOS Microprocessors

Description

The μPD70008 and μPD70008A are power saving, high performance, general purpose 8-bit microprocessor. It is a CMOS-process part with a standby mode that greatly reduces power consumption.

Features

- ☐ High performance μPD780 instruction set
- ☐ Instruction cycle:
  1 μs at 4 MHz (μPD70008, μPD70008A-4)
  0.66 μs at 6 MHz (μPD70008A-6)
- ☐ Direct addressing of up to 64 K bytes of memory
- ☐ Memory refresh function
- ☐ Interrupt functions:
  – Maskable external interrupt ($\overline{INT}$)
  – Nonmaskable external interrupt ($\overline{NMI}$)
- ☐ Low-power standby mode (HALT)
- ☐ CMOS standby mode (HALT)
- ☐ Single power supply

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD70008C	40-pin plastic DIP	4 MHz
μPD70008AC-4	40-pin plastic DIP	4 MHz
μPD70008AC-6	40-pin plastic DIP	6 MHz
μPD70008AG-4	44-pin plastic miniflat	4 MHz
μPD70008AG-6	44-pin plastic miniflat	6 MHz
μPD70008AL-6	44-pin PLCC	6 MHz

Absolute Maximum Ratings

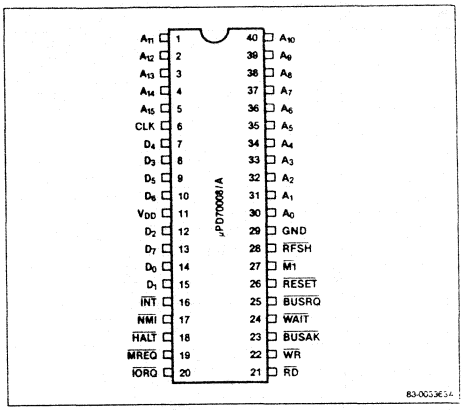
$T_A = 25°C$

Power supply voltage, V_{DD}	−0.3 V to +7 V
Input voltage, V_{IN}	−0.3 V to V_{DD} +0.3 V
Output voltage, V_O	−0.3 V to V_{DD} +0.3 V
Operating temperature, T_{OPT}	
μPD70008	−10°C to +70°C
μPD70008A	−45°C to +85°C
Storage temperature, T_{STG}	−65°C to +150°C

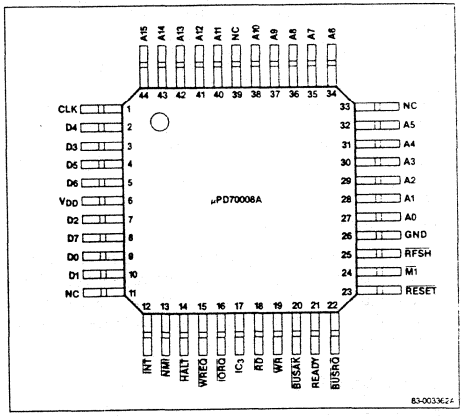
Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Pin Configurations

40-Pin Plastic DIP



44-Pin Plastic Miniflat



Pin Identification

40-Pin Plastic DIP

No.	Symbol	Function
1-5	A_{11}-A_{15}	Address bus, high bits, outputs
6	CLK	Clock input
7-10	D_3-D_6	Data bus, bits 3-6, inputs/outputs
11	V_{DD}	Power supply
12	D_2	Datra bus, bit 2, input/output
13	D_7	Data bus, bit 7, input/output
14, 15	D_0, D_1	Data bus, bits 0, 1, inputs/outputs
16	$\overline{INT}$	Interrupt input
17	$\overline{NMI}$	Nonmaskable interrupt input
18	$\overline{HALT}$	Halt/standby mode output
19	$\overline{MREQ}$	Memory request output
20	$\overline{IORQ}$	I/O request output
21	$\overline{RD}$	Read strobe output
22	$\overline{WR}$	Write strobe output
23	$\overline{BUSAK}$	Bus acknowledge output
24	$\overline{WAIT}$	Wait input
25	$\overline{BUSRQ}$	Bus request input
26	$\overline{RESET}$	Reset input
27	$\overline{M1}$	Machine cycle 1 output
28	$\overline{RFSH}$	Refresh request output
29	GND	Ground
30-40	A_0-A_{10}	Address bus, low bits, outputs

44-Pin Plastic Miniflat

No.	Symbol	Function
40-44	A_{11}-A_{15}	Address bus, high bits, outputs
1	CLK	Clock input
2-5	D_3-D_6	Data bus, bits 3-6, inputs/outputs
6	V_{DD}	Power supply
7	D_2	Datra bus, bit 2, input/output
8	D_7	Data bus, bit 7, input/output
9-10	D_0, D_1	Data bus, bits 0, 1, inputs/outputs
12	$\overline{INT}$	Interrupt input
13	$\overline{NMI}$	Nonmaskable interrupt input
14	$\overline{HALT}$	Halt/standby mode output
15	$\overline{MREQ}$	Memory request output
16	$\overline{IORQ}$	I/O request output
18	$\overline{RD}$	Read strobe output
19	$\overline{WR}$	Write strobe output
20	$\overline{BUSAK}$	Bus acknowledge output
21	$\overline{WAIT}$	Wait input
22	$\overline{BUSRQ}$	Bus request input
23	$\overline{RESET}$	Reset input
24	$\overline{M1}$	Machine cycle 1 output
25	$\overline{RFSH}$	Refresh request output
26	GND	Ground
28-32, 34-38	A_0-A_{10}	Address bus, low bits, outputs
17	IC	Internally connected
11, 33, 39	NC	Not connected

Pin Functions

A_{15}-A_0 (Address Bus)

These three-state output pins form a 16-bit address bus for addressing memory or peripheral devices. The address bus enters the high impedance state when bus acknowledge is active. In the standby mode, these pins output high- or low-level signals.

D_7-D_0 (Data Bus)

These three-state pins form an 8-bit bidirectional data bus. On this bus data is transferred between the μPD70008/A and memory or peripheral devices. This bus enters the high impedance state when bus acknowledge is active. In the standby mode, these pins are high-level.

$\overline{INT}$ (Interrupt)

This pin is an active-low interrupt input which can be masked by software. $\overline{NMI}$ has a lower priority than $\overline{NMI}$ and $\overline{BUSRQ}$. $\overline{INT}$ releases the standby mode.

$\overline{NMI}$ (Nonmaskable Interrupt)

This pin inputs an interrupt which is not maskable by software. $\overline{NMI}$ is active-low in the μPD70008, and is falling edge triggered in the μPD70008A. $\overline{NMI}$ has a higher priority than $\overline{INT}$, but a lower priority than $\overline{BUSRQ}$ and $\overline{RESET}$. $\overline{NMI}$ releases the standby mode.

$\overline{MREQ}$ (Memory Request)

This three-state pin is an active-low output. The μPD70008/A asserts $\overline{MREQ}$ to indicate that the information on the address bus is a memory address. This pin enters the high impedance state when bus acknowledge is active. $\overline{MREQ}$ is inactive (high) in the standby mode.

Pin Functions (cont)

$\overline{IORQ}$ (I/O Request)

This three-state pin is an active-low output. The μPD70008/A asserts $\overline{IORQ}$ to indicate that the information on the address bus is a peripheral device address. $\overline{IORQ}$ is also asserted during a maskable interrupt service to request the interrupting device to output its interrupt vector to the data bus. This pin enters the high impedance state when bus acknowledge is active. $\overline{IORQ}$ is inactive (high) in the standby mode.

$\overline{RD}$ (Read Strobe)

This three-state active-low output provides a read strobe for the memory and peripheral devices. The pin enters the high impedance state when the bus acknowledge is active. $\overline{RD}$ is inactive (high) in the standby mode.

$\overline{WR}$ (Write Strobe)

This three-state active-low output provides a write strobe for the memory and peripheral devices. This pin enters the high impedance state when bus acknowledge is active. $\overline{WR}$ is inactive (high) in the standby mode.

$\overline{BUSRQ}$ (Bus Request)

This is an active-low input. Peripheral devices assert $\overline{BUSRQ}$ to request the μPD70008/A to release control of the address bus (A_{15}-A_0), data bus (D_7-D_0) and control bus ($\overline{MREQ}$, $\overline{IORQ}$, $\overline{RD}$ and $\overline{WR}$) and assert bus acknowledge. $\overline{BUSRQ}$ has a higher priority than either $\overline{INT}$ or $\overline{NMI}$, but is lower in priority than $\overline{RESET}$. $\overline{BUSRQ}$ will temporarily suspend the standby mode. The μPD70008/A leaves standby mode when $\overline{BUSRQ}$ is asserted, but returns to the standby mode when $\overline{BUSRQ}$ is released.

$\overline{BUSAK}$ (Bus Acknowledge)

This active-low output indicates that the data bus (D_7-D_0), address bus (A_{15}-A_0), and control bus ($\overline{MREQ}$, $\overline{IORQ}$, $\overline{RD}$ and $\overline{WR}$) have entered the high impedance state. This releases the buses from CPU control and makes them available to the peripheral devices for data exchange. This state cannot be released by $\overline{NMI}$ or $\overline{INT}$, but responds only to $\overline{RESET}$ or the release of $\overline{BUSRQ}$.

$\overline{HALT}$ (Halt/Standby Mode)

This active-low output is asserted after the halt command has been executed and indicates that the μPD70008/A has entered the standby mode.

$\overline{WAIT}$ (Wait)

This pin is an active-low input. Memory and peripheral devices assert this signal to increase read or write access time. When $\overline{WAIT}$ is asserted, the μPD70008/A inserts wait states (TW) into the machine cycle until $\overline{WAIT}$ is released.

$\overline{RESET}$ (Reset)

This active-low input is used to reset the μPD70008/A. The standby mode is released on Reset. Reset has the highest priority.

$$\overline{INTI} < \overline{NMI} < \overline{BUSRQ} < \overline{RESET}$$

$\overline{RFSH}$ (Refresh Request)

This pin is an active-low output. The μPD70008/A asserts $\overline{RFSH}$ to trigger the external memory refresh operation. When $\overline{RFSH}$ is low, the lower seven bits of the address bus (A_6-A_0) are a refresh address. This pin is inactive (high) in the standby mode.

$\overline{M1}$ (Machine Cycle 1)

This pin is an active-low output. When $\overline{M1}$ is asserted, it indicates that the μPD70008/A is in the opcode fetch cycle, $\overline{M1}$.

CLK (Clock)

This pin is the system clock input.

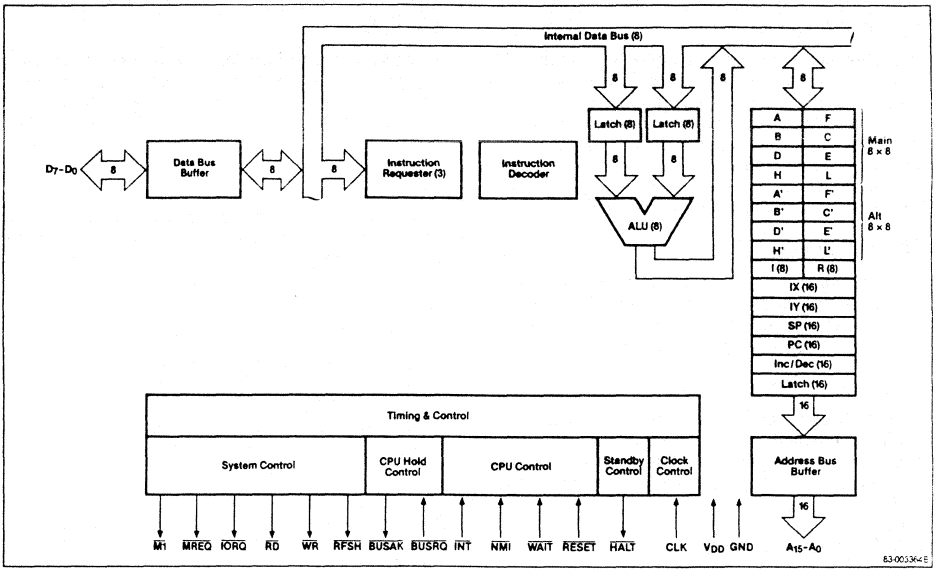
V_{DD} (Power Supply)

This pin is the +5 V power supply input.

GND (Ground)

This pin is the ground pin.

Block Diagram



DC Characteristics

μPD70008: $T_A = -10°C$ to $+70°C$, μPD70008A: $T_A = -40°C$ to $+85°C$, $V_{DD} = +5V \pm 10\%$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage high	V_{IH1}	2.2		V_{DD}	V	Except CLK, $\overline{RESET}$
	V_{IH2}	$V_{DD}-0.6$		$V_{DD}+0.3$	V	CLK, $\overline{RESET}$
Input voltage low	V_{IL1}	−0.3		0.8	V	Except CLK, $\overline{RESET}$
	V_{IL2}	−0.3		0.45	V	CLK, $\overline{RESET}$
Output voltage high	V_{OH}	2.4			V	$I_{OH} = -400\,\mu A$
Output voltage low	V_{OL}			0.4	V	$I_{OL} = 2.5$ mA
Input leakage current high	I_{LIH}			10	μA	$V_I = V_{DD}$
Input leakage current low	I_{LIL}			−10	μA	$V_{IN} = 0$ V
Output leakage current high	I_{LOH}			10	μA	$V_O = V_{DD}$
Output leakage current low	I_{LOL}			−10	μA	$V_O = 0$ V

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Supply current (Note 1)						
μPD70008	I_{DD1}		10	30	mA	$t_{CYK} = 0.25\,\mu s$
	I_{DD2}		500		μA	$t_{CYK} = 0.25\,\mu s$
μPD70008A-4	I_{DD1}		9	20	mA	$t_{CYK} = 0.25\,\mu s$
	I_{DD2}		80	240	μA	$t_{CYK} = 0.25\,\mu s$
μPD70008A-6	I_{DD1}		14	30	mA	$t_{CYK} = 0.165\,\mu s$
	I_{DD2}		120	360	μA	$t_{CYK} = 0.165\,\mu s$

Note:

(1) I_{DD1} is normal operating current.
I_{DD2} is standby mode current.

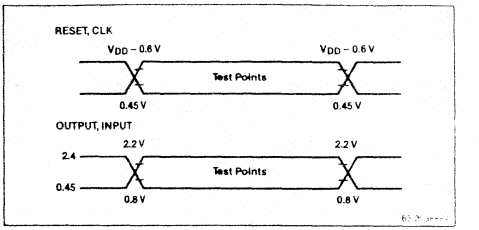
Capacitance

$T_A = 25°C$, $f_C = 1MHz$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
CLK input capacitance	C_K			35	pF	(Note 1)
Input capacitance	C_I			5	pF	(Note 1)
Output capacitance	C_O			10	pF	(Note 1)
I/O capacitance	C_{IO}			10	pF	(Note 1)

Note:
(1) All unmeasured pins returned to 0 V.

AC Test Points



AC Characteristics

μPD70008: $T_A = -10°C$ to $+70°C$, μPD70008A: $T_A = -40°C$ to $+85°C$, $V_{CC} = 5V \pm 10\%$

Signal	Parameter	Symbol	Limits μPD70008/A-4 Min	Max	μPD70008A-6 Min	Max	Unit	Test Conditions
CLK	Clock period	t_{CYK}	0.25	(Note 1)	0.165	(Note 8)	μs	
	Clock pulse width high	t_{KKH}	0.11	200	0.065	200	μs	
	Clock pulse width low	t_{KKL}	110	2000	65	2000	ns	
	Clock pulse rise and fall time	t_{KR}, t_{KF}		30		20	ns	
A_{15}–A_0	Address output delay	t_{DKA}		110		90	ns	$C_L = 100$ pF
	Address delay to float	t_{FKA}		90		80	ns	$C_L = 100$ pF
	Address stable prior to $\overline{MREQ}$, memory cycle	t_{SAM}	(Note 2)		(Note 9)		ns	$C_L = 100$ pF
	Address stable prior to $\overline{IORQ}$ in I/O cycle	t_{SAI}	$t_{CYK}-70$		(Note 10)		ns	$C_L = 100$ pF
	Address stable from $\overline{RD}$, $\overline{WR}$, $\overline{IORQ}$, $\overline{MREQ}$	t_{HRA}	(Note 3)		(Note 11)		ns	$C_L = 100$ pF
	Address stable from $\overline{RD}$, $\overline{WR}$ during float	t_{FCA}	(Note 4)		(Note 12)		ns	$C_L = 100$ pF
D_7–D_0	Data output delay	t_{DKD}		180		130	ns	$C_L = 100$ pF
	Delay to float during write cycle	t_{FKD}		90		80	ns	$C_L = 100$ pF
	Data setup time to CLK during $\overline{M1}$ cycle	t_{SDKR}	35		30		ns	$C_L = 100$ pF
	Data setup time to CLK during M2 to M5 cycles	t_{SDKF}	50		40		ns	$C_L = 100$ pF
	Data stable prior to $\overline{WR}$ (memory cycle)	t_{SMDW}	$t_{CYK}-170$		(Note 13)		ns	$C_L = 100$ pF
	Data stable prior to $\overline{WR}$ (I/O cycle)	t_{SIDW}	$t_{KKL}+t_{KR}-170$		(Note 14)		ns	$C_L = 100$ pF
	Data stable from $\overline{WR}$	t_{FCD}	(Note 5)		(Note 15)		ns	$C_L = 100$ pF
$\overline{WR}$	$\overline{WR}$ delay from CLK ↑ to $\overline{WR}$ low	t_{DKRWL}		65		60	ns	
	$\overline{WR}$ delay from CLK ↓ to $\overline{WR}$ low	t_{DKFWL}		80		70	ns	
	$\overline{WR}$ delay from CLK ↓ to $\overline{WR}$ high	t_{DKFWH}		80		70	ns	
	$\overline{WR}$ low pulse width	t_{WWL}	$t_{CYK}-30$		(Note 18)		ns	
$\overline{M1}$	$\overline{M1}$ delay from CLK ↑ to $\overline{M1}$ low	t_{DKM1L}		100		80	ns	$C_L = 100$ pF
	$\overline{M1}$ delay from CLK ↑ to $\overline{M1}$ high	t_{DKM1H}		100		80	ns	$C_L = 100$ pF

AC Characteristics (cont)

μPD70008: $T_A = -10°C$ to $+70°C$, μPD70008A: $T_A = -40°C$ to $+85°C$, $V_{CC} = 5\,V \pm 10\%$

Signal	Parameter	Symbol	Limits μPD70008/A-4 Min	Limits μPD70008/A-4 Max	Limits μPD70008A-6 Min	Limits μPD70008A-6 Max	Unit	Test Conditions
$\overline{RFSH}$	$\overline{RFSH}$ delay from CLK ↑ to $\overline{RFSH}$ low	t_{DKRFL}		130		110	ns	$C_L = 100$ pF
	$\overline{RFSH}$ delay from CLK ↑ to $\overline{RFSH}$ high	t_{DKRFH}		120		100	ns	$C_L = 100$ pF
$\overline{WAIT}$	$\overline{WAIT}$ setup time to CLK ↓	t_{SWTK}	70		60		ns	
$\overline{HALT}$	$\overline{HALT}$ delay from CLK ↓	t_{DKHT}		300		260	ns	$C_L = 100$ pF
$\overline{INT}$	$\overline{INT}$ setup time to CLK ↑	t_{SITK}	80		70		ns	
$\overline{NMI}$	$\overline{NMI}$ low pulse width	t_{NNL}	80		70		ns	
$\overline{BUSRQ}$	$\overline{BUSRQ}$ setup time to CLK ↓	t_{SBQK}	50		50		ns	
$\overline{BUSAK}$	$\overline{BUSAK}$ delay from CLK ↑ to $\overline{BUSAK}$ low	t_{DKRBA}		100		90	ns	$C_L = 100$ pF
	$\overline{BUSAK}$ delay from CLK ↓ to $\overline{BUSAK}$ high	t_{DKFBA}		100		90	ns	$C_L = 100$ pF
$\overline{RESET}$	$\overline{RESET}$ setup to CLK	t_{SRSK}	60		60		ns	
Other	Delay to float ($\overline{MREQ}$, $\overline{IORQ}$, $\overline{RD}$, $\overline{WR}$)	t_{FKC}		80		70	ns	
	$\overline{M1}$ stable prior to $\overline{IORQ}$ (interrupt acknowledge)	t_{SM1I}	(Note 7)		(Note 19)		ns	
	Hold time for setup time	t_H	0		0		ns	
$\overline{MREQ}$	$\overline{MREQ}$ delay from CLK ↓ to $\overline{MREQ}$ low	t_{DKFML}		85		70	ns	$C_L = 100$ pF
	$\overline{MREQ}$ delay from CLK ↑ to $\overline{MREQ}$ high	t_{DKRMH}		85		70	ns	$C_L = 100$ pF
	$\overline{MREQ}$ delay from CLK ↓ $\overline{MREQ}$ high	t_{DKFMH}		85		70	ns	$C_L = 100$ pF
	Pulse width $\overline{MREQ}$ low	t_{MML}	$t_{CYK} - 30$		(Note 16)		ns	$C_L = 100$ pF
	Pulse width $\overline{MREQ}$ high	t_{MMH}	(Note 6)		(Note 17)		ns	$C_L = 100$ pF
$\overline{IORQ}$	$\overline{IORQ}$ delay from CLK ↑ to $\overline{IORQ}$ low	t_{DKRIL}		75		65	ns	$C_L = 100$ pF
	$\overline{IORQ}$ delay from CLK ↓ to $\overline{IORQ}$ low	t_{DKFIL}		85		70	ns	$C_L = 100$ pF
	$\overline{IORQ}$ delay from CLK ↑ to $\overline{IORQ}$ high	t_{DKRIH}		85		70	ns	$C_L = 100$ pF
	$\overline{IORQ}$ delay from CLK ↓ to $\overline{IORQ}$ high	t_{DKFIH}		85		70	ns	$C_L = 100$ pF
$\overline{RD}$	$\overline{RD}$ delay from CLK ↑ to $\overline{RD}$ low	t_{DKRRL}		85		70	ns	$C_L = 100$ pF
	$\overline{RD}$ delay from CLK ↓ to $\overline{RD}$ low	t_{DKRFL}		95		80	ns	$C_L = 100$ pF
	$\overline{RD}$ delay from CLK ↑ to $\overline{RD}$ high	t_{DKRRH}		85		70	ns	$C_L = 100$ pF
	$\overline{RD}$ delay from CLK ↓ to $\overline{RD}$ high	t_{DKFRH}		85		70	ns	$C_L = 100$ pF

Note:

(1) $t_{CYK} = t_{KKH} + t_{KKL} + t_{KR} + t_{KF}$

(2) $t_{SAM} = t_{KKH} + t_{KF} - 65$

(3) $t_{HRA} = t_{KKL} + t_{HR} - 50$

(4) $t_{FCA} = t_{KKL} + t_{KR} - 45$

(5) $t_{FCD} = t_{KKL} + t_{KR} - 70$

(6) $t_{MMH} = t_{KKH} + t_{KF} - 20$

(7) $t_{SM1I} = 2t_{CYK} + t_{KKH} + t_{KF} - 65$

(8) $t_{CYK} = t_{KKH} + t_{KKL} + t_{KR} + t_{KF}$

(9) $t_{SAM} = t_{KKH} + t_{KF} - 50$

(10) $t_{SAI} = t_{CYK} - 55$

(11) $t_{HRA} = t_{KKL} + t_{KR} - 50$

(12) $t_{FCA} = t_{KKL} + t_{KR} - 40$

(13) $t_{SMDW} = t_{CYK} - 140$

(14) $t_{SIDW} = t_{KKL} + t_{KR} - 140$

(15) $t_{FCD} = t_{KKL} + t_{KR} - 55$

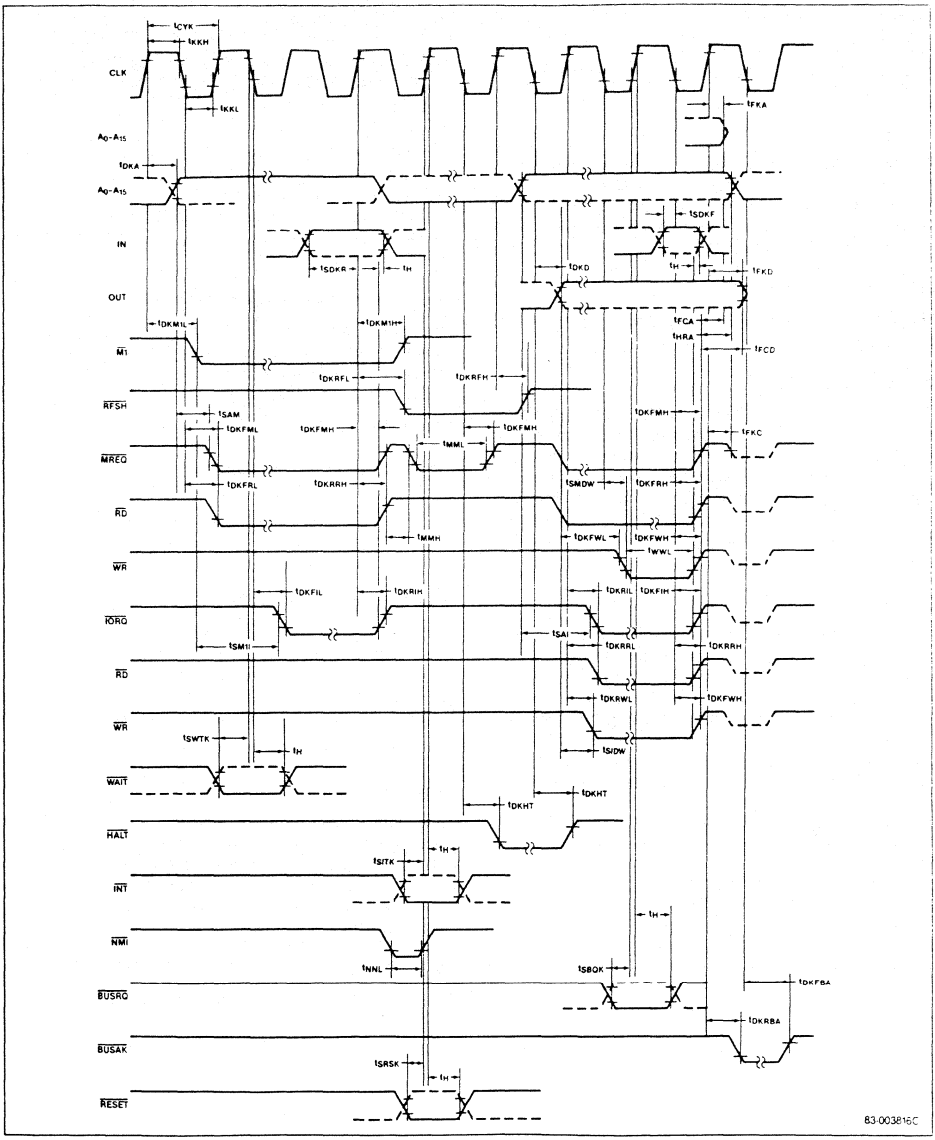
(16) $t_{MML} = t_{CYK} - 30$

(17) $t_{MMH} = t_{KKH} + t_{KF} - 20$

(18) $t_{WWL} = t_{CYK} - 30$

(19) $t_{SM1I} = 2t_{CYK} + t_{KKH} + t_{KF} - 50$

Timing Waveforms



Register Configuration

Program Counter (PC)

The 16-bit program counter contains the address of the next instruction to be fetched and executed. It is set to 0000H at reset.

Stack Pointer (SP)

The 16-bit stack pointer stores the first address of the portion of main memory used as a LIFO stack. SP is decremented when a CALL or PUSH is executed, or when an interrupt occurs. It is incremented when a RET, POP, or interrupt return is executed.

Index Registers (IX, IY)

These two 16-bit registers are used to perform indexed addressing.

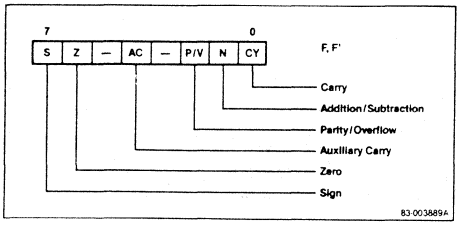
Accumulators (A, A')

The μPD70008/A has two 8-bit accumulators: the main accumulator (A) which is used to perform arithmetic and logic operations, and an alternate accumulator (A'). The contents of the main and alternate accumulators can be exchanged using the (EX) instruction. The alternate accumulator can be used for background operation, or to save the data in the main accumulator when an interrupt is processed.

Flag Registers (F, F')

The μPD70008/A has two 8-bit flag registers: main (F) and alternate (F') of the format shown in figure 1. The main flag register (F) has the status flags resulting from normal operation. The contents of the main and alternate registers can be exchanged using the exchange (EX) instruction. The alternate (F') register can be used for background operation, or to save the state of the main flag register when an interrupt is processed.

Figure 1. Flag Register Format



General Purpose Registers

The μPD70008/A has twelve 8-bit general purpose registers: six main registers (B, C, D, E, H, and L) and six alternate registers (B', C', D', E', H', and L'). Each register can be used individually as an 8-bit register, or can be used in pairs as 16-bit registers (BC, B'C', DE, D'E', HL, and H'L').

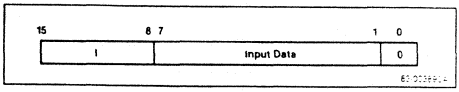
The main registers are used when instructions are executed normally. The contents of the main and alternate registers are exchanged using the EX instruction. The alternate registers may be used for background operation or to save the contents of the main registers when an interrupt is processed.

Interrupt Page Address Register (I)

This 8-bit register is used to generate addresses in maskable interrupt mode 2. See figure 2. These addresses are used with externally input data to reference an interrupt start address table.

This register is cleared to 00H at reset.

Figure 2. Interrupt Reference Address



Memory Refresh Register (R)

This 7-bit register retains the refresh address for the external dynamic memory. The contents of this register are automatically incremented in each opcode fetch (M1) cycle. The contents of this register are output on the lower 7 bits of the address bus (A_6-A_0).

This register is cleared to 00H at reset.

Timing

This section describes read and write timing for memory and I/O devices in connection with CPU operation timing. A single clock cycle (from one leading edge to the next) is defined as one timing state. The nth state is represented as Tn. A single instruction consists of two to six machine cycles. A single machine cycle requires three to six timing states. The nth machine cycle is represented as Mn.

Table 1 lists the number of states normally required by each cycle.

Table 1. Timing States per Cycle

Cycle	Number of States per Machine Cycle
Opcode fetch	4
Memory read	3
Memory write	3
I/O read	4
I/O write	4

The four states for I/O read and write include a single wait state (TW). The μPD70008/A inserts one wait state in every I/O read or write. Slower external devices may assert the $\overline{WAIT}$ signal to request longer read and write access times. This time will be added to the original number of clock states. The $\overline{WAIT}$ signal is monitored on the trailing edge of clock state T2. If $\overline{WAIT}$ is asserted, a wait state (TW) is generated. The μPD70008/A continues to monitor $\overline{WAIT}$ on the clock's trailing edge, and supplies additional wait states a long as that signal is asserted. When $\overline{WAIT}$ is released the μPD70008/A proceeds to the T3 state.

Opcode Fetch Cycle

The first machine cycle of each instruction, M1, is the opcode fetch cycle. See figure 3. The opcode is fetched from memory during the first half of this cycle, and the dynamic memory is refreshed during the latter half.

The memory outputs the opcode to the data bus when $\overline{MREQ}$, $\overline{RD}$, or $\overline{M1}$ is asserted. It is then read into the CPU at the leading edge of clock state T3.

The CPU outputs a refresh address onto A_6-A_0 during T3. It is applied to the dynamic memory when $\overline{RFSH}$ or $\overline{MREQ}$ are asserted.

Memory Read Cycle

The memory contents are read out to the data bus when $\overline{MREQ}$ or $\overline{RD}$ is asserted. The μPD70008/A reads data from the data bus on the trailing edge of T3. See figure 4.

Memory Write Cycle

Write data is output to the data bus between the last half of state T1 of the current machine cycle and the first half of state T1 of the next cycle. It is written to memory when $\overline{WR}$ or $\overline{MREQ}$ is asserted. See figure 5.

Figure 3. Opcode Fetch Cycle

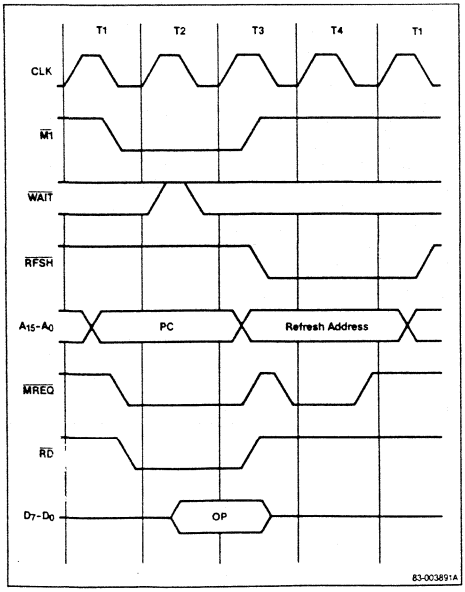


Figure 4. Memory Read Cycle

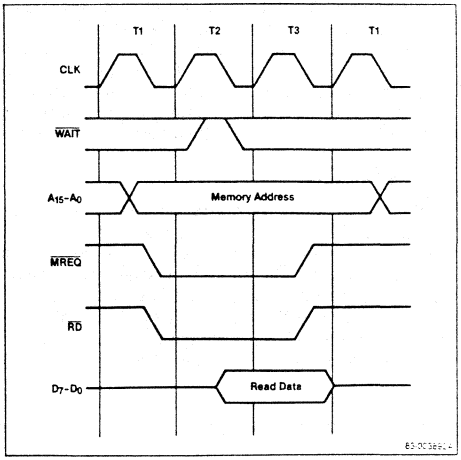


Figure 5. Memory Write Cycle

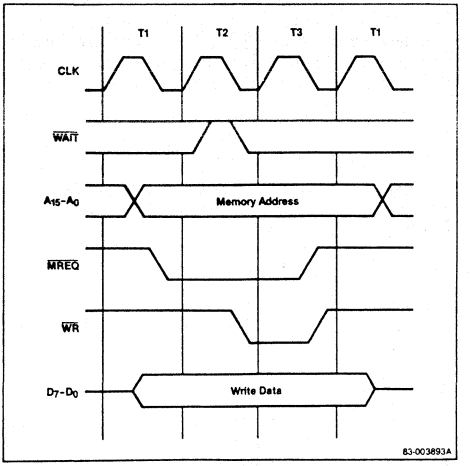
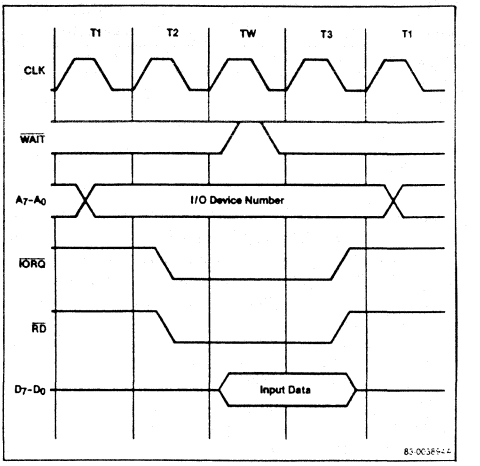


Figure 6. I/O Read Cycle



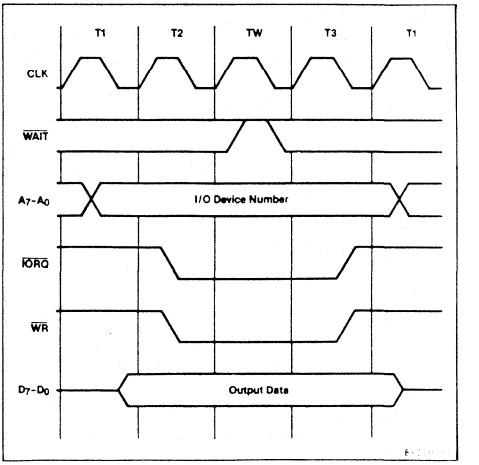
I/O Read Cycle

The contents of an I/O device are read out to the data bus when $\overline{IORQ}$ or $\overline{RD}$ is asserted. The μPD70008/A reads the data bus on the trailing edge of the T3 clock state. See figure 6. To compensate for I/O devices with longer access times, the μPD70008/A generates one wait state (TW) regardless of the condition of the $\overline{WAIT}$ signal. To extend the access time, the CPU must detect the $\overline{WAIT}$ signal asserted at the falling edge of TW.

I/O Write Cycle

Write data is output to the data bus between the last half of state T1 of the current machine cycle and the first half of T1 of the next machine cycle. It is written to an I/O device when $\overline{IORQ}$ or $\overline{WR}$ is asserted. As in the I/O read cycle, one wait state is automatically inserted in the I/O write cycle. See figure 7. The $\overline{WAIT}$ signal is used to insert additional wait states in the I/O write cycle in exactly the same way as in the read cycle.

Figure 7. I/O Write Cycle



Bus Request State

The bus request causes the μPD70008/A address bus (A_{15}-A_0), data bus (D_7-D_0), and control bus ($\overline{MREQ}$, $\overline{IORQ}$, $\overline{RD}$, and $\overline{WR}$) pins to enter the high impedance state.This makes the buses available to external devices for DMA access.

The bus request state is controlled by the bus request ($\overline{BUSRQ}$) signal. See figure 8. The μPD70008/A detects $\overline{BUSRQ}$ at the rising edge of the last state of each machine cycle. If it is active (low) the μPD70008/A does not move on the next machine cycle, but enters the bus request state. The μPD70008/A asserts $\overline{BUSAK}$ to indicate that the $\overline{BUSRQ}$ signal has been received, and the three buses have entered the high impedance state.

$\overline{BUSRQ}$ is checked at the rising edge of all clock states. When it becomes inactive the μPD70008/A leaves the bus request state, and proceeds to the next cycle.

$\overline{BUSRQ}$ temporarily suspends the standby mode. When $\overline{BUSRQ}$ is asserted, the μPD70008/A leaves the standby mode and enters the bus request state. When $\overline{BUSRQ}$ is released the μPD70008/A returns to the standby mode.

Interrupts are disabled during the bus request state.

Interrupts

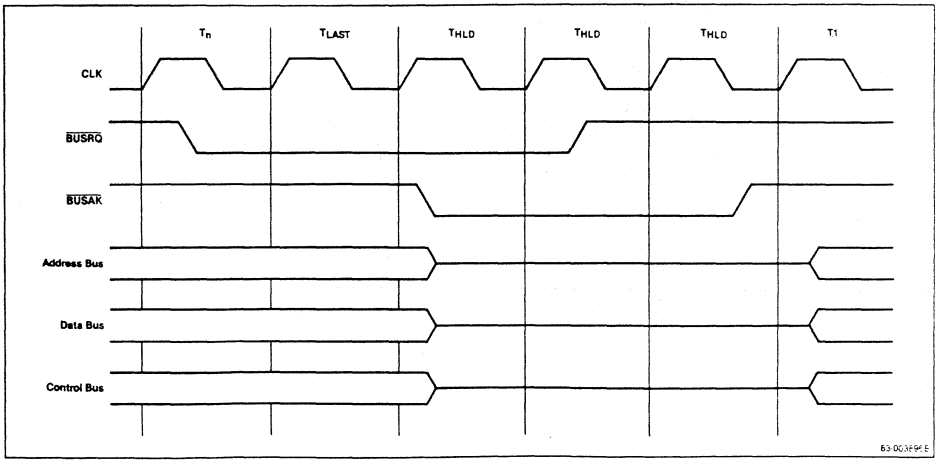
The μPD70008/A has two types of interrupt: maskable ($\overline{INT}$) and nonmaskable ($\overline{NMI}$). The nonmaskable interrupt request cannot be masked by software. It will be acknowledged unless the μPD70008/A is in the bus request state. The maskable interrupt can be masked by software. It is controlled by setting or resetting the interrupt enable flip-flop (IFF) using the EI or DI instructions. $\overline{INT}$ has a lower priority than the nonmaskable interrupt. The maskable interrupt will therefore not be acknowledged if there is a nonmaskable interrupt, or if the μPD70008/A is in the bus request state.

$$\overline{INTI} < \overline{NMI} < \overline{BUSRQ} < \overline{RESET}$$

Nonmaskable Interrupt Operation

The falling edge of $\overline{NMI}$ always sets the nonmaskable interrupt flip-flop. The μPD70008/A checks the flip-flop at the rising edge of the last clock state of an instruction. If it is set, the μPD70008/A transfers control to the nonmaskable interrupt service routine. The interrupt process starts at the opcode fetch cycle, (M1, 5 states) but the opcode fetched at this point is ignored. The contents of the PC are stored on the stack in the next two machine cycles (M2, 3 states and M3, 3 states). At the same time, the address 0066H is loaded into the PC, and the state of the interrupt enable flip-flop is saved to an exclusive flip-flop. The entire interrupt routine requires 3 machine cycles (11 states). The contents of the PC and IFF are restored by the execution of the RETN instruction at the end of the interrupt procedure.

Figure 8. Bus Request State



Maskable Interrupt Operation

Maskable interrupts are processed in three modes. In each mode, the $\overline{INT}$ signal is detected at the rising edge of the last clock state of each instruction. The M1 instruction specifies which mode is to be used.

Mode 0. In this mode, the data placed on the bus by the interrupting device is treated as an instruction. It is fetched in the opcode fetch cycle (M1, 7 states) and executed. The instruction used in this mode is usually a CALL (3 bytes) or RST (1 byte).

If a 1-byte RST instruction is executed, the contents of the PC are saved to the stack. A fixed address specified by the opcode is loaded into the PC during the next M2 (3 states) and M3 (3 states). The execution of this interrupt requires 3 machine cycles or 13 states.

If a 3-byte CALL instruction is executed, the second and third bytes are fetched during the M2 and M3 cycles (3 states each). During M4 and M5 (3 states each), the contents of the PC are saved to the stack and the second and third bytes of the CALL instruction are loaded into the PC. This interrupt requires 5 machine cyces and a total of 19 clock states.

Mode 1. In this mode, the data fetched during M1 (7 states) is ignored, and the μPD70008/A proceeds to the next cycle. During the M2 and M3 machine cycles (3 states each), the contents of the PC are saved to the stack and replaced by the interrupt address 0038H. This interrupt requires 3 machine cycles or 13 states.

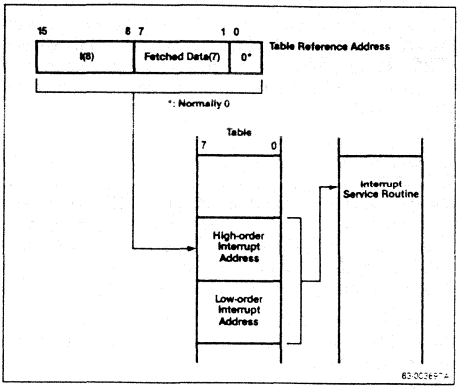
Mode 2. In this mode, the data fetched from the interrupting device and the contents of the interrupt page register (I) are used to reference an interrupt start address table. Program execution jumps to the 16-bit address referenced by the table. See figure 9. The data is fetched during the opcode fetch cycle (M1, 7 states). During M2 and M3 (3 states each) the contents of the PC are saved to the stack. During the M4 and M5 cycles, (3 states each) the table is referenced and the contents of the table location are loaded into the PC. This interrupt requires 5 machine cycles or 19 states.

Standby Mode

The μPD70008/A is provided with a standby mode (HALT). In the standby mode, power consumption is approximately 2% of normal operating power consumption. The standby mode is set by executing the HALT instruction.

In the standby mode, the state of the μPD70008/A is retained. The contents of all registers and the state of all flags are retained as well. Clock signals are supplied only to indispensable circuits in the μPD70008/A to minimize power consumption.

Figure 9. Interrupt Address Table



External operations such as memory access and memory refresh are not performed in the standby mode.

Table 2 shows the state of each output pin in the standby mode.

Table 2. Standby Mode

Pin	Status
Data bus D_7–D_0	High level, pulled up through internal resistance
Address bus A_{15}–A_0	High or low level signals
Control bus $\overline{RD}$, $\overline{WR}$, $\overline{MREQ}$, $\overline{IORQ}$, $\overline{M1}$	High level (inactive)
$\overline{RFSH}$	High level (inactive)
$\overline{HALT}$	Low level (active)

The standby mode is released when a reset or an interrupt occurs. The standby mode is temporarily suspended by a bus request, but not released.

$\overline{RESET}$ in Standby Mode

When the $\overline{RESET}$ signal becomes active (low) the standby mode is released and a normal reset is performed.

$\overline{NMI}$ in Standby Mode

When the $\overline{NMI}$ signal is asserted (low) the standby mode is released and normal nonmaskable interrupt processing is performed. The interrupt is not performed in the bus request state.

$\overline{INT}$ in Standby Mode

When the $\overline{INT}$ signal is asserted (low) the standby mode is released. If the interrupt is enabled, normal interrupt processing is performed. If the interrupt is disabled, execution resumes at the instruction following the HALT instruction.

$\overline{BUSRQ}$ in Standby Mode

The $\overline{BUSRQ}$ signal is detected at the rising edge of each clock in the standby mode. If the $\overline{BUSRQ}$ signal is active (low) the μPD70008/A leaves the standby mode, and enters the bus request state. When $\overline{BUSRQ}$ is released, the standby mode is resumed. The standby mode is not released by the $\overline{BUSRQ}$ signal.

$\overline{RESET}$

The $\overline{RESET}$ signal must be asserted (low) for over 3 clock cycles to be recognized. The following steps are the reset initialization process:

- The program counter (PC) is cleared to 0000H.
- The interrupt enable flip-flop (IFF) is reset to 0, disabling maskable interrupts.The interrupt mode is set to 0.
- The interrupt page address register (I) is cleared to 00H.
- The memory refresh register (R) is cleared to 00H.
- The address bus (A_{15}-A_0) and data bus (D_7-D_0) are set to high impedance.
- All control outputs are set in their inactive state.
- The standby mode is released.

The following registers are undefined at reset:

Stack pointer (SP)
Accumulators (A,A')
Flag registers (F,F')
General purpose registers
(B, B', C, C', D, D', E, E', H, H', L, L')
Index registers (IX,IY)

When $\overline{RESET}$ is released the program will begin execution from location 0000H.

Instruction Set

Each operand should be written in the operand column of an instruction according to the description in table 3. Capital letters are keywords and should be written as they appear.

Table 3. Operand Description

Indentifier	Description
addr	16-bit immediate data or label
faddr	00H, 08H, 10H, 18H, 20H, 28H, 30H, 38H immediate data or label
word	16-bit immediate data or label
byte	8-bit immediate data or label
bit	3-bit immediate data or label (bit specification of 8-bit register / memory)
d	8-bit displacement (signed 2's complement)
r	A, B, C, D, E, H, L
r'	A', B', C', D', E', H', L'
rp	BC, DE, HL, AF
rp1	BC, DE, HL, SP
rp2	BC, DE, IX, SP
rp3	BC, DE, IY, SP
e	Displacement for relative jump (signed 2's complement)

Selection of Register and Condition

rp	qq	rp1	ss, dd	rp2	pp	rp3	rr
BC	00	BC	00	BC	00	BC	00
DE	01	DE	01	DE	01	DE	01
HL	10	HL	10	IX	10	IY	10
AF	11	SP	11	SP	11	SP	11

r, r'	r, r'	bit	b	faddr	t
B B'	000	0	000	00H	000
C C'	001	1	001	08H	001
D D'	010	2	010	10H	010
E E'	011	3	011	18H	011
H H'	100	4	100	20H	100
L L'	101	5	101	28H	101
A A'	111	6	110	30H	110
		7	111	38H	111

Flag Operation

(Blank): Flag not affected

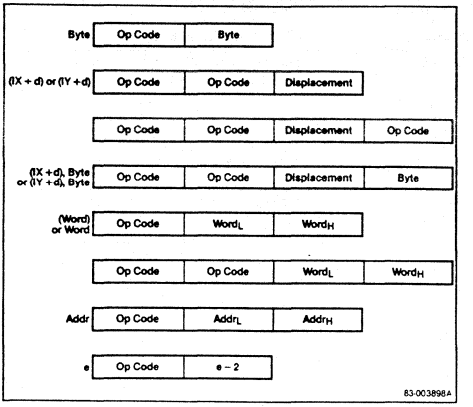
0: Flag reset

1: Flag set

X: Flag affected according to result of operation

U: Flag unknown

Structure of Instruction Byte for Addressing



Instruction Set

Mnemonic	Operands	Operation	Operation Code																No. of Clocks	No. of Bytes	Flags					
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0			S	Z	H	P/V	N	C
8-Bit Transfer Instructions																										
LD	r, r'	r ← r'	0	1		r			r'										4	1						
	r, byte	r ← byte	0	0		r		1	1	0									7	2						
	r, (HL)	r ← (HL)	0	1		r		1	1	0									7	1						
	r, (IX + d)	r ← (IX + disp)	1	1	0	1	1	1	0	1	0	1		r		1	1	0	19	3						
			disp																							
	r, (IY = d)	r ← (IY + disp)	1	1	1	1	1	1	0	1	0	1		r		1	1	0	19	3						
			disp																							
	(HL), r	(HL) ← r	0	1	1	1	0		r										7	1						
	(IX + d), r	(IX + disp) ← r	1	1	0	1	1	1	0	1	0	1	1	1	0		r		19	3						
			disp																							
	(IY + d), r	(IY + disp) ← r	1	1	1	1	1		0	1	0	1	1	1	0		r		19	3						
			disp																							
	(HL), byte	(HL) ← byte	0	0	1	1	0	1	1	0									10	2						
	(IX + d), byte	(IX + disp) ← byte	1	1	0	1	1	1	0	1	0	0	1	1	0	1	1	0	19	4						
			disp																							
	(IY + d), byte	(IY + disp) ← byte	1	1	1	1	1	1	0	1	0	0	1	1	0	1	1	0	19	4						
			disp																							
	A, (BC)	A ← (BC)	0	0	0	0	1	0	1	0									7	1						
	A, (DE)	A ← (DE)	0	0	0	1	1	0	1	0									7	1						
	A, (word)	A ← (word)	0	0	1	1	1	0	1	0									13	3						
	(BC), A	(BC) ← A	0	0	0	0	0	0	1	0									7	1						
	(DE), A	(DE) ← A	0	0	0	1	0	0	1	0									7	1						
	(word), A	(word) ← A	0	0	1	1	0	0	1	0									13	3						
	A, I	A ← I	1	1	1	0	1	1	0	1	0	1	0	1	0	1	1	1	9	2	x	x	0	IFF	0	
	A, R	A ← R	1	1	1	0	1	1	0	1	0	1	0	1	1	1	1	1	9	2	x	x	0	IFF	0	
	I, A	I ← A	1	1	1	0	1	1	0	1	0	1	0	0	0	1	1	1	9	2						
	R, A	R ← A	1	1	1	0	1	1	0	1	0	1	0	0	1	1	1	1	9	2						
	rp1, word	rp1 ← word	0	0	d	d	0	0	0	1									10	3						
	IX, word	IX ← word	1	1	0	1	1	1	0	1	0	0	1	0	0	0	0	1	14	4						
	IY, word	IY ← word	1	1	1	1	1	1	0	1	0	0	1	0	0	0	0	1	14	4						
	HL, (word)	H ← (word + 1), L ← (word)	0	0	1	0	1	0	1	0									16	3						

Instruction Set (cont)

Mnemonic	Operands	Operation	Operation Code																No. of Clocks	No. of Bytes	Flags						
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0			S	Z	H	P/V	N	C
Sixteen-Bit Transfer Instructions																										
LD	rp1, (word)	$rp1_H \leftarrow (word + 1)$, $rp1_L \leftarrow (word)$	1	1	1	0	1	1	0	1	0	1	d	d	1	0	1	1	20	4						
	IX, (word)	$IX_H \leftarrow (word + 1)$, $IX_L \leftarrow (word)$	1	1	0	1	1	1	0	1	0	0	1	0	1	0	1	0	20	4						
	IY, (word)	$IY_H \leftarrow (word + 1)$, $IY_L \leftarrow (word)$	1	1	1	1	1	1	0	1	0	0	1	0	1	0	1	0	20	4						
	(word), HL	$(word + 1) \leftarrow H$, $(word) \leftarrow L$	0	0	1	0	0	0	1	0									16	3						
	(word), rp1	$(word + 1) \leftarrow rp1_H$, $(word) \leftarrow rp1_L$	1	1	1	0	1	1	0	1	0	1	d	d	0	0	1	1	20	4						
	(word), IX	$(word + 1) \leftarrow IX_H$, $(word) \leftarrow IX_L$	1	1	0	1	1	1	0	1	0	0	1	0	0	0	1	0	20	4						
	(word), IY	$(word + 1) \leftarrow IY_H$, $(word) \leftarrow IY_L$	1	1	1	1	1	1	0	1	0	0	1	0	0	0	1	0	20	4						
	SP, HL	$SP \leftarrow HL$	1	1	1	1	1	0	0	1									6	1						
	SP, IX	$SP \leftarrow IX$	1	1	0	1	1	1	0	1	1	1	1	1	1	0	0	1	10	2						
	SP, IY	$SP \leftarrow IY$	1	1	1	1	1	1	0	1	1	1	1	1	1	0	0	1	10	2						
PUSH	rp	$(SP - 1) \leftarrow rp_L$, $(SP - 2) \leftarrow rp_H$, $SP \leftarrow SP - 2$	1	1	q	q	0	1	0	1									11	1						
	IX	$(SP - 1) \leftarrow IX_L$, $(SP - 2) \leftarrow IX_H$, $SP \leftarrow SP - 2$	1	1	0	1	1	1	0	1	1	1	1	0	0	1	0	1	15	2						
	IY	$(SP - 1) \leftarrow IY_L$, $(SP - 2) \leftarrow IY_H$, $SP \leftarrow SP - 2$	1	1	1	1	1	1	0	1	1	1	1	0	0	1	0	1	15	2						
POP	rp	$rp_L \leftarrow (SP)$, $rp_H \leftarrow (SP + 1)$, $SP \leftarrow SP = 2$	1	1	q	q	0	0	0	1									10	1						
	IX	$IX_L \leftarrow (SP)$, $IX_H \leftarrow (SP + 1)$, $SP \leftarrow SP + 2$	1	1	0	1	1	1	0	1	1	1	1	0	0	0	0	1	14	2						
	IY	$IY_L \leftarrow (SP)$, $IY_H \leftarrow (SP + 1)$, $SP \leftarrow SP + 2$	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0	1	14	2						

Instruction Set (cont)

Mnemonic	Operands	Operation	Operation Code								No. of Clocks	No. of Bytes	Flags					
			7	6	5	4	3	2	1	0			S	Z	H	P/V	N	C
Data Conversion Instructions																		
EX	DE, HL	DE ↔ HL	1	1	1	0	1	0	1	1	4	1						
	AF, AF'	A ↔ A', F ↔ F'	0	0	0	0	1	0	0	0	4	1						
EXX		BC ↔ BC', DE ↔ DE', HL ↔ HL'	1	1	0	1	1	0	0	1	4	1						
EX	(SP), HL	(SP) ↔ L, (SP + 1) ↔ H, SP ← SP + 2	1	1	1	0	0	0	1	1	19	1						
	(SP), IX	(SP) ↔ IX_L, (SP + 1) ↔ IX_H, SP ← SP + 2	1	1	0	1	1	1	0	1	23	2						
	(SP), IY	(SP) ↔ IY_L, (SP + 1) ↔ IY_H, SP ← SP + 2	1	1	1	1	1	1	0	1	23	2						
Block Transfer Instructions																		
LDI		(DE) ← (HL), DE ← DE + 1, HL ← HL + 1, BC ← BC − 1	1	1	1	0	1	1	0	1	16	2			0	x	0	
LDIR		(DE) ← (HL), DE ← DE + 1, HL ← HL + 1, BC ← BC − 1, End if BC = 0	1	1	1	0	1	1	0	1	21/16(1)	2			0	0	0	
LDD		(DE) ← (HL), DE ← DE − 1, HL ← HL − 1, BC ← BC − 1	1	1	1	0	1	1	0	1	16	2			0	x	0	
LDDR		(DE) ← (HL), DE ← DE − 1, HL ← HL − 1, BC ← BC − 1, End if BC = 0	1	1	1	0	1	1	0	1	21/16(1)	2			0	0	0	
Block Search Instructions																		
CPI		A − (HL), HL ← HL + 1, BC ← BC − 1	1	1	1	0	1	1	0	1	16	2	x	x	x	x	1	
CPIR		A − (HL), HL ← HL + 1, BC ← BC − 1, End if A = (HL) or BC = 0	1	1	1	0	1	1	0	1	21/16(2)	2	x	x	x	x	1	

Instruction Set (cont)

Mnemonic	Operands	Operation	Operation Code																No. of Clocks	No. of Bytes	Flags					
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0			S	Z	H	P/V	N	C
Block Search Instructions (cont)																										
CPD		A − (HL), HL ← HL − 1, BC ← BC − 1	1	1	1	0	1	1	0	1	1	0	1	0	1	0	0	1	16	2	x	x	x	x	1	
CPDR		A − (HL), HL ← HL − 1, BC ← BC − 1, End if A = (HL) or BC = 0	1	1	1	0	1	1	0	1	1	0	1	1	1	0	0	1	21/16(2)	2	x	x	x	x	1	
Eight-Bit Arithmetic Operation Instructions																										
ADD	A, r	A ← A + r	1	0	0	0	0		r										4	1	x	x	x	V	0	x
	A, byte	A ← A + byte	1	1	0	0	0	1	1	0									7	2	x	x	x	V	0	x
	A, (HL)	A ← A + (HL)	1	0	0	0	0	1	1	0									7	1	x	x	x	V	0	x
	A, (IX + d)	A ← A + (IX + disp)	1	1	0	1	1	1	0	1	1	0	0	0	0	1	1	0	19	3	x	x	x	V	0	x
			disp																							
	A, (IY + d)	A ← A + (IY + disp)	1	1	1	1	1	1	0	1	1	0	0	0	0	1	1	0	19	3	x	x	x	V	0	x
			disp																							
ADC	A, r	A ← A + r + CY	1	0	0	0	1		r										4	1	x	x	x	V	0	x
	A, byte	A ← A + byte + CY	1	1	0	0	1	1	1	0									7	2	x	x	x	V	0	x
	A, (HL)	A ← A + (HL) + CY	1	0	0	0	1	1	1	0									7	1	x	x	x	V	0	x
	A, (IX + d)	A ← A + (IX + disp) + CY	1	1	0	1	1	1	0	1	1	0	0	0	1	1	1	0	19	3	x	x	x	V	0	x
			disp																							
	A, (IY + d)	A ← A + (IY + disp) + CY	1	1	1	1	1	1	0	1	1	0	0	0	1	1	1	0	19	3	x	x	x	V	0	x
			disp																							
SUB	A, r	A ← A − r	1	0	0	1	0		r										4	1	x	x	x	V	1	x
	A, byte	A ← A − byte	1	1	0	1	0	1	1	0									7	2	x	x	x	V	1	x
	A, (HL)	A ← A − (HL)	1	0	0	1	0	1	1	0									7	1	x	x	x	V	1	x
	A, (IX + d)	A ← A − (IX + disp)	1	1	0	1	1	1	0	1	1	0	0	1	0	1	1	0	19	3	x	x	x	V	1	x
			disp																							
	A, (IY + d)	A ← A − (IY + disp)	1	1	1	1	1	1	0	1	1	0	0	1	0	1	1	0	19	3	x	x	x	V	1	x
			disp																							

Instruction Set (cont)

Mnemonic	Operands	Operation	Operation Code																No. of Clocks	No. of Bytes	Flags					
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0			S	Z	H	P/V	N	C
Eight-Bit Arithmetic Operation Instructions (cont)																										
SBC	A, r	A ← A − r − CY	1	0	0	1	1		r									4	1	x	x	x	V	1	x	
	A, byte	A ← A − byte − CY	1	1	0	1	1	1	1	0									7	2	x	x	x	V	1	x
	A, (HL)	A ← A − (HL) − CY	1	0	0	1	1	1	1	0									7	1	x	x	x	V	1	x
	A, (IX + d)	A ← A − (IX + disp) − CY	1	1	0	1	1	1	0	1	1	0	0	1	1	1	1	0	19	3	x	x	x	V	1	x
							disp																			
	A, (IY + d)	A ← A − (IY + disp) − CY	1	1	1	1	1	1	0	1	1	0	0	1	1	1	1	0	19	3	x	x	x	V	1	x
							disp																			
Eight-Bit Logical Operation Instructions																										
AND	A, r	A ← A AND r	1	0	1	0	0		r									4	1	x	x	1	P	0	0
	A, byte	A ← A AND byte	1	1	1	0	0	1	1	0									7	2	x	x	1	P	0	0
	A, (HL)	A ← A AND (HL)	1	0	1	0	0	1	1	0									7	1	x	x	1	P	0	0
	A, (IX + d)	A ← A AND (IX + disp) − CY	1	1	0	1	1	1	0	1	1	0	1	0	0	1	1	0	19	3	x	x	1	P	0	0
							disp																			
	A, (IY + d)	A ← A AND (IY + disp)	1	1	1	1	1	1	0	1	1	0	1	0	0	1	1	0	19	3	x	x	1	P	0	0
							disp																			
OR	A, r	A ← A OR r	1	0	1	1	0		r									4	1	x	x	0	P	0	0
	A, byte	A ← A OR byte	1	1	1	1	0	1	1	0									7	2	x	x	0	P	0	0
	A, (HL)	A ← A OR (HL)	1	0	1	1	0	1	1	0									7	1	x	x	0	P	0	0
	A, (IX + d)	A ← A OR (IX + disp)	1	1	0	1	1	1	0	1	1	0	1	1	0	1	1	0	19	3	x	x	0	P	0	0
							disp																			
	A, (IY + d)	A ← A OR (IYJ + disp)	1	1	1	1	1	1	0	1	1	0	1	1	0	1	1	0	19	3	x	x	0	P	0	0
							disp																			
XOR	A, r	A ← A XOR r	1	0	1	0	1		r									4	1	x	x	0	P	0	0
	A, byte	A ← A XOR byte	1	1	1	0	1	1	1	0									7	2	x	x	0	P	0	0
	A, (HL)	A ← A XOR (HL)	1	0	1	0	1	1	1	0									7	1	x	x	0	P	0	0
	A, (IX + d)	A ← A XOR (IX + disp)	1	1	0	1	1	1	0	1	1	0	1	0	1	1	1	0	19	3	x	x	0	P	0	0
							disp																			
	A, (IY + d)	A ← A XOR (IY + disp)	1	1	1	1	1	1	0	1	1	0	1	0	1	1	1	0	19	3	x	x	0	P	0	0
							disp																			

Instruction Set (cont)

Mnemonic	Operands	Operation	Operation Code																No. of Clocks	No. of Bytes	Flags					
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0			S	Z	H	P/V	N	C
Eight-Bit Logical Operation Instructions (cont)																										
CP	A, r	A – r	1	0	1	1	1		r										4	1	x	x	x	V	1	x
	A, byte	A – byte	1	1	1	1	1	1	1	0									7	2	x	x	x	V	1	x
	A, (HL)	A – (HL)	1	0	1	1	1	1	1	0									7	1	x	x	x	V	1	x
	A, (IX + d)	A – (IX + disp)	1	1	0	1	1	1	0	1	1	0	1	1	1	1	1	0	19	3	x	x	x	V	1	x
			disp																							
	A, (IY + d)	A – (IY + disp)	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	0	19	3	x	x	x	V	1	x
			disp																							
Eight-Bit Increment / Decrement Instructions																										
INC	r	r ← r + 1	0	0		r			1	0	0								4	1	x	x	x	V	0	
	(HL)	(HL) ← (HL) + 1	0	0	1	1	0	1	0	0									11	1	x	x	x	V	0	
	(IX + d)	(IX + disp) ← (IX + disp) + 1	1	1	0	1	1	1	0	1	0	0	1	1	0	1	0	0	23	3	x	x	x	V	0	
			disp																							
	(IY + d)	(IY + disp) ← (IX + disp) + 1	1	1	1	1	1	1	0	1	0	0	1	1	0	1	0	0	23	3	x	x	x	V	0	
			disp																							
DEC	r	r ← r – 1	0	0		r			1	0	1								4	1	x	x	x	V	1	
	(HL)	(HL) ← (HL) – 1	0	0	1	1	0	1	0	1									11	1	x	x	x	V	1	
	(IX + d)	(IX + disp) ← (IX + disp) – 1	1	1	0	1	1	1	0	1	0	0	1	1	0	1	0	1	23	3	x	x	x	V	1	
			disp																							
	(IY + d)	(IY + disp) ← (IY + disp) – 1	1	1	1	1	1	1	0	1	0	0	1	1	0	1	0	1	23	3	x	x	x	V	1	
			disp																							
Sixteen-Bit Arithmetic Operation Instructions																										
ADD	HL, rp1	HL ← HL + rp1	0	0	s	s	1	0	0	1									11	1			U		0	x
ADC	HL, rp1	HL ← HL + rp1 + CY	1	1	1	0	1	1	0	1	0	1	s	s	1	0	1	0	15	2	x	x	U	V	0	x
SBC	HL, rp1	HL ← HL – rp1 – CY	1	1	1	0	1	1	0	1	0	1	s	s	0	0	1	0	15	2	x	x	U	V	1	x
ADD	IX, rp2	IX ← IX + rp2	1	1	0	1	1	1	0	1	0	0	p	p	1	0	0	1	15	2			U		0	x
	IY, rp3	IY ← IY + rp3	1	1	1	1	1	1	0	1	0	0	r	r	1	0	0	1	15	2			U		0	x
Sixteen-Bit Increment / Decrement Instructions																										
INC	rp1	rp1 ← rp1 + 1	0	0	s	s	0	0	1	1									6	1						
	IX	IX ← IX + 1	1	1	0	1	1	1	0	1	0	0	1	0	0	0	1	1	10	2						
	IY	IY ← IY + 1	1	1	1	1	1	1	0	1	0	0	1	0	0	0	1	1	10	2						
DEC	rp1	rp1 ← rp1 – 1	0	0	s	s	1	0	1	1									6	1						
	IX	IX ← IX – 1	1	1	0	1	1	1	0	1	0	0	1	0	1	0	1	1	10	2						
	IY	IY ← IY – 1	1	1	1	1	1	1	0	1	0	0	1	0	1	0	1	1	10	2						

Instruction Set (cont)

Mnemonic	Operands	Operation	Operation Code								No. of Clocks	No. of Bytes	Flags					
			7	6	5	4	3	2	1	0			S	Z	H	P/V	N	C
Accumulator Operation Instructions																		
DAA		Decimal adjust accumulator	0	0	1	0	0	1	1	1	4	1	x	x	x	P		x
CPL		$A \leftarrow \overline{A}$	0	0	1	0	1	1	1	1	4	1			1		1	
NEG		$A \leftarrow \overline{A} + 1$	1	1	1	0	1	1	0	1	8	2	x	x	x	V	1	x
CCF		$CY \leftarrow \overline{CY}$	0	0	1	1	1	1	1	1	4	1			U		0	x
SCF		CY ← 1	0	0	1	1	0	1	1	1	4	1			0		0	1
Rotate Instructions																		
RLCA			0	0	0	0	0	1	1	1	4	1			0		0	x
RLA			0	0	0	1	0	1	1	1	4	1			0		0	x
RRCA			0	0	0	0	1	1	1	1	4	1			0		0	x
RRA			0	0	0	1	1	1	1	1	4	1			0	0	x	
RLC	r		1	1	0	0	1	0	1	1	0	0	0	0	0		r		8	2	x	x	0	P	0	x
	(HL)		1	1	0	0	1	0	1	1	0	0	0	0	0	1	1	0	15	2	x	x	0	P	0	x
	(IX + d)		1	1	0	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4	x	x	0	P	0	x
			disp								0	0	0	0	0	1	1	0								
	(IY + d)	r, (HL), (IX + disp), (IY + disp)	1	1	1	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4	x	x	0	P	0	x
			disp								0	0	0	0	0	1	1	0								
RL	r		1	1	0	0	1	0	1	1	0	0	0	1	0		r		8	2	x	x	0	P	0	x
	(HL)		1	1	0	0	1	0	1	1	0	0	0	1	0	1	1	0	15	2	x	x	0	P	0	x
	(IX + d)		1	1	0	1	1	1	0	1	1	1	0	1	1	0	1	1	23	4	x	x	0	P	0	x
			disp								0	0	0	1	0	1	1	0								
	(IY + d)	r, (HL), (IX + disp), (IY + disp)	1	1	1	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4	x	x	0	P	0	x
			disp								0	0	0	1	0	1	1	0								
RRC	r		1	1	0	0	1	0	1	1	0	0	0	0	1		r		8	2	x	x	0	P	0	x
	(HL)		1	1	0	0	1	0	1	1	0	0	0	0	1	1	1	0	15	2	x	x	0	P	0	x
	(IX + d)		1	1	0	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4	x	x	0	P	0	x
			disp								0	0	0	0	1	1	1	0								
	(IY + d)	r, (HL), (IX + disp), (IY + disp)	1	1	1	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4	x	x	0	P	0	x
			disp								0	0	0	0	1	1	1	0								

Instruction Set (cont)

Mnemonic	Operands	Operation	Operation Code																No. of Clocks	No. of Bytes	Flags					
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0			S	Z	H	P/V	N	C
Rotate Instructions (cont)																										
RR	r		1	1	0	0	1	0	1	1	0	0	0	1	1		r		8	2	x	x	0	P	0	x
	(HL)		1	1	0	0	1	0	1	1	0	0	0	1	1	1	1	0	15	2	x	x	0	P	0	x
	(IX + d)		1	1	0	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4	x	x	0	P	0	x
							disp				0	0	0	1	1	1	1	0								
	(IY + d)	r, (HL), (IX + disp), (IY + disp)	1	1	1	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4	x	x	0	P	0	x
							disp				0	0	0	1	1	1	1	0								
RLD			1	1	1	0	1	1	0	1	0	1	1	0	1	1	1	1	18	2	x	x	0	P	0	
RRD			1	1	1	0	1	1	0	1	0	1	1	0	0	1	1	1	18	2	x	x	0	P	0	
Shift Instructions																										
SLA	r		1	1	0	0	1	0	1	1	0	0	1	0	0		r		8	2	x	x	0	P	0	x
	(HL)		1	1	0	0	1	0	1	1	0	0	1	0	0	1	1	0	15	2	x	x	0	P	0	x
	(IX + d)		1	1	0	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4	x	x	0	P	0	x
							disp				0	0	1	0	0	1	1	0								
	(IY + d)	r, (HL), (IX + disp), (IY + disp)	1	1	1	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4	x	x	0	P	0	x
							disp				0	0	1	0	0	1	1	0								
SRA	r		1	1	0	0	1	0	1	1	0	0	1	0	1		r		8	2	x	x	0	P	0	x
	(HL)		1	1	0	0	1	0	1	1	0	0	1	0	1	1	1	0	15	2	x	x	0	P	0	x
	(IX + d)		1	1	0	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4	x	x	0	P	0	x
							disp				0	0	1	0	1	1	1	0								
	(IY + d)	r, (HL), (IX + disp), (IY + disp)	1	1	1	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4	x	x	0	P	0	x
							disp				0	0	1	0	1	1	1	0								
SRL	r		1	1	0	0	1	0	1	1	0	0	1	1	1		r		8	2	x	x	0	P	0	x
	(HL)		1	1	0	0	1	0	1	1	0	0	1	1	1	1	1	0	15	2	x	x	0	P	0	x
	(IX + d)		1	1	0	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4	x	x	0	P	0	x
							disp				0	0	1	1	1	1	1	0								
	(IY + d)	r, (HL), (IX + disp), (IY + disp)	1	1	1	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4	x	x	0	P	0	x
							disp				0	0	1	1	1	1	1	0								

Instruction Set (cont)

Mnemonic	Operands	Operation	Operation Code																No. of Clocks	No. of Bytes	Flags					
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0			S	Z	H	P/V	N	C
Bit Operation Instructions																										
BIT	bit, r	$Z \leftarrow \overline{r_b}$	1	1	0	0	1	0	1	1	0	1		b			r		8	2	U	x	1	U	0	
	bit, (HL)	$Z \leftarrow \overline{(HL)_b}$	1	1	0	0	1	0	1	1	0	1		b		1	1	0	12	2	U	x	1	U	0	
	bit, (IX + d)	$Z \leftarrow \overline{(IX + disp)_b}$	1	1	0	1	1	1	0	1	1	1	0	0	1	0	1	1	20	4	U	x	1	U	0	
							disp				0	1		b		1	1	0								
	bit, (IY + d)	$Z \leftarrow \overline{(IY + disp)_b}$	1	1	1	1	1	1	0	1	1	1	0	0	1	0	1	1	20	4	U	x	1	U	0	
							disp				0	1		b		1	1	0								
SET	bit, r	$r_b \leftarrow 1$	1	1	0	0	1	0	1	1	1	1		b			r		8	2						
	bit, (HL)	$(HL)_b \leftarrow 1$	1	1	0	0	1	0	1	1	1	1		b		1	1	0	15	2						
	bit (IX + d)	$(IX + disp)_b \leftarrow 1$	1	1	0	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4						
							disp				1	1		b		1	1	0								
	bit (IY + d)	$(IY + disp)_b \leftarrow 1$	1	1	1	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4						
							disp				1	1		b		1	1	0								
RES	bit, r	$r_b \leftarrow 0$	1	1	0	0	1	0	1	1	1	0		b			r		8	2						
	bit, (HL)	$(HL)_b \leftarrow 0$	1	1	0	0	1	0	1	1	1	0		b		1	1	0	15	2						
	bit (IX + d)	$(IX + disp)_b \leftarrow 0$	1	1	0	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4						
							disp				1	0		b		1	1	0								
	bit (IY + d)	$(IY + disp)_b \leftarrow 0$	1	1	1	1	1	1	0	1	1	1	0	0	1	0	1	1	23	4						
							disp				1	0		b		1	1	0								
Jump Instructions																										
JP	addr	PC ← addr	1	1	0	0	0	0	1	1									10	3						
	NZ, addr	If Z = 0, PC ← addr	1	1	0	0	0	0	1	0									10	3						
	Z, addr	If Z = 1, PC ← addr	1	1	0	0	1	0	1	0									10	3						
	NC, addr	If C = 0, PC ← addr	1	1	0	1	0	0	1	0									10	3						
JP	C, addr	If C = 1, PC ← addr	1	1	0	1	1	0	1	0									10	3						
	PO, addr	If P = 0, PC ← addr	1	1	1	0	0	0	1	0									10	3						
	PE, addr	If P = 1, PC ← addr	1	1	1	0	1	0	1	0									10	3						
	P, addr	If S = 0, PC ← addr	1	1	1	1	0	0	1	0									10	3						
	M, addr	If S = 1, PC ← addr	1	1	1	1	1	0	1	0									10	3						

Instruction Set (cont)

Mnemonic	Operands	Operation	Operation Code																No. of Clocks	No. of Bytes	Flags					
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0			S	Z	H	P/V	N	C
Jump Instructions (cont)																										
JR	e	PC ← PC + e	0	0	0	1	1	0	0	0									12	2						
	NZ, e	If Z = 0, PC ← PC + e	0	0	1	0	0	0	0	0									12 / 7(3)	2						
	Z, e	If Z = 1, PC ← PC + e	0	0	1	0	1	0	0	0									12 / 7(3)	2						
	NC, e	If C = 0, PC ← PC + e	0	0	1	1	0	0	0	0									12 / 7(3)	2						
	C, e	If C = 1, PC ← PC + e	0	0	1	1	1	0	0	0									12 / 7(3)	2						
JP	(HL)	PC ← HL	1	1	1	0	1	0	0	1									4	1						
	(IX)	PC ← IX	1	1	0	1	1	1	0	1	1	1	1	0	1	0	0	1	8	2						
	(IY)	PC ← IY	1	1	1	1	1	1	0	1	1	1	1	0	1	0	0	1	8	2						
DJNZ	e	B ← B − 1; if B ≠ 0, PC ← PC + e	0	0	0	1	0	0	0	0									8 / 13(4)	2						
Call Instructions																										
CALL	addr	(SP − 1) ← PC_H, (SP − 2) ← PC_L, SP ← SP − 2, PC ← addr	1	1	0	0	1	1	0	1									17	3						
	NZ, addr	If conditions met, (SP − 1) ← PC_H, (SP − 2) ← PC_L, SP ← SP − 2, PC ← addr	1	1	0	0	0	1	0	0									17 / 10(5)	3						
	Z, addr	If conditions met, (SP − 1) ← PC_H, (SP − 2) ← PC_L, SP ← SP − 2, PC ← addr	1	1	0	0	1	1	0	0									17 / 10(5)	3						
	NC, addr	If conditions met, (SP − 1) ← PC_H, (SP − 2) ← PC_L, SP ← SP − 2, PC ← addr	1	1	0	1	0	1	0	0									17 / 10(5)	3						
	C, addr	If conditions met, (SP − 1) ← PC_H, (SP − 2) ← PC_L, SP ← SP − 2, PC ← addr	1	1	0	1	1	1	0	0									17 / 10(5)	3						
	PO, addr	If conditions met, (SP − 1) ← PC_H, (SP − 2) ← PC_L, SP ← SP − 2, PC ← addr	1	1	1	0	0	1	0	0									17 / 10(5)	3						

Instruction Set (cont)

Mnemonic	Operands	Operation	Operation Code 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	No. of Clocks	No. of Bytes	Flags S	Z	H	P/V	N	C
Call Instructions (cont)																										
CALL	PE, addr	If conditions met, (SP − 1) ← PC_H, (SP − 2) ← PC_L, SP ← SP − 2, PC ← addr	1	1	1	0	1	1	0	0									17 / 10(5)	3						
	P, addr	If conditions met, (SP − 1) ← PC_H, (SP − 2) ← PC_L, SP ← SP − 2, PC ← addr	1	1	1	1	0	1	0	0									17 / 10(5)	3						
	M, addr	If conditions met, (SP − 1) ← PC_H, (SP − 2) ← PC_L, SP ← SP − 2, PC ← addr	1	1	1	1	1	1	0	0									17 / 10(5)	3						
RST	faddr	(SP − 1) ← PC_H, (SP − 2) ← PC_L, SP ← SP − 2, PC_H ← 0, PC_L ← faddr	1	1		t		1	1	1									11	1						
Return Instructions																										
RET		PC_L ← (SP), PC_H ← (SP + 1), SP ← SP + 2	1	1	0	0	1	0	0	1									10	1						
	NZ	If conditions met, PC_L ← (SP), PC_H ← (SP + 1), SP ← SP + 2	1	1	0	0	0	0	0	0									11 / 5(6)	1						
	Z	If conditions met, PC_L ← (SP), PC_H ← (SP + 1), SP ← SP + 2	1	1	0	0	1	0	0	0									11 / 5(6)	1						
	NC	If conditions met, PC_L ← (SP), PC_H ← (SP + 1), SP ← SP + 2	1	1	0	1	0	0	0	0									11 / 5(6)	1						
	C	If conditions met, PC_L ← (SP), PC_H ← (SP + 1), SP ← SP + 2	1	1	0	1	1	0	0	0									11 / 5(6)	1						
	PO	If conditions met, PC_L ← (SP), PC_H ← (SP + 1), SP ← SP + 2	1	1	1	0	0	0	0	0									11 / 5(6)	1						
	PE	If conditions met, PC_L ← (SP), PC_H ← (SP + 1), SP ← SP + 2	1	1	1	0	1	0	0	0									11 / 5(6)	1						
	P	If conditions met, PC_L ← (SP), PC_H ← (SP + 1), SP ← SP + 2	1	1	1	1	0	0	0	0									11 / 5(6)	1						
	M	If conditions met, PC_L ← (SP), PC_H ← (SP + 1), SP ← SP + 2	1	1	1	1	1	0	0	0									11 / 5(6)	1						
RETI		Return from interrupt	1	1	1	0	1	1	0	1	0	1	0	0	1	1	0	1	14	2						
RETN		Return from interrupt, nonmaskable	1	1	1	0	1	1	0	1	0	1	0	0	0	1	0	1	14	2						

Instruction Set (cont)

Mnemonic	Operands	Operation	Operation Code																No. of Clocks	No. of Bytes	Flags					
			7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0			S	Z	H	P/V	N	C
Return Instructions (cont)																										
IN	A, byte	A ← (byte), A_7–A_0 ← byte, A_{15}–A_8 ← byte	1	1	0	1	1	0	1	1									11	2						
	r, (C)	r ← (C), A_7–A_0 ← C, A_{15}–A_8 ← B	1	1	1	0	1	1	0	1	0	1		r		0	0	0	12	2	x	x	x	P	0	
INI		(HL) ← (C), B ← B – 1, HL ← HL + 1, A_7–A_0 ← C, A_{15}–A_8 ← B	1	1	1	0	1	1	0	1	1	0	1	0	0	0	1	0	16	2	U	x	U	U	1	
IND		(HL) ← (C), B ← B – 1, HL ← HL – 1, A_7–A_0 ← C, A_{15}–A_8 ← B	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	16	2	U	x	U	U	1	
INIR		(HL) ← (C), B ← B – 1, HL ← HL + 1, A_7–A_0 ← C, A_{15}–A_8 ← B, End if B = 0	1	1	1	0	1	1	0	1	1	0	1	1	0	0	1	0	21/16(7)	2	U	1	U	U	1	
INDR		(HL) ← (C), B ← B – 1, HL ← HL – 1, A_7–A_0 ← C, A_{15}–A_8 ← B, End if B = 0	1	1	1	0	1	1	0	1	1	0	1	1	1	0	1	0	21/16(7)	2	U	1	U	U	1	
OUT	byte, A	(byte) ← A, A_7–A_0 ← byte, A_{15}–A_8 ← B	1	1	0	1	0	0	1	1									11	2						
	(C), r	(C) ← r, A_7–A_0 ← C, A_{15}–A_8 ← B	1	1	1	0	1	1	0	1	0	1		r		0	0	1	12	2						
OUTI		(C) ← (HL), B ← B – 1, HL ← HL + 1, A_7–A_0 ← C, A_{15}–A_8 ← B	1	1	1	0	1	1	0	1	1	0	1	0	0	0	1	1	16	2	U	x	U	U	1	
OUTD		(C) ← (HL), B ← B – 1, HL ← HL – 1, A_7–A_0 ← C, A_{15}–A_8 ← B	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	1	16	2	U	x	U	U	1	
OUTIR		(C) ← (HL), B ← B – 1, HL ← HL + 1, A_7–A_0 ← C, A_{15}–A_8 ← B, End if B = 0	1	1	1	0	1	1	0	1	1	0	1	1	0	0	1	1	21/16(7)	2	U	1	U	U	1	
OUTDR		(C) ← (HL), B ← B – 1, HL ← HL – 1, A_7–A_0 ← C, A_{15}–A_8 ← B, End if B = 0	1	1	1	0	1	1	0	1	1	0	1	1	1	0	1	1	16	2	U	1	U	U	1	

Instruction Set (cont)

Mnemonic	Operands	Operation	Operation Code 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	No. of Clocks	No. of Bytes	Flags S	Z	H	P/V	N	C
CPU Control Instructions																										
NOP		No operation	0	0	0	0	0	0	0	0									4	1						
HALT		Halt	0	1	1	1	0	1	1	0									4	1						
DI		Disable interrupts (IFF ← 0)	1	1	1	1	0	0	1	1									4	1						
EI		Enable interrupts (IFF ← 1)	1	1	1	1	1	0	1	1									4	1						
IM	0	Set interrupt mode 0	1	1	1	0	1	1	0	1	0	1	0	0	0	1	1	0	8	2						
	1	Set interrupt mode 1	1	1	1	0	1	1	0	1	0	1	0	1	0	1	1	0	8	2						
	2	Set interrupt mode 2	1	1	1	0	1	1	0	1	0	1	0	1	1	1	1	0	8	2						

Note:

(1) 21 if BC ≠ 0, 16 if BC = 0

(2) 21 if BC ≠ 0 and A ≠ (HL), 16 if BC = 0 or A = (HL)

(3) 12 if condition is met, 7 if not

(4) 8 if B = 0, 13 if B ≠ 0

(5) 17 if condition is met, 10 if not

(6) 11 if condition is met, 5 if not

(7) 21 if B = 0, 16 if B ≠ 0

Description

The μPD70108 (V20) is a CMOS 16-bit microprocessor with internal 16-bit architecture and an 8-bit external data bus. The μPD70108 instruction set is a superset of the μPD8086/8088; however, mnemonics and execution times are different. The μPD70108 additionally has a powerful instruction set including bit processing, packed BCD operations, and high-speed multiplication/division operations. The μPD70108 can also execute the entire 8080 instruction set and comes with a standby mode that significantly reduces power consumption. It is software-compatible with the μPD70116 16-bit microprocessor.

Features

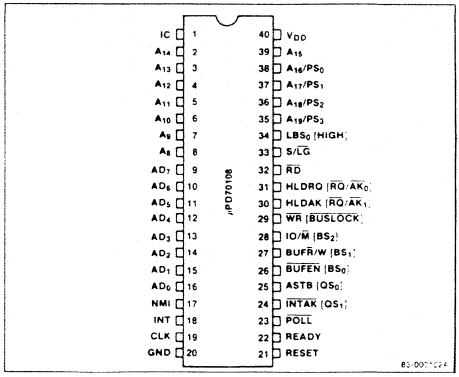
- ☐ Minimum instruction execution time: 250 ns (at 8 MHz)
- ☐ Maximum addressable memory: 1 Mbyte
- ☐ Abundant memory addressing modes
- ☐ 14 x 16-bit register set
- ☐ 101 instructions
- ☐ Instruction set is a superset of μPD8086/8088 instruction set
- ☐ Bit, byte, word, and block operations
- ☐ Bit field operation instructions
- ☐ Packed BCD instructions
- ☐ Multiplication/division instruction execution time: 4 μs to 6 μs (at 8 MHz)
- ☐ High-speed block transfer instructions: 1 Mbyte/s (at 8 MHz)
- ☐ High-speed calculation of effective addresses: 2 clock cycles in any addressing mode
- ☐ Maskable (INT) and nonmaskable (NMI) interrupt inputs
- ☐ IEEE-796 bus compatible interface
- ☐ 8080 emulation mode
- ☐ CMOS technology
- ☐ Low-power consumption
- ☐ Low-power standby mode
- ☐ Single power supply
- ☐ 5 MHz, 8 MHz or 10 MHz clock

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD70108C-5	40-pin plastic DIP	5 MHz
μPD70108C-8	40-pin plastic DIP	8 MHz
μPD70108D-5	40-pin ceramic DIP	5 MHz
μPD70108D-8	40-pin ceramic DIP	8 MHz
μPD70108D-10	40-pin ceramic DIP	10 MHz
μPD70108G-5	52-pin plastic flat pack	5 MHz
μPD70108G-8	52-pin plastic flat pack	8 MHz
μPD70108L-5	44-pin PLCC	5 MHz
μPD70108L-8	44-pin PLCC	8 MHz

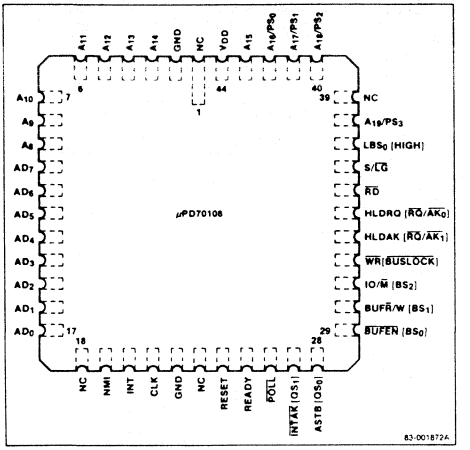
Pin Configurations

40-Pin Plastic DIP/Cerdip

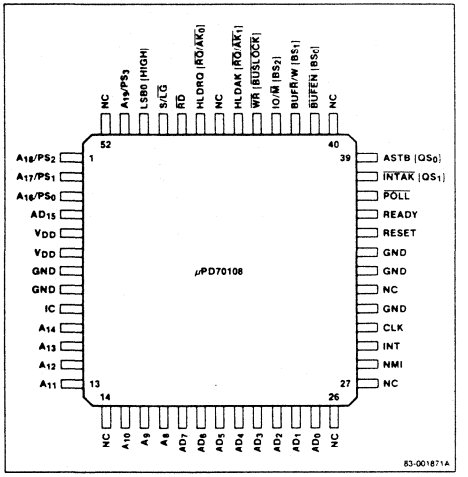


Pin Configurations (cont)

44-Pin Plastic Leadless Chip Carrier (PLCC)



52-Pin Plastic Flat Pack



Pin Identification

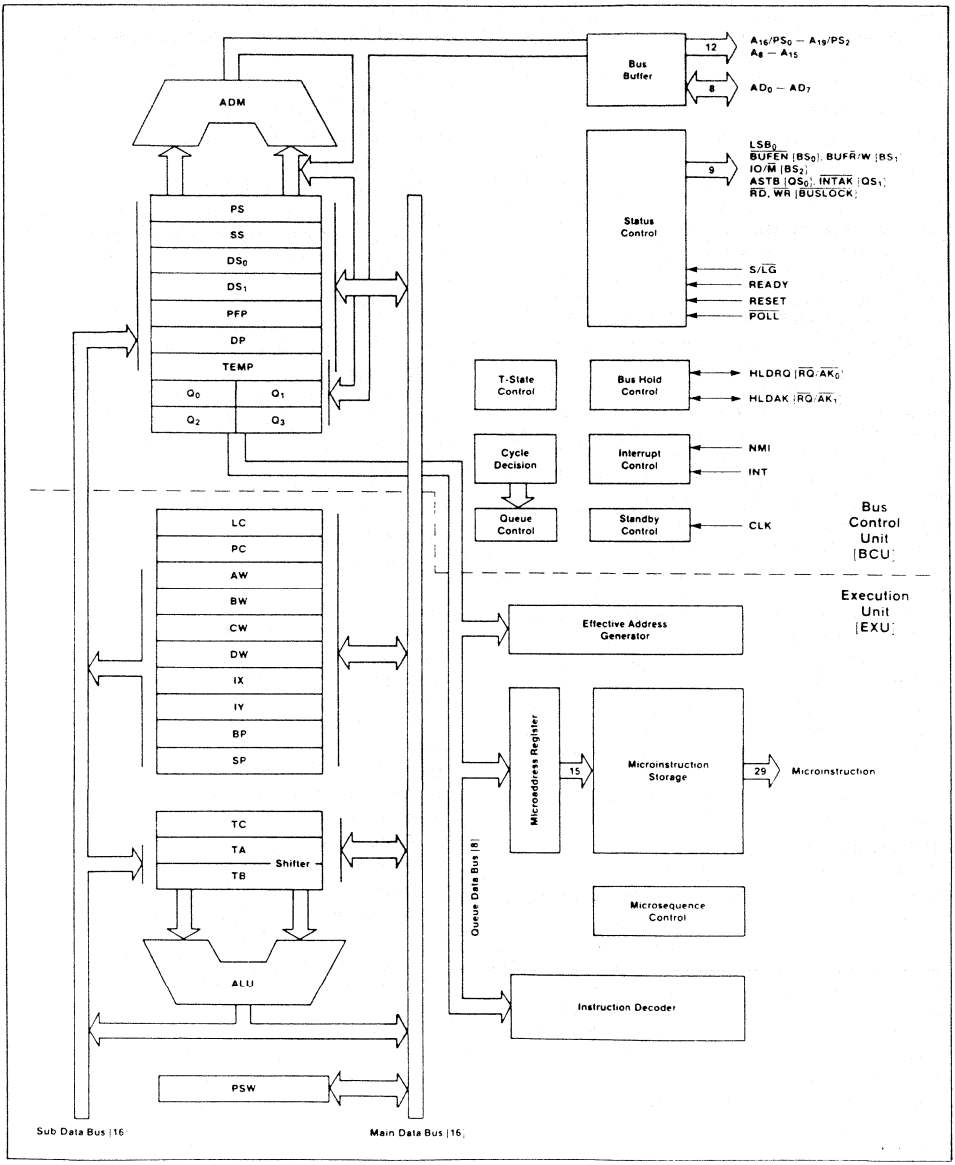
Symbol	Direction	Function
IC*		Internally connected
A_{14} - A_8	Out	Address bus, middle bits
AD_7 - AD_0	In/Out	Address/data bus
NMI	In	Nonmaskable interrupt input
INT	In	Maskable interrupt input
CLK	In	Clock input
GND		Ground potential
RESET	In	Reset input
READY	In	Ready input
$\overline{POLL}$	In	Poll input
$\overline{INTAK}$ (QS_1)	Out	Interrupt acknowledge output (queue status bit 1 output)
ASTB (QS_0)	Out	Address strobe output (queue status bit 0 output)
$\overline{BUFEN}$ (BS_0)	Out	Buffer enable output (bus status bit 0 output)
$BUF\overline{R}/W$ (BS_1)	Out	Buffer read/write output (bus status bit 1 output)
$IO/\overline{M}$ (BS_2)	Out	Access is I/O or memory (bus status bit 2 output)
$\overline{WR}$ ($\overline{BUSLOCK}$)	Out	Write strobe output (bus lock output)
HLDAK ($\overline{RQ}/\overline{AK}_1$)	Out (In/Out)	Hold acknowledge output. (bus hold request input/acknowledge output 1)
HLDRQ ($\overline{RQ}/\overline{AK}_0$)	In (In/Out)	Hold request input (bus hold request input/acknowledge output 0)
$\overline{RD}$	Out	Read strobe output
$S/\overline{LG}$	In	Small-scale/large-scale system input
LBS_0 (HIGH)	Out	Latched bus status output 0 (always high in large-scale systems)
A_{19}/PS_3 - A_{16}/PS_0	Out	Address bus, high bits or processor status output
A_{15}	Out	Address bus, bit 15
V_{DD}		Power supply

Notes: * IC should be connected to ground.

Where pins have different functions in small- and large-scale systems, the large-scale system pin symbol and function are in parentheses.

Unused input pins should be tied to ground or V_{DD} to minimize power dissipation and prevent the flow of potentially harmful currents.

Block Diagram



Pin Functions

Some pins of the μPD70108 have different functions according to whether the microprocessor is used in a small- or large-scale system. Other pins function the same way in either type of system.

A_{15} - A_8 [Address Bus]
For small- and large-scale systems.

The CPU uses these pins to output the middle 8 bits of the 20-bit address data. They are three-state outputs and become high impedance during hold acknowledge.

AD_7 - AD_0 [Address/Data Bus]
For small- and large-scale systems.

The CPU uses these pins as the time-multiplexed address and data bus. When high, an AD bit is a one; when low, an AD bit is a zero. This bus contains the lower 8 bits of the 20-bit address during T1 of the bus cycle and is used as an 8-bit data bus during T2, T3, and T4 of the bus cycle.

Sixteen-bit data I/O is performed in two steps. The low byte is sent first, followed by the high byte. The address/data bus is a three-state bus and can be at a high or low level during standby mode. The bus will be high impedance during hold and interrupt acknowledge.

NMI [Nonmaskable Interrupt]
For small- and large-scale systems.

This pin is used to input nonmaskable interrupt requests. NMI cannot be masked by software. This input is positive edge triggered and must be held high for five clocks to guarantee recognition. Actual interrupt processing begins, however, after completion of the instruction in progress.

The contents of interrupt vector 2 determine the starting address for the interrupt-servicing routine. Note that a hold request will be accepted even during NMI acknowledge.

This interrupt will cause the μPD70108 to exit the standby mode.

INT [Maskable Interrupt]
For small- and large-scale systems.

This pin is an interrupt request that can be masked by software.

INT is active high level and is sensed during the last clock of the instruction. The interrupt will be accepted if the interrupt enable flag IE is set. The CPU outputs the INTAK signal to inform external devices that the interrupt request has been granted. INT must be asserted until the interrupt acknowledge is returned.

If NMI and INT interrupts occur at the same time, NMI has higher priority than INT and INT cannot be accepted. A hold request will be accepted during INT acknowledge.

This interrupt causes the μPD70108 to exit the standby mode.

CLK [Clock]
For small- and large-scale systems.

This pin is used for external clock input.

RESET [Reset]
For small- and large-scale systems.

This pin is used for the CPU reset signal. It is an active high level. Input of this signal has priority over all other operations. After the reset signal input returns to a low level, the CPU begins execution of the program starting at address FFFF0H.

In addition to causing normal CPU start, RESET input will cause the μPD70108 to exit the standby mode.

READY [Ready]
For small- and large-scale systems.

When the memory or I/O device being accessed cannot complete data read or write within the CPU basic access time, it can generate a CPU wait state (Tw) by setting this signal to inactive (low level) and requesting a read/write cycle delay.

If the READY signal is active (high level) during either the T3 or Tw state, the CPU will not generate a wait state.

$\overline{\text{POLL}}$ [Poll]
For small- and large-scale systems.

The CPU checks this input upon execution of the $\overline{\text{POLL}}$ instruction. If the input is low, then execution continues. If the input is high, the CPU will check the $\overline{\text{POLL}}$ input every five clock cycles until the input becomes low again.

The $\overline{\text{POLL}}$ and READY functions are used to synchronize CPU program execution with the operation of external devices.

$\overline{\text{RD}}$ [Read Strobe]
For small- and large-scale systems.

The CPU outputs this strobe signal during data read from an I/O device or memory. The IO/$\overline{\text{M}}$ signal is used to select between I/O and memory.

The three-state output is held high during standby mode and enters the high-impedance state during hold acknowledge.

S/$\overline{\text{LG}}$ [Small/Large]
For small- and large-scale systems.

This signal determines the operation mode of the CPU. This signal is fixed at either a high or low level. When

this signal is a high level, the CPU will operate in small-scale system mode, and when low, in the large-scale system mode. A small-scale system will have at most one bus master such as a DMA controller device on the bus. A large-scale system can have more than one bus master accessing the bus as well as the CPU.

$\overline{\text{INTAK}}$ [Interrupt Acknowledge]
For small-scale systems.

The CPU generates the $\overline{\text{INTAK}}$ signal low when it accepts an INT signal.

The interrupting device synchronizes with this signal and outputs the interrupt vector to the CPU via the data bus (AD_7 - AD_0).

ASTB [Address Strobe]
For small-scale systems.

The CPU outputs this strobe signal to latch address information at an external latch.

ASTB is held at a low level during standby mode and hold acknowledge.

$\overline{\text{BUFEN}}$ [Buffer Enable]
For small-scale systems.

This is used as the output enable signal for an external bidirectional buffer. The CPU generates this signal during data transfer operations with external memory or I/O devices or during input of an interrupt vector.

This three-state output is held high during standby mode and enters the high-impedance state during hold acknowledge.

BUF$\overline{\text{R}}$/W [Buffer Read/Write]
For small-scale systems.

The output of this signal determines the direction of data transfer with an external bidirectional buffer. A high output causes transmission from the CPU to the external device; a low signal causes data transfer from the external device to the CPU.

BUF$\overline{\text{R}}$/W is a three-state output and becomes high impedance during hold acknowledge.

IO/$\overline{\text{M}}$ [IO/Memory]
For small-scale systems.

The CPU generates this signal to specify either I/O access or memory access. A high-level output specifies I/O and a low-level signal specifies memory.

IO/M's output is three state and becomes high impedance during hold acknowledge.

$\overline{\text{WR}}$ [Write Strobe]
For small-scale systems.

The CPU generates this strobe signal during data write to an I/O device or memory. Selection of either I/O or memory is performed by the IO/M signal.

This three-state output is held high during standby mode and enters the high-impedance state during hold acknowledge.

HLDAK [Hold Acknowledge]
For small-scale systems.

The HLDAK signal is used to indicate that the CPU accepts the hold request signal (HLDRQ). When this signal is a high level, the address bus, address/data bus, and the control lines become high impedance.

HLDRQ [Hold Request]
For small-scale systems.

This input signal is used by external devices to request the CPU to release the address bus, address/data bus, and the control bus.

LBS_0 [Latched Bus Status 0]
For small-scale systems.

The CPU uses this signal along with the IO/$\overline{\text{M}}$ and BUF$\overline{\text{R}}$/W signals to inform an external device what the current bus cycle is.

IO/$\overline{\text{M}}$	BUFR/$\overline{\text{W}}$	LBS_0	Bus Cycle
0	0	0	Program fetch
0	0	1	Memory read
0	1	0	Memory write
0	1	1	Passive state
1	0	0	Interrupt acknowledge
1	0	1	I/O read
1	1	0	I/O write
1	1	1	Halt

A_{19}/PS_3 - A_{16}/PS_0 [Address Bus/Processor Status]
For small- and large-scale systems.

These pins are time multiplexed to operate as an address bus and as processor status signals.

When used as the address bus, these pins are the high 4 bits of the 20-bit memory address. During I/O access, all 4 bits output data 0.

The processor status signals are provided for both memory and I/O use. PS_3 is always 0 in the native mode and 1 in 8080 emulation mode. The interrupt enable flag (IE) is pin on pin PS_2. Pins PS_1 and PS_0 indicate which memory segment is being accessed.

A_{17}/PS_1	A_{16}/PS_0	Segment
0	0	Data segment 1
0	1	Stack segment
1	0	Program segment
1	1	Data segment 0

The output of these pins is three state and becomes high impedance during hold acknowledge.

QS_1, QS_0 [Queue Status]
For large-scale systems.

The CPU uses these signals to allow external devices, such as the floating-point arithmetic processor chip, (μPD72091) to monitor the status of the internal CPU instruction queue.

QS_1	QS_0	Instruction Queue Status
0	0	NOP (queue does not change)
0	1	First byte of instruction
1	0	Flush queue
1	1	Subsequent bytes of instruction

The instruction queue status indicated by these signals is the status when the execution unit (EXU) accesses the instruction queue. The data output from these pins is therefore valid only for one clock cycle immediately following queue access. These status signals are provided so that the floating-point processor chip can monitor the CPU's program execution status and synchronize its operation with the CPU when control is passed to it by the FPO (Floating Point Operation) instructions.

BS_2 - BS_0 [Bus Status]
For large-scale systems.

The CPU uses these status signals to allow an external bus controller to monitor what the current bus cycle is.

The external bus controller decodes these signals and generates the control signals required to perform access of the memory or I/O device.

BS_2	BS_1	BS_0	Bus Cycle
0	0	0	Interrupt acknowledge
0	0	1	I/O read
0	1	0	I/O write
0	1	1	Halt
1	0	0	Program fetch
1	0	1	Memory read
1	1	0	Memory write
1	1	1	Passive state

The output of these signals is three state and becomes high impedance during hold acknowledge.

$\overline{BUSLOCK}$ [Bus Lock]
For large-scale systems.

The CPU uses this signal to secure the bus while executing the instruction immediately following the BUSLOCK prefix instruction, or during an interrupt acknowledge cycle. It is a status signal to the other bus masters in a multiprocessor system, inhibiting them from using the system bus during this time.

The output of this signal is three state and becomes high impedance during hold acknowledge. $\overline{BUSLOCK}$ is high during standby mode except if the HALT instruction has a $\overline{BUSLOCK}$ prefix.

$\overline{RQ}/\overline{AK}_1$, $\overline{RQ}/\overline{AK}_0$ [Hold Request/Acknowledge]
For large-scale systems.

These pins function as bus hold request inputs ($\overline{RQ}$) and as bus hold acknowledge outputs ($\overline{AK}$). $\overline{RQ}/\overline{AK}_0$ has a higher priority than $\overline{RQ}/\overline{AK}_1$.

These pins have three-state outputs with on-chip pull-up resistors which keep the pin at a high level when the output is high impedance.

V_{DD} [Power Supply]
For small- and large-scale systems.

This pin is used for the +5 V power supply.

GND [Ground]
For small- and large-scale systems.

This pin is used for ground.

IC [Internally Connected]
This pin is used for tests performed at the factory by NEC. The μPD70108 is used with this pin at ground potential.

Absolute Maximum Ratings

T_A = +25°C

Power supply voltage, V_{DD}	−0.5 V to +7.0 V
Power dissipation, PD_{MAX}	0.5 W
Input voltage, V_I	−0.5 V to V_{DD} + 0.3 V
CLK input voltage, V_K	−0.5 V to V_{DD} + 1.0 V
Output voltage, V_O	−0.5 V to V_{DD} + 0.3 V
Operating temperature, T_{OPT}	−40°C to +85°C
Storage temperature, T_{STG}	−65°C to +150°C

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

T_A = +25°C, V_{DD} = 0 V

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Input capacitance	C_I		15	pF	fc = 1 MHz
I/O capacitance	C_{IO}		15	pF	Unmeasured pins returned to 0 V

DC Characteristics

μPD70108-5, T_A = −40°C to +85°C, V_{DD} = +5 V ± 10%
μPD70108-8, μPD70108-10, T_A = −10°C to +70°C, V_{DD} = +5 V ± 5%

Parameter	Symbol	Limits Min	Limits Typ	Limits Max	Unit	Test Conditions
Input voltage high	V_{IH}	2.2		V_{DD} + 0.3	V	
Input voltage low	V_{IL}	−0.5		0.8	V	
CLK input voltage high	V_{KH}	3.9		V_{DD} + 1.0	V	
CLK input voltage low	V_{KL}	−0.5		0.6	V	
Output voltage high	V_{OH}	0.7 x V_{DD}			V	I_{OH} = −400 μA
Output voltage low	V_{OL}			0.4	V	I_{OL} = 2.5 mA
Input leakage current high	I_{LIH}			10	μA	$V_I = V_{DD}$
Input leakage current low	I_{LIL}			−10	μA	V_I = 0 V
Output leakage current high	I_{LOH}			10	μA	$V_O = V_{DD}$
Output leakage current low	I_{LOL}			−10	μA	V_O = 0 V
Supply current	I_{DD}	70108-5	30	60	mA	Normal operation
		5 MHz	5	10	mA	Standby mode
		70108-8	45	80	mA	Normal operation
		8 MHz	6	12	mA	Standby mode
		70108-10	60	100	mA	Normal operation
		10 MHz	7	14	mA	Standby mode

AC Characteristics

μPD70108-5, T_A = −40°C to +85°C, V_{DD} = +5 V ± 10%
μPD70108-8, μPD70108-10, T_A = −10°C to +70°C, V_{DD} = +5 V ± 5%

		μPD70108-5		μPD70108-8		μPD70108-10			
Parameter	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Conditions**
Small/Large Scale									
Clock cycle	t_{CYK}	200	500	125	500	100	500	ns	
Clock pulse width high	t_{KKH}	69		44		41		ns	V_{KH} = 3.0 V
Clock pulse width low	t_{KKL}	90		60		49		ns	V_{KL} = 1.5 V
Clock rise time	t_{KR}		10		8		5	ns	1.5 V to 3.0 V
Clock fall time	t_{KF}		10		7		5	ns	3.0 V to 1.5 V
READY inactive setup to CLK↓	t_{SRYLK}	−8		−8		−10		ns	
READY inactive hold after CLK↑	t_{HKRYH}	30		20		20		ns	
READY active setup to CLK↑	t_{SRYHK}	t_{KKL} − 8		t_{KKL} − 8		t_{KKL} −10		ns	
READY active hold after CLK↑	t_{HKRYL}	30		20		20		ns	
Data setup time to CLK ↓	t_{SDK}	30		20		10		ns	
Data hold time after CLK ↓	t_{HKD}	10		10		10		ns	
NMI, INT, $\overline{\text{POLL}}$ setup time to CLK ↑	t_{SIK}	30		15		15		ns	
Input rise time (except CLK)	t_{IR}		20		20		20	ns	0.8 V to 2.2 V
Input fall time (except CLK)	t_{IF}		12		12		12	ns	2.2 V to 0.8 V
Output rise time	t_{OR}		20		20		20	ns	0.8 V to 2.2 V
Output fall time	t_{OF}		12		12		12	ns	2.2 V to 0.8 V
Small Scale									
Address delay time from CLK	t_{DKA}	10	90	10	60	10	48	ns	
Address hold time from CLK	t_{HKA}	10		10		10		ns	
PS delay time from CLK ↓	t_{DKP}	10	90	10	60	10	50	ns	
PS float delay time from CLK ↑	t_{FKP}	10	80	10	60	10	50	ns	
Address setup time to ASTB ↓	t_{SAST}	t_{KKL} − 60		t_{KKL} − 30		t_{KKL} − 30		ns	
Address float delay time from CLK ↓	t_{FKA}	t_{HKA}	80	t_{HKA}	60	t_{HKA}	50	ns	C_L = 100 pF
ASTB ↑ delay time from CLK ↓	t_{DKSTH}		80		50		40	ns	
ASTB ↓ delay time from CLK ↑	t_{DKSTL}		85		55		45	ns	
ASTB width high	t_{STST}	t_{KKL} − 20		t_{KKL} − 10		t_{KKL} − 10		ns	
Address hold time from ASTB ↓	t_{HSTA}	t_{KKH} − 10		t_{KKH} − 10		t_{KKH} −10		ns	

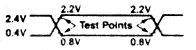
AC Characteristics (cont)

μPD70108-5, $T_A = -40°C$ to $+85°C$, $V_{DD} = +5\ V \pm 10\%$
μPD70108-8, μPD70108-10, $T_A = -10°C$ to $+70°C$, $V_{DD} = +5\ V \pm 5\%$

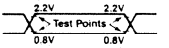
Parameter	Symbol	μPD70108-5		μPD70108-8		μPD70108-10		Unit	Conditions
		Min	Max	Min	Max	Min	Max		
Small Scale (cont)									
Control delay time from CLK	t_{DKCT}	10	110	10	65	10	55	ns	
Address float to $\overline{RD}\downarrow$	t_{AFRL}	0		0		0		ns	
$\overline{RD}\downarrow$ delay time from CLK $\downarrow$	t_{DKRL}	10	165	10	80	10	70	ns	
$\overline{RD}\uparrow$ delay time from CLK $\downarrow$	t_{DKRH}	10	150	10	80	10	60	ns	
Address delay time from $\overline{RD}\uparrow$	t_{DRHA}	$t_{CYK} - 45$		$t_{CYK} - 40$		$t_{CYK} - 35$		ns	
$\overline{RD}$ width low	t_{RR}	$2t_{CYK}-75$		$2t_{CYK}-50$		$2t_{CYK}-40$		ns	$C_L = 100$ pF
Data output delay time from CLK $\downarrow$	t_{DKD}	10	90	10	60	10	50	ns	
Data float delay time from CLK $\downarrow$	t_{FKD}	10	80	10	60	10	50	ns	
$\overline{WR}$ width low	t_{WW}	$2t_{CYK}-60$		$2t_{CYK}-40$		$2t_{CYK}-35$		ns	
HLDRQ setup time to CLK $\uparrow$	t_{SHQK}	35		20		20		ns	
HLDAK delay time from CLK $\downarrow$	t_{DKHA}	10	160	10	100	10	60	ns	
Large Scale									
Address delay time from CLK	t_{DKA}	10	90	10	60	10	48	ns	
Address hold time from CLK	t_{HKA}	10		10		10		ns	
PS delay time from CLK $\downarrow$	t_{DKP}	10	90	10	60	10	50	ns	
PS float delay time from CLK $\uparrow$	t_{FKP}	10	80	10	60	10	50	ns	
Address float delay time from CLK $\downarrow$	t_{FKA}	t_{HKA}	80	t_{HKA}	60	t_{HKA}	50	ns	
Address delay time from $\overline{RD}\uparrow$	t_{DRHA}	$t_{CYK} - 45$		$t_{CYK} - 40$		$t_{CYK} - 35$		ns	
ASTB delay time from BS $\downarrow$	t_{DBST}		15		15		15	ns	
BS $\downarrow$ delay time from CLK $\uparrow$	t_{DKBL}	10	110	10	60	10	50	ns	
BS $\uparrow$ delay time from CLK $\downarrow$	t_{DKBH}	10	130	10	65	10	50	ns	
$\overline{RD}\downarrow$ delay time from address float	t_{DAFRL}	0		0		0		ns	$C_L = 100$ pF
$\overline{RD}\downarrow$ delay time from CLK $\downarrow$	t_{DKRL}	10	165	10	80	10	70	ns	
$\overline{RD}\uparrow$ delay time from CLK $\downarrow$	t_{DKRH}	10	150	10	80	10	60	ns	
$\overline{RD}$ width low	t_{RR}	$2t_{CYK}-75$		$2t_{CYK}-50$		$2t_{CYK}-40$		ns	
Date output delay time from CLK $\downarrow$	t_{DKD}	10	90	10	60	10	50	ns	
Data float delay time from CLK $\uparrow$	t_{FKD}	10	80	10	60	10	50	ns	
$\overline{AK}$ delay time from CLK $\downarrow$	t_{DKAK}		70		50		40	ns	
$\overline{RQ}$ setup time to CLK $\uparrow$	t_{SRQK}	20		10		9		ns	
$\overline{RQ}$ hold time after CLK $\uparrow$	t_{HKRQ}	40		30		20		ns	

Timing Waveforms

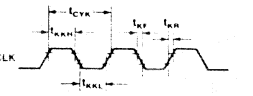
AC Test Input Waveform (Except CLK)



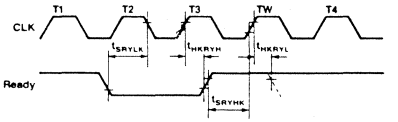
AC Output Test Points



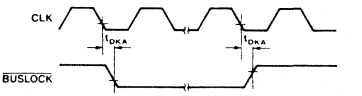
Clock Timing



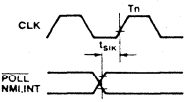
Wait (Ready) Timing



BUSLOCK Output Timing

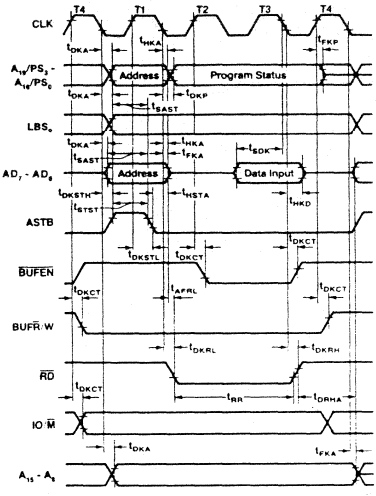


POLL, NMI, INT Input Timing

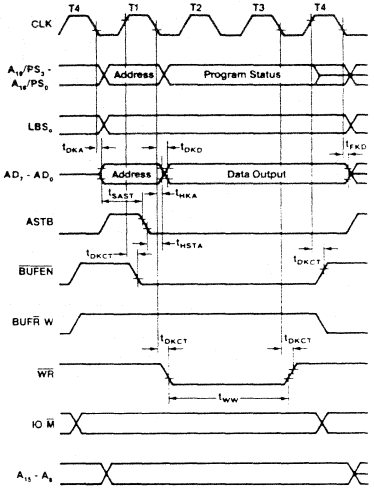


Timing Waveforms (cont)

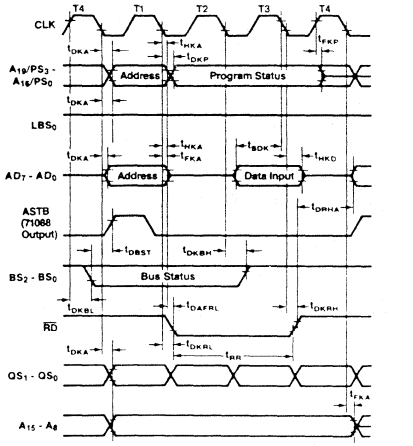
Read Timing [Small Scale]



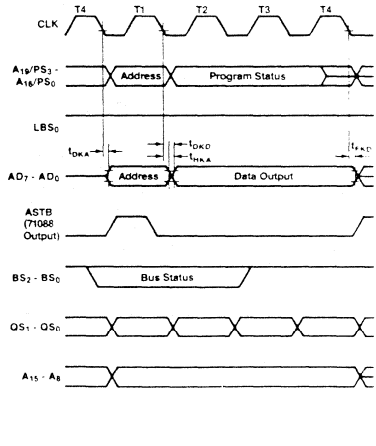
Write Timing [Small Scale]



Read Timing [Large Scale]

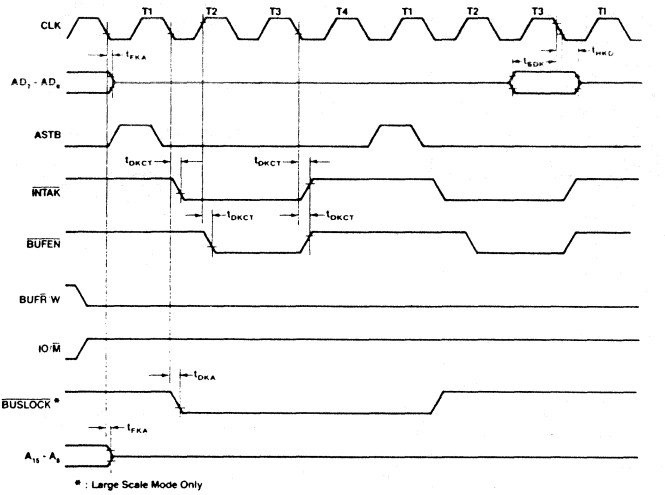


Write Timing [Large Scale]



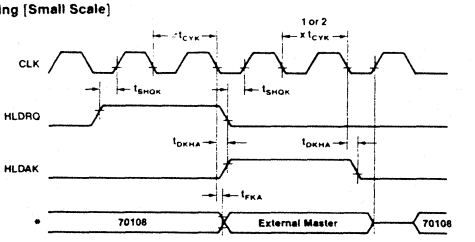
Timing Waveforms (cont)

Interrupt Acknowledge Timing



* : Large Scale Mode Only

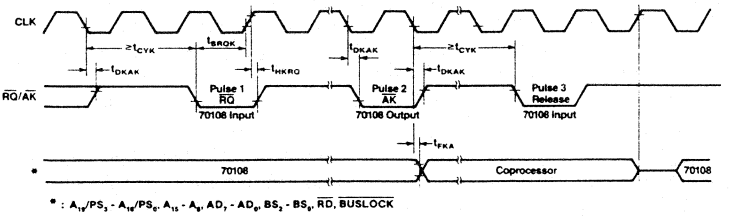
Hold Request/Acknowledge Timing [Small Scale]



* : A_{19}/PS_3 - A_{16}/PS_0, A_{15} - A_8, AD_7 - AD_0, $\overline{RD}$, LBS_0, IO/$\overline{M}$, BUFR/$\overline{W}$, $\overline{WR}$ $\overline{BUFEN}$

Timing Waveforms (cont)

Bus Request/Acknowledge Timing [Large Scale]



Register Configuration

Program Counter [PC]

The program counter is a 16-bit binary counter that contains the segment offset address of the next instruction which the EXU is to execute.

The PC increments each time the microprogram fetches an instruction from the instruction queue. A new location value is loaded into the PC each time a branch, call, return, or break instruction is executed. At this time, the contents of the PC are the same as the Prefetch Pointer (PFP).

Prefetch Pointer [PFP]

The prefetch pointer (PFP) is a 16-bit binary counter which contains a segment offset which is used to calculate a program memory address that the bus control unit (BCU) uses to prefetch the next byte for the instruction queue. The contents of PFP are an offset from the PS (Program Segment) register.

The PFP is incremented each time the BCU prefetches an instruction from the program memory. A new location will be loaded into the PFP whenever a branch, call, return, or break instruction is executed. At that time the contents of the PFP will be the same as those of the PC (Program Counter).

Segment Registers [PS, SS, DS_0, and DS_1]

The memory addresses accessed by the μPD70108 are divided into 64K-byte logical segments. The starting (base) address of each segment is specified by a 16-bit segment register, and the offset from this starting address is specified by the contents of another register or by the effective address.

These are the four types of segment registers used.

Segment Register	Default Offset
PS (Program Segment)	PFP
SS (Stack Segment)	SP, effective address
DS_0 (Data Segment 0)	IX, effective address
DS_1 (Data Segment 1)	IY

General-Purpose Registers [AW, BW, CW, and DW]

There are four 16-bit general-purpose registers. Each one can be used as one 16-bit register or as two 8-bit registers by dividing them into their high and low bytes (AH, AL, BH, BL, CH, CL, DH, DL).

Each register is also used as a default register for processing specific instructions. The default assignments are:

AW: Word multiplication/division, word I/O, data conversion

AL: Byte multiplication/division, byte I/O, BCD rotation, data conversion, translation

AH: Byte multiplication/division

BW: Translation

CW: Loop control branch, repeat prefix

CL: Shift instructions, rototation instructions, BCD operations

DW: Word multiplication/division, indirect addressing I/O

Pointers [SP, BP] and Index Registers [IX, IY]

These registers serve as base pointers or index registers when accessing the memory using based addressing, indexed addressing, or based indexed addressing.

These registers can also be used for data transfer and arithmetic and logical operations in the same manner as the general-purpose registers. They cannot be used as 8-bit registers.

Also, each of these registers acts as a default register for specific operations. The default assignments are:

SP: Stack operations

IX: Block transfer (source), BCD string operations

IY: Block transfer (destination), BCD string operations

Program Status Word [PSW]

The program status word consists of the following six status and four control flags.

Status Flags

- V (Overflow)
- S (Sign)
- Z (Zero)
- AC (Auxiliary Carry)
- P (Parity)
- CY (Carry)

Control Flags

- MD (Mode)
- DIR (Direction)
- IE (Interrupt Enable)
- BRK (Break)

When the PSW is pushed on the stack, the word images of the various flags are as shown here.

PSW

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MD	1	1	1	V	DIR	IE	BRK	S	Z	0	AC	0	P	1	CY

The status flags are set and reset depending upon the result of each type of instruction executed.

Instructions are provided to set, reset, and complement the CY flag directly.

Other instructions set and reset the control flags and control the operation of the CPU.

High-Speed Execution of Instructions

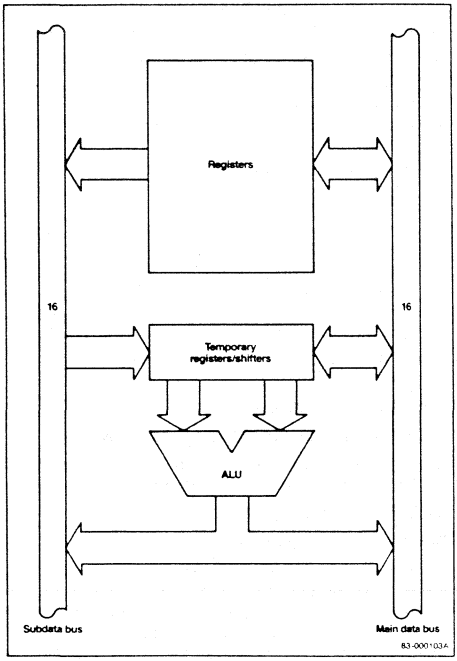
This section highlights the major architectural features that enhance the performance of the μPD70108.

- Dual data bus in EXU
- Effective address generator
- 16/32-bit temporary registers/shifters (TA, TB)
- 16-bit loop counter
- PC and PFP

Dual Data Bus Method

To reduce the number of processing steps for instruction execution, the dual data bus method has been adopted for the μPD70108 (figure 1). The two data buses (the main data bus and the subdata bus) are both 16 bits wide. For addition/subtraction and logical and comparison operations, processing time has been speeded up some 30% over single-bus systems.

Figure 1. Dual Data Buses



Example

ADD AW, BW ; AW ← AW + BW

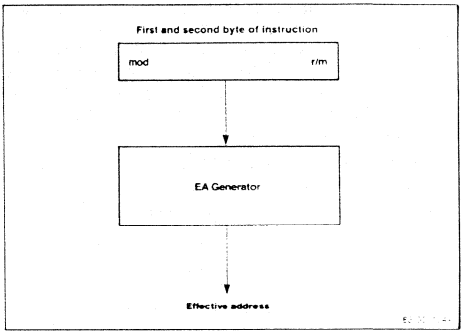
Single Bus	Dual Bus
Step 1 TA ← AW	TA ← AW, TB ← BW
Step 2 TB ← BW	AW ← TA + TB
Step 3 AW ← TA + TB	

Effective Address Generator

This circuit (figure 2) performs high-speed processing to calculate effective addresses for accessing memory.

Calculating an effective address by the microprogramming method normally requires 5 to 12 clock cycles. This circuit requires only two clock cycles for addresses to be generated for any addressing mode. Thus, processing is several times faster.

Figure 2. Effective Address Generator



16/32-Bit Temporary Registers/Shifters [TA, TB]

These 16-bit temporary registers/shifters (TA, TB) are provided for multiplication/division and shift rotation instructions.

These circuits have decreased the execution time of multiplication/division instructions. In fact, these instructions can be executed about four times faster than with the microprogramming method.

TA + TB: 32-bit temporary register/shifter for multiplication and division instructions.

TB: 16-bit temporary register/shifter for shift/rotation instructions.

Loop Counter [LC]

This counter is used to count the number of loops for a primitive block transfer instruction controlled by a repeat prefix instruction and the number of shifts that will be performed for a multiple bit shift/rotation instruction.

The processing performed for a multiple bit rotation of a register is shown below. The average speed is approximately doubled over the microprogram method.

Example

```
RORC    AW, CL    ; CL = 5
```

Microprogram method	LC method
8 + (4 x 5) = 28 clocks	7 + 5 = 12 clocks

Program Counter and Prefetch Pointer [PC and PFP]

The μPD70108 microprocessor has a program counter, (PC) which addresses the program memory location of the instruction to be executed next, and a prefetch pointer(PFP), which addresses the program memory location to be accessed next. Both functions are provided in hardware. A time saving of several clocks is realized for branch, call, return, and break instruction execution, compared with microprocessors that have only one instruction pointer.

Enhanced Instructions

In addition to the μPD8088/86 instructions, the μPD70108 has the following enhanced instructions.

Instruction	Function
PUSH imm	Pushes immediate data onto stack
PUSH R	Pushes 8 general registers onto stack
POP R	Pops 8 general registers from stack
MUL imm	Executes 16-bit multiply of register or memory contents by immediate data
SHL imm8 SHR imm8 SHRA imm8 ROL imm8 ROR imm8 ROLC imm8 RORC imm8	Shifts/rotates register or memory by immediate value
CHKIND	Checks array index against designated boundaries
INM	Moves a string from an I/O port to memory
OUTM	Moves a string from memory to an I/O port
PREPARE	Allocates an area for a stack frame and copies previous frame pointers
DISPOSE	Frees the current stack frame on a procedure exit

Enhanced Stack Operation Instructions

PUSH Imm

This instruction allows immediate data to be pushed onto the stack.

PUSH R/POP R

These instructions allow the contents of the eight general registers to be pushed onto or popped from the stack with a single instruction.

Enhanced Multiplication Instructions

MUL reg16, Imm16/MUL mem16, Imm16

These instructions allow the contents of a register or memory location to be 16-bit multiplied by immediate data.

Enhanced Shift and Rotate Instructions

SHL reg, Imm8/SHR reg, Imm8/SHRA reg, imm8

These instructions allow the contents of a register to be shifted by the number of bits defined by the immediate data.

ROL reg, Imm8/ROR reg, Imm8/ROLC reg, imm8/ RORC reg, Imm8

These instructions allow the contents of a register to be rotated by the number of bits defined by the immediate data.

Check Array Boundary Instruction

CHKIND reg16, mem32

This instruction is used to verify that index values pointing to the elements of an array data structure are within the defined range. The lower limit of the array should be in memory location mem32, the upper limit in mem32 + 2. If the index value in reg16 is not between these limits when CHKIND is executed, a BRK 5 will occur. This causes a jump to the location in interrupt vector 5.

Block I/O Instructions

OUTM DW, src-block/INM dst-block, DW

These instructions are used to output or input a string to or from memory, when preceded by a repeat prefix.

Stack Frame Instructions

PREPARE Imm16, Imm8

This instruction is used to generate the stack frames required by block-structured languages, such as PASCAL and Ada. The stack frame consists of two areas. One area has a pointer that points to another frame which has variables that the current frame can access. The other is a local variable area for the current procedure.

DISPOSE

This instruction releases the last stack frame generated by the PREPARE instruction. It returns the stack and base pointers to the values they had before the PREPARE instruction was used to call a procedure.

Unique Instructions

In addition to the μPD8088/86 instructions and the enhanced instructions, the μPD70108 has the following unique instructions.

Instruction	Function
INS	Insert bit field
EXT	Extract bit field
ADD4S	Adds packed decimal strings
SUB4S	Subtracts one packed decimal string from another
CMP4S	Compares two packed decimal strings
ROL4	Rotates one BCD digit left through AL lower 4 bits
ROR4	Rotates one BCD digit right through AL lower 4 bits
TEST1	Tests a specified bit and sets/resets Z flag
NOT1	Inverts a specified bit
CLR1	Clears a specified bit
SET1	Sets a specified bit
REPC	Repeats next instruction until CY flag is cleared
REPNC	Repeats next instruction until CY flag is set
FPO2	Additional floating point processor call

Variable Length Bit Field Operation Instructions

This category has two instructions: INS (Insert Bit Field) and EXT (Extract Bit Field). These instructions are highly effective for computer graphics and high-level languages. They can, for example, be used for data structures such as packed arrays and record type data used in PASCAL.

INS reg8, reg8/INS reg8, imm4

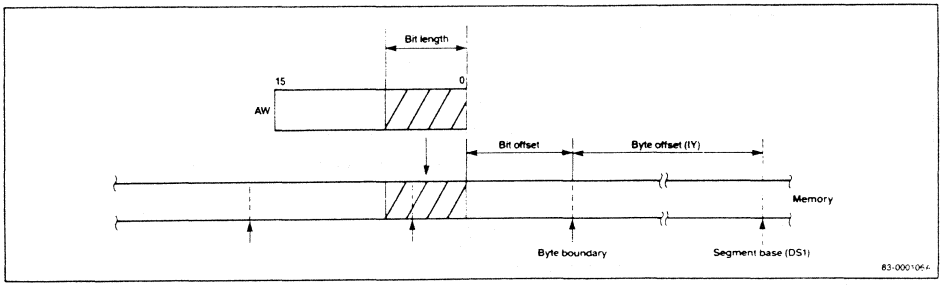
This instruction (figure 3) transfers low bits from the 16-bit AW register (the number of bits is specified by the second operand) to the memory location specified by the segment base (DS_1 register) plus the byte offset (IY register). The starting bit position within this byte is specified as an offset by the lower 4-bits of the first operand.

After each complete data transfer, the IY register and the register specified by the first operand are automatically updated to point to the next bit field.

Either immediate data or a register may specify the number of bits transferred (second operand). Because the maximum transferable bit length is 16-bits, only the lower 4-bits of the specified register (00H to 0FH) will be valid.

Bit field data may overlap the byte boundary of memory.

Figure 3. Bit Field Insertion



EXT reg8, reg8/EXT reg8, imm4

This instruction (figure 4) loads to the AW register the bit field data whose bit length is specified by the second operand of the instruction from the memory location that is specified by the DS0 segment register (segment base), the IX index register (byte offset), and the lower 4-bits of the first operand (bit offset).

After the transfer is complete, the IX register and the lower 4-bits of the first operand are automatically updated to point to the next bit field.

Either immediate data or a register may be specified for the second operand. Because the maximum transferrable bit length is 16 bits, however, only the lower 4-bits of the specified register (0H to 0FH) will be valid.

Bit field data may overlap the byte boundary of memory.

Packed BCD Operation Instructions

The instructions described here process packed BCD data either as strings (ADD4S, SUB4S, CMP4S) or byte-format operands (ROR4, ROL4). Packed BCD strings may be from 1 to 254 digits in length.

When the number of digits is even, the zero and carry flags will be set according to the result of the operation. When the number of digits is odd, the zero and carry flags may not be set correctly in this case, (CL = odd), the zero flag will not be set unless the upper 4 bits of the highest byte are all zero. The carry flag will not be set unless there is a carry out of the upper 4 bits of the highest byte. When CL is odd, the contents of the upper 4 bits of the highest byte of the result are undefined.

ADD4S

This instruction adds the packed BCD string addressed by the IX index register to the packed BCD string addressed by the IY index register, and stores the result in the string addressed by the IY register. The length of the string (number of BCD digits) is specified by the CL register, and the result of the operation will affect the overflow flag (V), the carry flag (CY), and zero flag (Z).

BCD string (IY, CL) ← BCD string (IY, CL) + BCD string (IX, CL)

SUB4S

This instruction subtracts the packed BCD string addressed by the IX index register from the packed BCD string addressed by the IY register, and stores the result in the string addressed by the IY register. The length of the string (number of BCD digits) is specified by the CL register, and the result of the operation will affect the overflow flag (V), the carry flag (CY), and zero flag (Z).

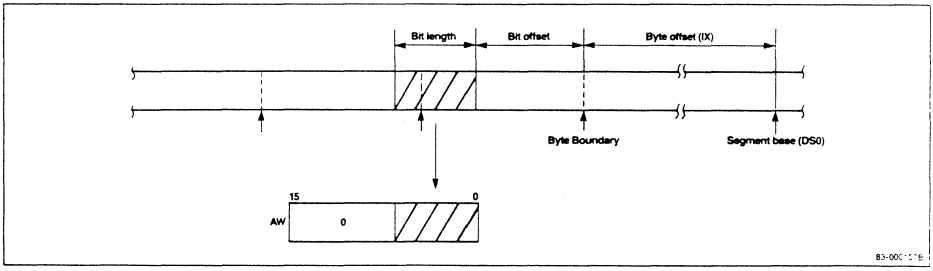
BCD string (IY, CL) ← BCD string (IY, CL) − BCD String (IX, CL)

CMP4S

This instruction performs the same operation as SUB4S except that the result is not stored and only the overflow (V), carry flags (CY) and zero flag (Z) are affected.

BCD string (IY, CL) − BCD string (IX, CL)

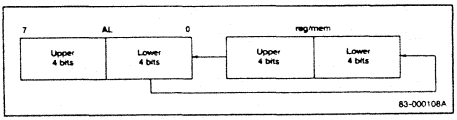
Figure 4. Bit Field Extraction



ROL4

This instruction (figure 5) treats the byte data of the register or memory directly specified by the instruction byte as BCD data and uses the lower 4-bits of the AL register (AL_L) to rotate that data one BCD digit to the left.

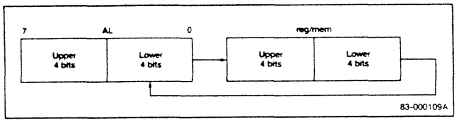
Figure 5. BCD Rotate Left (ROL4)



ROR4

This instruction (figure 6) treats the byte data of the register or memory directly specified by the instruction byte as BCD data and uses the lower 4-bits of the AL register (AL_L) to rotate that data one BCD digit to the right.

Figure 6. BCD Rotate Right (ROR4)



Bit Manipulation Instructions

TEST1

This instruction tests a specific bit in a register or memory location. If the bit is 1, the Z flag is reset to 0. If the bit is 0, the Z flag is set to 1.

NOT1

This instruction inverts a specific bit in a register or memory location.

CLR1

This instruction clears a specific bit in a register or memory location.

SET1

This instruction sets a specific bit in a register or memory location.

Repeat Prefix Instructions

REPC

This instruction causes the μPD70108 to repeat the following primitive block transfer instruction until the CY flag becomes cleared or the CW register becomes zero.

REPNC

This instruction causes the μPD70108 to repeat the following primitive block transfer instruction until the CY flag becomes set or the CW register is decremented to zero.

Floating Point Instruction

FPO2

This instruction is in addition to the μPD8088/86 floating point instruction, FPO1. These instructions are covered in a later section.

Mode Operation Instructions

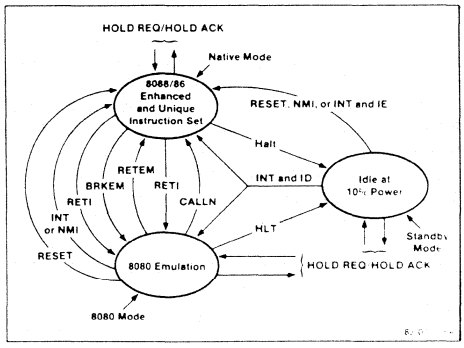
The μPD70108 has two operating modes (figure 7). One is the native mode which executes μPD8088/86 enhanced and unique instructions. The other is the 8080 emulation mode in which the instruction set of the μPD8080AF is emulated. A mode flag (MD) is provided to select between these two modes. Native mode is selected when MD is 1 and emulation mode when MD is 0. MD is set and reset, directly and indirectly, by executing the mode manipulation instructions.

Two instructions are provided to switch operation from the native mode to the emulation mode and back: BRKEM (Break for Emulation), and RETEM (Return from Emulation).

Two instructions are used to switch from the emulation mode to the native mode and back: CALLN (Call Native Routine), and RETI (Return from Interrupt).

The system will return from the 8080 emulation mode to the native mode when the RESET signal is present, or when an external interrupt (NMI or INT) is present.

Figure 7. V20 Modes



BRKEM imm8

This is the basic instruction used to start the 8080 emulation mode. This instruction operates exactly the same as the BRK instruction, except that BRKEM resets the mode flag (MD) to 0. PSW, PS, and PC are saved to the stack. MD is then reset and the interrupt vector specified by the operand imm8 of this command is loaded into PS and PC.

The instruction codes of the interrupt processing routine jumped to are then fetched. Then the CPU executes these codes as μPD8080AF instructions.

In 8080 emulation mode, registers and flags of the μPD8080AF are performed by the following registers and flags of the μPD70108.

	μPD8080AF	μPD70108
Registers:	A	AL
	B	CH
	C	CL
	D	DH
	E	DL
	H	BH
	L	BL
	SP	BP
	PC	PC
Flags:	C	CY
	Z	Z
	S	S
	P	P
	AC	AC

In the native mode, SP is used for the stack pointer. In the 8080 emulation mode this function is performed by BP.

This use of independent stack pointers allows independent stack areas to be secured for each mode and keeps the stack of one of the modes from being destroyed by an erroneous stack operation in the other mode.

The SP, IX, IY and AH registers and the four segment registers (PS, SS, DS_0, and DS_1) used in the native mode are not affected by operations in 8080 emulation mode.

In the 8080 emulation mode, the segment register for instructions is determined by the PS register (set automatically by the interrupt vector) and the segment register for data is the DS_0 register (set by the programmer immediately before the 8080 emulation mode is entered).

It is prohibited to nest BRKEM instructions.

RETEM [no operand]

When RETEM is executed in 8080 emulation mode (interpreted by the CPU as a μPD8080AF instruction), the CPU restores PS, PC, and PSW (as it would when returning from an interrupt processing routine), and returns to the native mode. At the same time, the contents of the mode flag (MD) which was saved to the stack by the BRKEM instruction, is restored to MD = 1. The CPU is set to the native mode.

CALLN imm8

This instruction makes it possible to call the native mode subroutines from the 8080 emulation mode. To return from subroutine to the emulation mode, the RETI instruction is used.

The processing performed when this instruction is executed in the 8080 emulation mode (it is interpreted by the CPU as μPD8080AF instruction), is similar to that performed when a BRK instruction is executed in the native mode. The imm8 operand specifies an interrupt vector type. The contents of PS, PC, and PSW are pushed on the stack and an MD flag value of 0 is saved. The mode flag is set to 1 and the interrupt vector specified by the operand is loaded into PS and PC.

RETI [no operand]

This is a general-purpose instruction used to return from interrupt routines entered by the BRK instruction or by an external interrupt in the native mode. When this instruction is executed at the end of a subroutine entered by the execution of the CALLN instruction, the operation that restores PS, PC, and PSW is exactly the same as the native mode execution. When PSW is restored, however, the 8080 emulation mode value of the mode flag (MD) is restored, the CPU is set in emulation mode, and all subsequent instructions are interpreted and executed as μPD8080AF instructions.

RETI is also used to return from an interrupt procedure initiated by an NMI or INT interrupt in the emulation mode.

Floating Point Operation Chip Instructions

FPO1 fp-op, mem/FPO2 fp-op, mem

These instructions are used for the external floating point processor. The floating point operation is passed to the floating point processor when the CPU fetches one of these instructions. From this point the CPU performs only the necessary auxiliary processing (effective address calculation, generation of physical addresses, and start-up of the memory read cycle).

The floating point processor always monitors the instructions fetched by the CPU. When it interprets one as an instruction to itself, it performs the appropriate processing. At this time, the floating point processor chip uses either the address alone or both the address and read data of the memory read cycle executed by the CPU. This difference in the data used depends on which of these instructions is executed.

Note: During the memory read cycle initiated by the CPU for FPO1 or FPO2 execution, the CPU does not accept any read data on the data bus from memory. Although the CPU generates the memory address, the data is used by the floating point processor.

Interrupt Operation

The interrupts used in the μPD70108 can be divided into two types: interrupts generated by external interrupt requests and interrupts generated by software processing. These are the classifications.

External Interrupts

(a) NMI input (nonmaskable)
(b) INT input (maskable)

Software Processing

As the result of instruction execution

— When a divide error occurs during execution of the DIV or DIVU instruction
— When a memory-boundary-over error is detected by the CHKIND instruction

Conditional break instruction

— When V = 1 during execution of the BRKV instruction

Unconditional break instructions

— 1-byte break instruction: BRK3
— 2-byte break instruction: BRK imm8

Flag processing

— When stack operations are used to set the BRK flag

8080 Emulation mode instructions

— BRKEM imm8
— CALLN imm8

Interrupt Vectors

Starting addresses for interrupt processing routines are either determined automatically by a single location of the interrupt vector table or selected each time interrupt processing is entered.

The interrupt vector table is shown in figure 8. The table uses 1K bytes of memory addresses 000H to 3FFH and can store starting address data for a maximum of 256 vectors (4 bytes per vector).

The corresponding interrupt sources for vectors 0 to 5 are predetermined and vectors 6 to 31 are reserved. These vectors consequently cannot be used for general applications.

The BRKEM instruction and CALLN instruction (in the emulation mode) and the INT input are available for general applications for vectors 32 to 255.

A single interrupt vector is made up of 4 bytes (figure 9). The 2 bytes in the low addresses of memory are loaded into PC as the offset, and the high 2 bytes are loaded into PS as the base address. The bytes are combined in reverse order. The lower-order bytes in the vector become the most significant bytes in the PC and PS, and the higher-order bytes become the least significant bytes.

Figure 8. Interrupt Vector Table

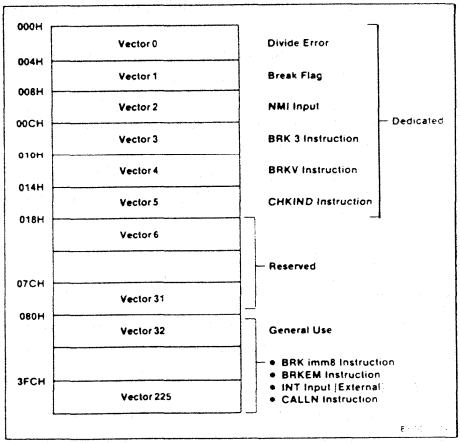
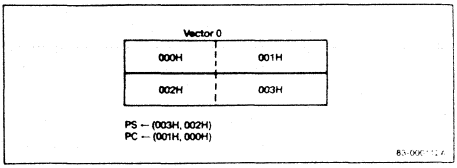


Figure 9. Interrupt Vector 0



Based on this format, the contents of each vector should be initialized at the beginning of the program.

The basic steps to jump to an interrupt processing routine are now shown.

(SP - 1, SP - 2) ← PSW
(SP - 3, SP - 4) ← PS
(SP - 5, SP - 6) ← PC
SP ← SP - 6
IE ← 0, BRK ← 0, MD ← 1
PS ← vector high bytes
PC ← vector low bytes

Standby Function

The μPD70108 has a standby mode to reduce power consumption during program wait states. This mode is set by the HALT instruction in both the native and the emulation mode.

In the standby mode, the internal clock is supplied only to those circuits related to functions required to release this mode and bus hold control functions. As a result, power consumption can be reduced to 1/10 the level of normal operation in either native or emulation mode.

The standby mode is released by inputting a RESET signal or an external interrupt (NMI, INT).

The bus hold function is effective during standby mode. The CPU returns to standby mode when the bus hold request is removed.

During standby mode, all control outputs are disabled and the addres/data bus will be at either high or low levels.

Instruction Set

Symbols

Preceding the instruction set, several tables explain symbols, abbreviations, and codes.

Clocks

In the Clocks column of the instruction set, the numbers cover these operations: instruction decoding, effective address calculation, operand fetch, and instruction execution.

Clock timings assume the instruction has been pre-fetched and is present in the four-byte instruction queue. Otherwise, add four clocks for each byte not present.

For instructions that reference memory operands, the number on the left side of the slash (/) is for byte operands and the number on the right side is for word operands.

For conditional control transfer or branch instructions, the number on the left side of the slash is applicable if the transfer or branch takes place. The number on the right side is applicable if it does not take place.

If a range of numbers is given, the execution time depends on the operands involved.

Symbols

Symbol	Meaning
acc	Accumulator (AW or AL)
disp	Displacement (8 or 16 bits)
dmem	Direct memory address
dst	Destination operand or address
ext-disp8	16-bit displacement (sign-extension byte + 8-bit displacement)
far_label	Label within a different program segment
far_proc	Procedure within a different program segment
fp_op	Floating point instruction operation
imm	8- or 16-bit immediate operand
imm3/4	3/4-bit immediate bit offset
imm8	8-bit immediate operand
imm16	16-bit immediate operand
mem	Memory field (000 to 111): 8- or 16-bit memory location
mem8	8-bit memory location
mem16	16-bit memory location
mem32	32-bit memory location
memptr16	Word containing the destination address within the current segment
memptr32	Double word containing a destination address in another segment
mod	Mode field (00 to 10)
near_label	Label within the current segment
near_proc	Procedure within the current segment
offset	Immediate offset data (16 bits)
pop_value	Number of bytes to discard from the stack
reg	Register field (000 to 111); 8- or 16-bit general-purpose register
reg8	8-bit general-purpose register
reg16	16-bit general-purpose register
regptr	16-bit register containing a destination address within the current segment
regptr16	Register containing a destination address within the current segment
seg	Immediate segment data (16 bits)
short_label	Label between −128 and +127 bytes from the end of the current instruction

Symbols (cont)

Symbol	Meaning
sr	Segment register
src	Source operand or address
temp	Temporary register (8/16/32 bits)
tmpcy	Temporary carry flag (1 bit)
AC	Auxiliary carry flag
AH	Accumulator (high byte)
AL	Accumulator (low byte)
AND	Logical product
AW	Accumulator (16 bits)
BH	BW register (high byte)
BL	BW register (low byte)
BP	BP register
BRK	Break flag
BW	BW register (16 bits)
CH	CW register (high byte)
CL	CW register (low byte)
CW	CW register (16 bits)
CY	Carry flag
DH	DW register (high byte)
DIR	Direction flag
DL	DW register (low byte)
DS0	Data segment 0 register (16 bits)
DS1	Data segment 1 register (16 bits)
DW	DW register (16 bits)
IE	Interrupt enable flag
IX	Index register (source) (16 bits)

Symbols

Symbol	Meaning
IY	Index register (destination) (16 bits)
MD	Mode flag
OR	Logical sum
P	Parity flag
PC	Program counter (16 bits)
PS	Program segment register (16 bits)
PSW	Program status word (16 bits)
R	Register set
S	Sign extend operand field S = 0 No sign extension S = 1 Sign extend immediate byte operand
S	Sign flag
SP	Stack pointer (16 bits)
SS	Stack segment register (16 bits)
V	Overflow flag
W	Word/byte field (0 to 1)
X, XXX, YYY, ZZZ	Data to identify the instruction code of the external floating point arithmetic chip
XOR	Exclusive logical sum
XXH	Two-digit hexadecimal value
XXXXH	Four-digit hexadecimal value
Z	Zero flag
( )	Values in parentheses are memory contents
←	Transfer direction
+	Addition
−	Subtraction
x	Multiplication
÷	Division
%	Modulo

Flag Operations

Symbol	Meaning
(blank)	No change
0	Cleared to 0
1	Set to 1
x	Set or cleared according to result
u	Undefined
R	Restored to previous state

Memory Addressing Modes

mem	mod = 00	mod = 01	mod = 10
000	BW + IX	BW + IX + disp8	BW + IX + disp16
001	BW + IY	BW + IY + disp8	BW + IY + disp16
010	BP + IX	BP + IX + disp8	BP + IX + disp16
011	BP + IY	BP + IY + disp8	BP + IY + disp16
100	IX	IX + disp8	IX + disp16
101	IY	IY + disp8	IY + disp16
110	Direct	BP + disp8	BP + disp16
111	BW	BW + disp8	BW + disp16

Register Selection (mod = 11)

reg	W = 0	W = 1
000	AL	AW
001	CL	CW
010	DL	DW
011	BL	BW
100	AH	SP
101	CH	BP
110	DH	IX
111	BH	IY

Segment Register Selection

sr	Segment Register
00	DS1
01	PS
10	SS
11	DS0

Instruction Set

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Data Transfer Instructions																									
MOV	reg, reg	1	0	0	0	1	0	1	W	1	1		reg			reg		2	2						
	mem, reg	1	0	0	0	1	0	0	W	mod			reg			mem		9/13	2-4						
	reg, mem	1	0	0	0	1	0	1	W	mod			reg			mem		11/15	2-4						
	mem, imm	1	1	0	0	0	1	1	W	mod			reg			mem		11/15	3-6						
	reg, imm	1	0	1	1	W		reg										4	2-3						
	acc, dmem	1	0	1	0	0	0	0	W									10/14	3						
	dmem, acc	1	0	1	0	0	0	1	W									9/13	3						
	sr, reg16	1	0	0	0	1	1	1	0	1	1	0	sr			reg		2	2						
	sr, mem16	1	0	0	0	1	1	1	0	mod		0	sr			mem		11/15	2-4						
	reg16, sr	1	0	0	0	1	1	0	0	1	1	0	sr			reg		2	2						
	mem16, sr	1	0	0	0	1	1	0	0	mod		0	sr			mem		10/14	2-4						
	DS0, reg16, mem32	1	1	0	0	0	1	0	1	mod			reg			mem		18/26	2-4						
	DS1, reg16, mem32	1	1	0	0	0	1	0	0	mod			reg			mem		18/26	2-4						
	AH, PSW	1	0	0	1	1	1	1	1									2	1						
	PSW, AH	1	0	0	1	1	1	1	0									3	1	x	x		x	x	x
LDEA	reg16, mem16	1	0	0	0	1	1	0	1	mod			reg			mem		4	2-4						
TRANS	src_table	1	1	0	1	0	1	1	1									9	1						
XCH	reg, reg	1	0	0	0	0	1	1	W	1	1		reg			reg		3	2						
	mem, reg	1	0	0	0	0	1	1	W	mod			reg			mem		16/26	2-4						
	AW, reg16	1	0	0	1	0		reg										3	1						
Repeat Prefixes																									
REPC		0	1	1	0	0	1	0	1									2	1						
REPNC		0	1	1	0	0	1	0	0									2	1						
REP REPE REPZ		1	1	1	1	0	0	1	1									2	1						
REPNE REPNZ		1	1	1	1	0	0	1	0									2	1						
Block Transfer Instructions																									
MOVBK	dst, src	1	0	1	0	0	1	0	W									11 + 8n	1						
CMPBK	dst, src	1	0	1	0	0	1	1	W									7 + 14n	1	x	x	x	x	x	x
CMPM	dst	1	0	1	0	1	1	1	W									7 + 10n	1	x	x	x	x	x	x
LDM	src	1	0	1	0	1	1	0	W									7 + 9n	1						
STM	dst	1	0	1	0	1	0	1	W									7 + 4n	1						
																		n = number of transfers							
I/O Instructions																									
IN	acc, imm8	1	1	1	0	0	1	0	W									9/13	2						
	acc, DW	1	1	1	0	1	1	0	W									8/12	1						
OUT	imm8, acc	1	1	1	0	0	1	1	W									8/12	2						
	DW, acc	1	1	1	0	1	1	1	W									8/12	1						
INM	dst, DW	0	1	1	0	1	1	0	W									9 + 8n	1						
OUTM	DW, src	0	1	1	0	1	1	1	W									9 + 8n	1						
																		n = number of transfers							

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
BCD Instructions																									
ADJBA		0	0	1	1	0	1	1	1									3	1	x	x	u	u	u	u
ADJ4A		0	0	1	0	0	1	1	1									3	1	x	x	u	x	x	x
ADJBS		0	0	1	1	1	1	1	1									7	1	x	x	u	u	u	u
ADJ4S		0	0	1	0	1	1	1	1									7	1	x	x	u	x	x	x
ADD4S	dst, src	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	0	7 + 19n	2	u	x	u	u	u	x
SUB4S	dst, src	0	0	0	0	1	1	1	1	0	0	1	0	0	0	1	0	7 + 19n	2	u	x	u	u	u	x
CMP4S	dst, src	0	0	0	0	1	1	1	1	0	0	1	0	0	1	1	0	7 + 19n	2	u	x	u	u	u	x
ROL4	reg8	0	0	0	0	1	1	1	1	0	0	1	0	1	0	0	0	25	3						
		1	1	0	0	0	reg																		
	mem8	0	0	0	0	1	1	1	1	0	0	1	0	1	0	0	0	28	3-5						
		mod			0	0	0	mem																	
ROR4	reg8	0	0	0	0	1	1	1	1	0	0	1	0	1	0	1	0	29	3						
		1	1	0	0	0	reg																		
	mem8	0	0	0	0	1	1	1	1	0	0	1	0	1	0	1	0	33	3-5						
		mod			0	0	0	mem																	
		n = number of BCD digits divided by 2																							
Data Type Conversion Instructions																									
CVTBD		1	1	0	1	0	1	0	0	0	0	0	0	1	0	1	0	15	2	u	u	u	x	x	x
CVTDB		1	1	0	1	0	1	0	1	0	0	0	0	1	0	1	0	7	2	u	u	u	x	x	x
CVTBW		1	0	0	1	1	0	0	0									2	1						
CVTWL		1	0	0	1	1	0	0	1									4-5	1						
Arithmetic Instructions																									
ADD	reg, reg	0	0	0	0	0	0	1	W	1	1		reg			reg		2	2	x	x	x	x	x	x
	mem, reg	0	0	0	0	0	0	0	W	mod			reg			mem		16/24	2-4	x	x	x	x	x	x
	reg, mem	0	0	0	0	0	0	1	W	mod			reg			mem		11/15	2-4	x	x	x	x	x	x
	reg, imm	1	0	0	0	0	0	S	W	1	1	0	0	0		reg		4	3-4	x	x	x	x	x	x
	mem, imm	1	0	0	0	0	0	S	W	mod			0	0	0	mem		18/26	3-6	x	x	x	x	x	x
	acc, imm	0	0	0	0	0	1	0	W									4	2-3	x	x	x	x	x	x
ADDC	reg, reg	0	0	0	1	0	0	1	W	1	1		reg			reg		2	2	x	x	x	x	x	x
	mem, reg	0	0	0	1	0	0	0	W	mod			reg			mem		16/24	2-4	x	x	x	x	x	x
	reg, mem	0	0	0	1	0	0	1	W	mod			reg			mem		11/15	2-4	x	x	x	x	x	x
	reg, imm	1	0	0	0	0	0	S	W	1	1	0	1	0		reg		4	3-4	x	x	x	x	x	x
	mem, imm	1	0	0	0	0	0	S	W	mod			0	1	0	mem		18/26	3-6	x	x	x	x	x	x
	acc, imm	0	0	0	1	0	1	0	W									4	2-3	x	x	x	x	x	x
SUB	reg, reg	0	0	1	0	1	0	1	W	1	1		reg			reg		2	2	x	x	x	x	x	x
	mem, reg	0	0	1	0	1	0	0	W	mod			reg			mem		16/24	2-4	x	x	x	x	x	x
	reg, mem	0	0	1	0	1	0	1	W	mod			reg			mem		11/15	2-4	x	x	x	x	x	x
	reg, imm	1	0	0	0	0	0	S	W	1	1	1	0	1		reg		4	3-4	x	x	x	x	x	x

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Arithmetic Instructions (cont)																									
	mem, imm	1	0	0	0	0	0	S	W	mod			1	0	1	mem		18/26	3-6	x	x	x	x	x	x
	acc, imm	0	0	1	0	1	1	0	W									4	2-3	x	x	x	x	x	x
SUBC	reg, reg	0	0	0	1	1	0	1	W	1	1		reg			reg		2	2	x	x	x	x	x	x
	mem, reg	0	0	0	1	1	0	0	W	mod			reg			mem		16/24	2-4	x	x	x	x	x	x
	reg, mem	0	0	0	1	1	0	1	W	mod			reg			mem		11/15	2-4	x	x	x	x	x	x
	reg, imm	1	0	0	0	0	0	S	W	1	1	0	1	1		reg		4	3-4	x	x	x	x	x	x
	mem, imm	1	0	0	0	0	0	S	W	mod		0	1	1		mem		18/26	3-6	x	x	x	x	x	x
	acc, imm	0	0	0	1	1	1	0	W									4	2-3	x	x	x	x	x	x
INC	reg8	1	1	1	1	1	1	1	0	1	1	0	0	0		reg		2	2	x		x	x	x	x
	mem	1	1	1	1	1	1	1	W	mod		0	0	0		mem		16/24	2-4	x		x	x	x	x
	reg16	0	1	0	0	0		reg										2	1	x		x	x	x	x
DEC	reg8	1	1	1	1	1	1	1	0	1	1	0	0	1		reg		2	2	x		x	x	x	x
	mem	1	1	1	1	1	1	1	W	mod		0	0	1		mem		16/24	2-4	x		x	x	x	x
	reg16	0	1	0	0	1		reg										2	1	x		x	x	x	x
MULU	reg	1	1	1	1	0	1	1	W	1	1	1	0	0		reg		21-30	2	U	x	x	U	U	U
	mem	1	1	1	1	0	1	1	W	mod			1	0	0	mem		27-36	2-4	U	x	x	U	U	U
MUL	reg	1	1	1	1	0	1	1	W	1	1	1	0	1		reg		33-47	2	U	x	x	U	U	U
	mem	1	1	1	1	0	1	1	W	mod			1	0	1	mem		39-57	2-4	U	x	x	U	U	U
	reg16,reg16,imm8	0	1	1	0	1	0	1	1	1	1		reg			reg		28-34	3	U	x	x	U	U	U
	reg16,mem16,imm8	0	1	1	0	1	0	1	1	mod			reg			mem		34-44	3-5	U	x	x	U	U	U
	reg16,reg16,imm16	0	1	1	0	1	0	0	1	1	1		reg			reg		36-42	4	U	x	x	U	U	U
	reg16,mem16,imm16	0	1	1	0	1	0	0	1	mod			reg			mem		46-52	4-6	U	x	x	U	U	U
DIVU	reg	1	1	1	1	0	1	1	W	1	1	1	1	0		reg		19-25	2	U	U	U	U	U	U
	mem	1	1	1	1	0	1	1	W	mod		1	1	0		mem		25-35	2-4	U	U	U	U	U	U
DIV	reg	1	1	1	1	0	1	1	W	1	1	1	1	1		reg		29-43	2	U	U	U	U	U	U
	mem	1	1	1	1	0	1	1	W	mod		1	1	1		mem		35-53	2-4	U	U	U	U	U	U
Comparison Instructions																									
CMP	reg, reg	0	0	1	1	1	0	1	W	1	1		reg			reg		2	2	x	x	x	x	x	x
	mem, reg	0	0	1	1	1	0	0	W	mod			reg			mem		11/15	2-4	x	x	x	x	x	x
	reg, mem	0	0	1	1	1	0	1	W	mod			reg			mem		11/15	2-4	x	x	x	x	x	x
	reg, imm	1	0	0	0	0	0	S	W	1	1	1	1	1		reg		4	3-4	x	x	x	x	x	x
	mem, imm	1	0	0	0	0	0	S	W	mod		1	1	1		mem		13/17	3-6	x	x	x	x	x	x
	acc, imm	0	0	1	1	1	1	0	W									4	2-3	x	x	x	x	x	x
Logical Instructions																									
NOT	reg	1	1	1	1	0	1	1	W	1	1	0	1	0		reg		2	2						
	mem	1	1	1	1	0	1	1	W	mod		0	1	0		mem		16/24	2-4						
NEG	reg	1	1	1	1	0	1	1	W	1	1	0	1	1		reg		2	2	x	x	x	x	x	x
	mem	1	1	1	1	0	1	1	W	mod		0	1	1		mem		16/24	2-4	x	x	x	x	x	x
TEST	reg, reg	1	0	0	0	0	1	0	W	1	1		reg			reg		2	2	U	0	0	x	x	x
	mem, reg	1	0	0	0	0	1	0	W	mod			reg			mem		10/14	2-4	U	0	0	x	x	x
	reg, imm	1	1	1	1	0	1	1	W	1	1	0	0	0		reg		4	3-4	U	0	0	x	x	x

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Logical Instructions (cont)																									
	mem, imm	1	1	1	1	0	1	1	W	mod			0	0	0	mem		11/15	3-6	u	0	0	x	x	x
	acc, imm	1	0	1	0	1	0	0	W									4	2-3	u	0	0	x	x	x
AND	reg, reg	0	0	1	0	0	0	1	W	1	1		reg			reg		2	2	u	0	0	x	x	x
	mem, reg	0	0	1	0	0	0	0	W	mod			reg			mem		16/20	2-4	u	0	0	x	x	x
	reg, mem	0	0	1	0	0	0	1	W	mod			reg			mem		11/15	2-4	u	0	0	x	x	x
	reg, imm	1	0	0	0	0	0	0	W	1	1	1	0	0		reg		4	3-4	u	0	0	x	x	x
	mem, imm	1	0	0	0	0	0	0	W	mod			1	0	0	mem		18/26	3-6	u	0	0	x	x	x
	acc, imm	0	0	1	0	0	1	0	W									4	2-3	u	0	0	x	x	x
OR	reg, reg	0	0	0	0	1	0	1	W	1	1		reg			reg		2	2	u	0	0	x	x	x
	mem, reg	0	0	0	0	1	0	0	W	mod			reg			mem		16/24	2-4	u	0	0	x	x	x
	reg, mem	0	0	0	0	1	0	1	W	mod			reg			mem		11/15	2-4	u	0	0	x	x	x
	reg, imm	1	0	0	0	0	0	0	W	1	1	0	0	1		reg		4	3-4	u	0	0	x	x	x
	mem, imm	1	0	0	0	0	0	0	W	mod			0	0	1	mem		18/26	3-6	u	0	0	x	x	x
	acc, imm	0	0	1	0	0	1	0	W									4	2-3	u	0	0	x	x	x
XOR	reg, reg	0	0	1	1	0	0	1	W	1	1		reg			reg		2	2	u	0	0	x	x	x
	mem, reg	0	0	1	1	0	0	0	W	mod			reg			mem		16/24	2-4	u	0	0	x	x	x
	reg, mem	0	0	1	1	0	0	1	W	mod			reg			mem		11/15	2-4	u	0	0	x	x	x
	reg, imm	1	0	0	0	0	0	0	W	1	1	1	1	0		reg		4	3-4	u	0	0	x	x	x
	mem, imm	1	0	0	0	0	0	0	W	mod			1	1	0	mem		18/26	3-6	u	0	0	x	x	x
	acc, imm	0	0	1	0	0	1	0	W									4	2-3	u	0	0	x	x	x
Bit Manipulation Instructions																									
INS	reg8, reg8	0	0	0	0	1	1	1	1	0	0	1	1	0	0	0	1	35-133	3						
		1	1		reg				reg																
	reg8, imm8	0	0	0	0	1	1	1	1	0	0	1	1	1	0	0	1	35-133	4						
		1	1	0	0	0		reg																	
EXT	reg8, reg8	0	0	0	0	1	1	1	1	0	0	1	1	0	0	1	1	34-59	3						
		1	1		reg				reg																
	reg8, imm8	0	0	0	0	1	1	1	1	0	0	1	1	1	0	1	1	34-59	4						
		1	1	0	0	0		reg																	
TEST1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	0	W	3	3	u	0	0	u	u	x
		1	1	0	0	0		reg																	
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	0	W	12/16	3-5	u	0	0	u	u	x
		mod		0	0	0		mem																	
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	0	W	4	4	u	0	0	u	u	x
		1	1	0	0	0		reg																	
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	0	W	13/21	4-6	u	0	0	u	u	x
		mod		0	0	0		mem																	
SET1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	0	W	4	3						
		1	1	0	0	0		reg																	
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	0	W	13/21	3-5						
		mod		0	0	0		mem																	

Instruction Set (cont)

Mnemonic	Operands	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Bit Manipulation Instructions (cont)																									
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	0	W	5	4						
		1	1	0	0	0	reg																		
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	0	W	14/22	4-6						
		mod		0	0	0	mem																		
	CY	1	1	1	1	1	0	0	1									2	1		1				
	DIR	1	1	1	1	1	1	0	1									2	1						
CLR1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	1	W	5	3						
		1	1	0	0	0	reg																		
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	1	W	14/22	3-5						
		mod		0	0	0	mem																		
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1	W	6	4						
		1	1	0	0	0	reg																		
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1	W	15/27	4-6						
		mod		0	0	0	mem																		
	CY	1	1	1	1	1	0	0	0									2	1		0				
	DIR	1	1	1	1	1	1	0	0									2	1						
NOT1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	1	W	4	3						
		1	1	0	0	0	reg																		
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	1	W	18/26	3-5						
		mod		0	0	0	mem																		
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	1	W	5	4						
		1	1	0	0	0	reg																		
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	1	W	19/27	4-6						
		mod		0	0	0	mem																		
	CY	1	1	1	1	0	1	0	1									2	1		x				
Shift/Rotate Instructions																									
SHL	reg, 1	1	1	0	1	0	0	0	W	1	1	1	0	0	reg			2	2	u	x	x	x	x	x
	mem, 1	1	1	0	1	0	0	0	W	mod			1	0	0	mem		16/24	2-4	u	x	x	x	x	x
	reg, CL	1	1	0	1	0	0	1	W	1	1	1	0	0	reg			7 + n	2	u	x	u	x	x	x
	mem, CL	1	1	0	1	0	0	1	W	mod			1	0	0	mem		19/27 + n	2-4	u	x	u	x	x	x
	reg, imm8	1	1	0	0	0	0	0	W	1	1	1	0	0	reg			7 + n	3	u	x	u	x	x	x
	mem, imm8	1	1	0	0	0	0	0	W	mod			1	0	0	mem		19/27 + n	3-5	u	x	u	x	x	x
SHR	reg, 1	1	1	0	1	0	0	0	W	1	1	1	0	1	reg			2	2	u	x	x	x	x	x
	mem, 1	1	1	0	1	0	0	0	W	mod			1	0	1	mem		16/24	2-4	u	x	x	x	x	x
	reg, CL	1	1	0	1	0	0	1	W	1	1	1	0	1	reg			7 + n	2	u	x	u	x	x	x
	mem, CL	1	1	0	1	0	0	1	W	mod			1	0	1	mem		19/27 + n	2-4	u	x	u	x	x	x
	reg, imm8	1	1	0	0	0	0	0	W	1	1	1	0	1	reg			7 + n	3	u	x	u	x	x	x
	mem, imm8	1	1	0	0	0	0	0	W	mod			1	0	1	mem		19/27 + n	3-5	u	x	u	x	x	x

n = number of shifts

Instruction Set (cont)

Mnemonic	Operands	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Shift/Rotate Instructions (cont)																									
SHRA	reg, 1	1	1	0	1	0	0	0	W	1	1	1	1	1		reg		2	2	u	x	0	x	x	x
	mem, 1	1	1	0	1	0	0	0	W	mod					1	1	1	16/24	2-4	u	x	0	x	x	x
	reg, CL	1	1	0	1	0	0	1	W	1	1	1	1	1		reg		7 + n	2	u	x	u	x	x	x
	mem, CL	1	1	0	1	0	0	1	W	mod					1	1	1	19/27 + n	2-4	u	x	u	x	x	x
	reg, imm8	1	1	0	0	0	0	0	W	1	1	1	1	1		reg		7 + n	3	u	x	u	x	x	x
	mem, imm8	1	1	0	0	0	0	0	W	mod					1	1	1	19/27 + n	3-5	u	x	u	x	x	x
ROL	reg, 1	1	1	0	1	0	0	0	W	1	1	0	0	0		reg		2	2		x	x			
	mem, 1	1	1	0	1	0	0	0	W	mod					0	0	0	16/24	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	0	0		reg		7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod					0	0	0	19/27 + n	2-4		x	u			
	reg, imm	1	1	0	0	0	0	0	W	1	1	0	0	0		reg		7 + n	3		x	u			
	mem, imm	1	1	0	0	0	0	0	W	mod					0	0	0	19/27 + n	3-5		x	u			
ROR	reg, 1	1	1	0	1	0	0	0	W	1	1	0	0	1		reg		2	2		x	u			
	mem, 1	1	1	0	1	0	0	0	W	mod					0	0	1	16/24	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	0	1		reg		7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod					0	0	1	19/27 + n	2-4		x	u			
	reg, imm8	1	1	0	0	0	0	0	W	1	1	0	0	1		reg		7 + n	3		x	u			
	mem, imm8	1	1	0	0	0	0	0	W	mod					0	0	1	19/27 + n	3-5		x	u			
ROLC	reg, 1	1	1	0	1	0	0	0	W	1	1	0	1	0		reg		2	2		x	x			
	mem, 1	1	1	0	1	0	0	0	W	mod					0	1	0	16/28	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	1	0		reg		7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod					0	1	0	19/27 + n	2-4		x	u			
	reg, imm8	1	1	0	0	0	0	0	W	1	1	0	1	0		reg		7 + n	3		x	u			
	mem, imm8	1	1	0	0	0	0	0	W	mod					0	1	0	19/27 + n	3-5		x	u			
RORC	reg, 1	1	1	0	1	0	0	0	W	1	1	0	1	1		reg		2	2		x	x			
	mem, 1	1	1	0	1	0	0	0	W	mod					0	1	1	16/24	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	1	1		reg		7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod					0	1	1	19/27 + n	2-4		x	u			
	reg, imm8	1	1	0	0	0	0	0	W	1	1	0	1	1		reg		7 + n	3		x	u			
	mem, imm8	1	1	0	0	0	0	0	W	mod					0	1	1	19/27 + n	3-5		x	u			
										n = number of shifts															
Stack Manipulation Instructions																									
PUSH	mem16	1	1	1	1	1	1	1	1	mod					1	1	0	26	2-4						
	reg16	0	1	0	1	0	reg											12	1						
	sr	0	0	0	sr		1	1	0									12	1						
	PSW	1	0	0	1	1	1	0	0									12	1						
	R	0	1	1	0	0	0	0	0									67	1						
	imm	0	1	1	0	1	0	S	0									11/12	2-3						

Instruction Set (cont)

Mnemonic	Operands	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Stack Manipulation Instructions (cont)																									
POP	mem16	1	0	0	0	1	1	1	1	mod			0	0	0	mem		25	2-4						
	reg16	0	1	0	1	1	reg											12	1						
	sr	0	0	0	sr		1	1	1									12	1						
	PSW	1	0	0	1	1	1	0	1									12	1	R	R	R	R	R	R
	R	0	1	1	0	0	0	0	1									75	1						
PREPARE	imm16, imm8	1	1	0	0	1	0	0	0									*	4						
										*imm8 = 0 : 12 imm8 > 1 : 19 + 8 (imm8 − 1)															
DISPOSE		1	1	0	0	1	0	0	1									10	1						
Control Transfer Instructions																									
CALL	near_proc	1	1	1	0	1	0	0	0									20	3						
	regptr	1	1	1	1	1	1	1	1	1	1	0	1	0	reg			18	1						
	memptr16	1	1	1	1	1	1	1	1	mod			0	1	0	mem		31	2-4						
	far_proc	1	0	0	1	1	0	1	0									29	5						
	memptr32	1	1	1	1	1	1	1	1	mod			0	1	1	mem		47	2-4						
RET		1	1	0	0	0	0	1	1									19	1						
	pop_value	1	1	0	0	0	0	1	0									24	3						
		1	1	0	0	1	0	1	1									29	1						
	pop_value	1	1	0	0	1	0	1	0									32	3						
BR	near_label	1	1	1	0	1	0	0	1									13	3						
	short_label	1	1	1	0	1	0	0	1									12	2						
	reg	1	1	1	1	1	1	1	1	1	1	1	0	0	reg			11	2						
	memptr16	1	1	1	1	1	1	1	1	mod			1	0	0	mem		24	2-4						
	far_label	1	1	1	0	1	0	1	0									15	5						
	memptr32	1	1	1	1	1	1	1	1	mod			1	0	1	mem		35	2-4						
BV	near_label	0	1	1	1	0	0	0	0									14/4	2						
BNV	near_label	0	1	1	1	0	0	0	1									14/4	2						
BC, BL	near_label	0	1	1	1	0	0	1	0									14/4	2						
BNC, BNL	near_label	0	1	1	1	0	0	1	1									14/4	2						
BE, BZ	near_label	0	1	1	1	0	1	0	0									14/4	2						
BNE, BNZ	near_label	0	1	1	1	0	1	0	1									14/4	2						
BNH	near_label	0	1	1	1	0	1	1	0									14/4	2						
BH	near_label	0	1	1	1	0	1	1	1									14/4	2						
BN	near_label	0	1	1	1	1	0	0	0									14/4	2						
BP	near_label	0	1	1	1	1	0	0	1									14/4	2						
BPE	near_label	0	1	1	1	1	0	1	0									14/4	2						
BPO	near_label	0	1	1	1	1	0	1	1									14/4	2						
BLT	near_label	0	1	1	1	1	1	0	0									14/4	2						
BGE	near_label	0	1	1	1	1	1	0	1									14/4	2						

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Control Transfer Instructions (cont)																									
BLE	near_label	0	1	1	1	1	1	1	0									14/4	2						
BGT	near_label	0	1	1	1	1	1	1	1									14/4	2						
DBNZNE	near_label	1	1	1	0	0	0	0	0									14/5	2						
DBNZE	near_label	1	1	1	0	0	0	0	1									14/5	2						
DBNZ	near_label	1	1	1	0	0	0	1	0									13/5	2						
BCWZ	near_label	1	1	1	0	0	0	1	1									13/5	2						
Interrupt Instructions																									
BRK	3	1	1	0	0	1	1	0	0									50	1						
	imm8	1	1	0	0	1	1	0	1									50	2						
BRKV	imm8	1	1	0	0	1	1	1	1									52/3	1						
RETI		1	1	0	0	1	1	1	0									39	1	R	R	R	R	R	R
CHKIND	reg16, mem32	0	1	1	0	0	0	1	0	mod			reg				mem	73-76/26	2-4						
BRKEM	imm8	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	50	3						
CPU Control Instructions																									
HALT		1	1	1	1	0	1	0	0									2	1						
BUSLOCK		1	1	1	1	0	0	0	0									2	1						
FPO1	fp_op	1	1	0	1	1	X	X	X	1	1	Y	Y	Y	Z	Z	Z	2	2						
	fp_op, mem	1	1	0	1	1	X	X	X	mod		Y	Y	Y		mem		15	2-4						
FPO2	fp_op	0	1	1	0	0	1	1	X	1	1	Y	Y	Y	Z	Z	Z	2	2						
	fp_op, mem	0	1	1	0	0	1	1	X	mod		Y	Y	Y		mem		15	2-4						
POLL		1	0	0	1	1	0	1	1	n = number of times POLL pin is sampled.								2 + 5n	1						
NOP		1	0	0	1	0	0	0	0									3	1						
DI		1	1	1	1	1	0	1	0									2	1						
EI		1	1	1	1	1	0	1	1									2	1						
8080 Instruction Set Enhancements																									
RETEM		1	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	39	2	R	R	R	R	R	R
CALLN	imm8	1	1	1	0	1	1	0	1	1	1	1	0	1	1	0	1	58	3						

μPD70116 (V30™) 16-BIT HIGH-PERFORMANCE CMOS MICROPROCESSOR

Description

The μPD70116 (V30) is a CMOS 16-bit microprocessor with an internal 16-bit architecture and a 16-bit external data bus. The μPD70116 instruction set is a superset of the μPD8086/8088; however, mnemonics and execution times are different. The μPD70116 additionally has a powerful instruction set including bit processing, packed BCD operations, and high-speed multiplication/division operations. The μPD70116 can also execute the entire 8080 instruction set and comes with a standby mode that significantly reduces power consumption. It is software-compatible with the μPD70108 microprocessor.

Features

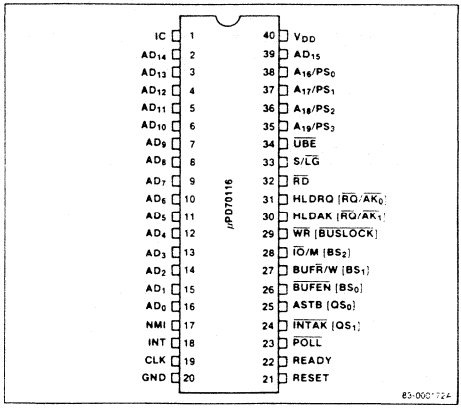
- ☐ Minimum instruction execution time: 250 ns (at 8 MHz)
- ☐ Maximum addressable memory: 1 Mbyte
- ☐ Abundant memory addressing modes
- ☐ 14 x 16-bit register set
- ☐ 101 instructions
- ☐ Instruction set is a superset of μPD8086/8088 instruction set
- ☐ Bit, byte, word, and block operations
- ☐ Bit field operation instructions
- ☐ Packed BCD instructions
- ☐ Multiplication/division instruction execution time: 4 μs to 6 μs (at 8 MHz)
- ☐ High-speed block transfer instructions: 2 Mbyte/s (at 8 MHz)
- ☐ High-speed calculation of effective addresses: 2 clock cycles in any addressing mode
- ☐ Maskable (INT) and nonmaskable (NMI) interrupt inputs
- ☐ IEEE-796 bus compatible interface
- ☐ 8080 emulation mode
- ☐ CMOS technology
- ☐ Low-power consumption
- ☐ Low-power standby mode
- ☐ Single power supply
- ☐ 5-MHz, 8-MHz or 10-MHz clock

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD70116C-5	40-pin plastic DIP	5 MHz
μPD70116C-8	40-pin plastic DIP	8 MHz
μPD70116D-5	40-pin ceramic DIP	5 MHz
μPD70116D-8	40-pin ceramic DIP	8 MHz
μPD70116D-10	40-pin ceramic DIP	10 MHz
μPD70116G-5	52-pin plastic flat pack	5 MHz
μPD70116G-8	52-pin plastic flat pack	8 MHz
μPD70116L-5	44-pin PLCC	5 MHz
μPD70116L-8	44-pin PLCC	8 MHz

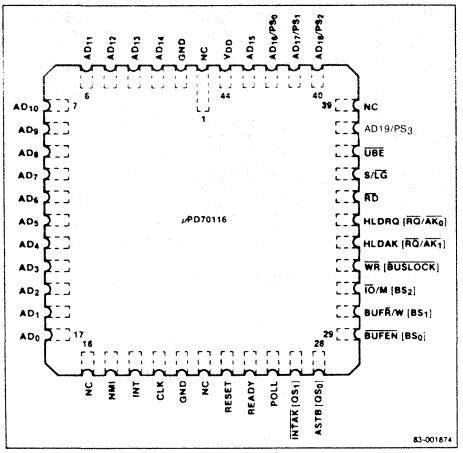
Pin Configurations

40-Pin Plastic DIP/Cerdip

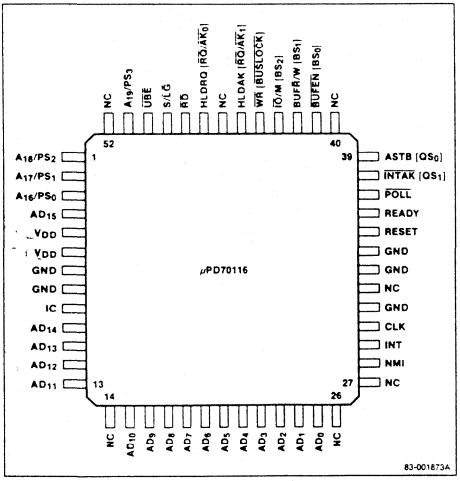


Pin Configurations (cont)

44-Pin Plastic Leadless Chip Carrier (PLCC)



52-Pin Plastic Flat Pack



Pin Identification

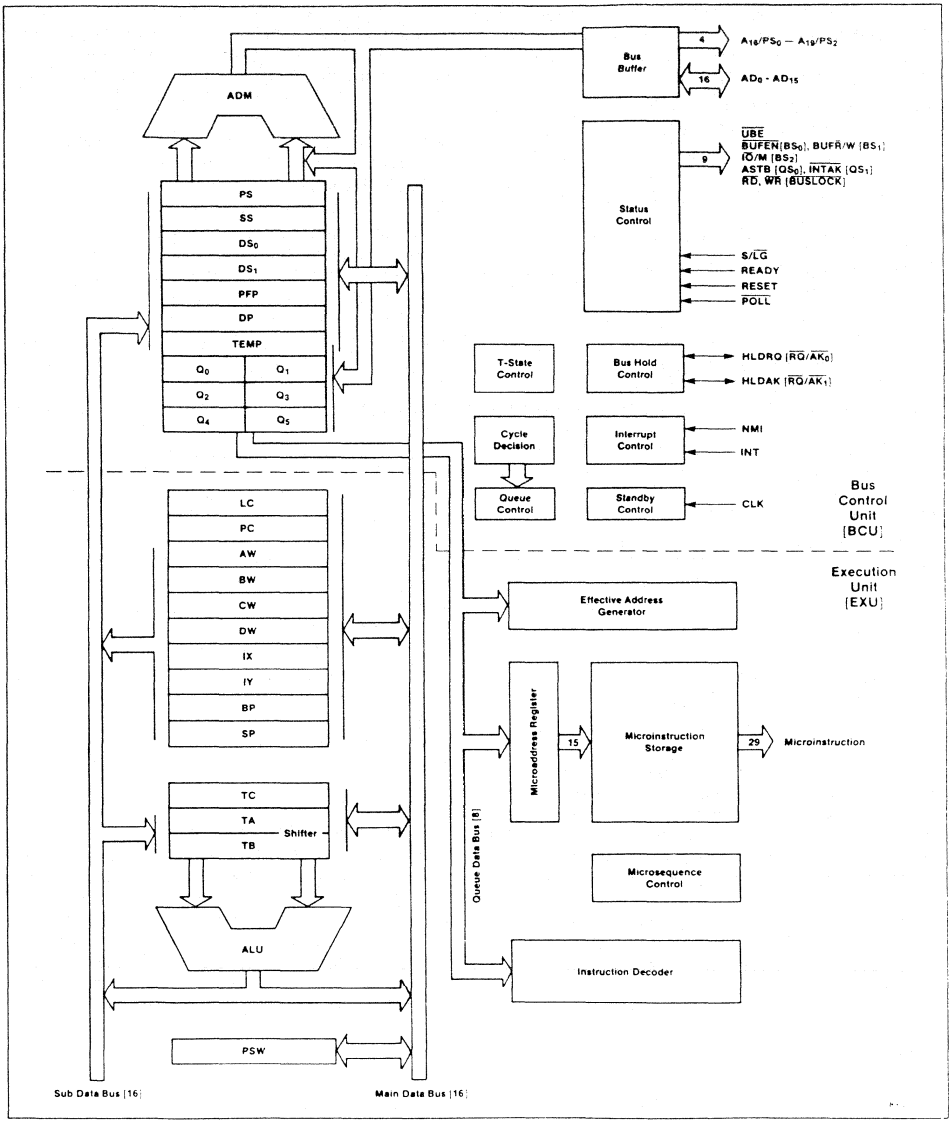
Symbol	Direction	Function
IC*		Internally connected
AD_{14} - AD_0	In/Out	Address/data bus
NMI	In	Nonmaskable interrupt input
INT	In	Maskable interrupt input
CLK	In	Clock input
GND		Ground potential
RESET	In	Reset input
READY	In	Ready input
POLL	In	Poll input
INTAK (QS_1)	Out	Interrupt acknowledge output (queue status bit 1 output)
ASTB (QS_0)	Out	Address strobe output (queue status bit 0 output)
BUFEN (BS_0)	Out	Buffer enable output (bus status bit 0 output)
BUFR/W (BS_1)	Out	Buffer read/write output (bus status bit 1 output)
IO/M (BS_2)	Out	Access is I/O or memory (bus status bit 2 output)
WR (BUSLOCK)	Out	Write strobe output (bus lock output)
HLDAK (RQ/AK_1)	Out (In/Out)	Hold acknowledge output (bus hold request input acknowledge output 1)
HLDRQ (RQ/AK_0)	In (In/Out)	Hold request input (bus hold request input/ acknowledge output 0)
RD	Out	Read strobe output
S/LG	In	Small-scale/large-scale system input
UBE	Out	Upper byte enable
A_{19}/PS_3 - A_{16}/PS_0	Out	Address bus, high bits or processor status output
AD_{15}	In/Out	Address/data bus, bit 15
V_{DD}		Power supply

Notes: * IC should be connected to ground.

Where pins have different functions in small- and large-scale systems, the large-scale system pin symbol and function are in parentheses.

Unused input pins should be tied to ground or V_{DD} to minimize power dissipation and prevent the flow of potentially harmful currents.

Block Diagram



Pin Functions

Some pins of the μPD70116 have different functions according to whether the microprocessor is used in a small- or large-scale system. Other pins function the same way in either type of system.

AD_{15} - AD_0 [Address/Data Bus]
For small- and large-scale systems.

AD_{15} - AD_0 is a time-multiplexed address and data bus. When high, an AD bit is a one; when low, an AD bit is a zero. This bus contains the lower 16 bits of the 20-bit address during T1 of the bus cycle. It is used as a 16-bit data bus during T2, T3, and T4 of the bus cycle.

The address/data bus is a three-state bus and can be at a high or low level during standby mode. The bus will be high impedance during hold and interrupt acknowledge.

NMI [Nonmaskable Interrupt]
For small- and large-scale systems.

This pin is used to input nonmaskable interrupt requests. NMI cannot be masked by software. This input is positive edge triggered and must be held high for five clocks to guarantee recognition. Actual interrupt processing begins, however, after completion of the instruction in progress.

The contents of interrupt vector 2 determine the starting address for the interrupt-servicing routine. Note that a hold request will be accepted even during NMI acknowledge.

This interrupt will cause the μPD70116 to exit the standby mode.

INT [Maskable Interrupt]
For small- and large-scale systems.

This pin is an interrupt request that can be masked by software.

INT is active high level and is sensed during the last clock of the instruction. The interrupt will be accepted if the interrupt enable flag IE is set. The CPU outputs the $\overline{\text{INTAK}}$ signal to inform external devices that the interrupt request has been granted. INT must be asserted until the interrupt acknowledge signal is returned.

If NMI and INT interrupts occur at the same time, NMI has higher priority than INT and INT cannot be accepted. A hold request will be accepted during INT acknowledge.

This interrupt causes the μPD70116 to exit the standby mode.

CLK [Clock]
For small- and large-scale systems.

This pin is used for external clock input.

RESET [Reset]
For small- and large-scale systems.

This pin is used for the CPU reset signal. It is an active high level. Input of this signal has priority over all other operations. After the reset signal input returns to a low level, the CPU begins execution of the program starting at address FFFF0H.

In addition to causing normal CPU start, RESET input will cause the μPD70116 to exit the standby mode.

READY [Ready]
For small- and large-scale systems.

When the memory or I/O device being accessed cannot complete data read or write within the CPU basic access time, it can generate a CPU wait state (Tw) by setting this signal to inactive (low level) and requesting a read/write cycle delay.

If the READY signal is active (high level) during either the T3 or Tw state, the CPU will not generate a wait state.

$\overline{\text{POLL}}$ [Poll]
For small- and large-scale systems.

The CPU checks this input upon execution of the POLL instruction. If the input is low, then execution continues. If the input is high, the CPU will check the $\overline{\text{POLL}}$ input every five clock cycles until the input becomes low again.

The $\overline{\text{POLL}}$ and READY functions are used to synchronize CPU program execution with the operation of external devices.

$\overline{\text{RD}}$ [Read Strobe]
For small- and large-scale systems.

The CPU outputs this strobe signal during data read from an I/O device or memory. The $\overline{\text{IO}}$/M signal is used to select between I/O and memory.

This three-state output is held high during standby mode and enters the high-impedance state during hold acknowledge.

S/$\overline{\text{LG}}$ [Small/Large]
For small- and large-scale systems.

This signal determines the operation mode of the CPU. This signal is fixed at either a high or low level. When this signal is a high level, the CPU will operate in small-scale system mode, and when low, in the large-scale system mode. A small-scale system will have at most one bus master such as a DMA controller device on the bus. A large-scale system can have more than one bus master accessing the bus as well as the CPU.

$\overline{\text{INTAK}}$ [Interrupt Acknowledge]
For small-scale systems.

The CPU generates the $\overline{\text{INTAK}}$ signal low when it accepts an INT signal.

The interrupting device synchronizes with this signal and outputs the interrupt vector to the CPU via the data bus (AD_7 - AD_0).

ASTB [Address Strobe]
For small-scale systems.

The CPU outputs this strobe signal to latch address information at an external latch.

ASTB is held at a low level during standby mode and hold acknowledge.

$\overline{\text{BUFEN}}$ [Buffer Enable]
For small-scale systems.

This is used as the output enable signal for an external bidirectional buffer. The CPU generates this signal during data transfer operations with external memory or I/O devices or during input of an interrupt vector.

This three-state output is held high during standby mode and enters the high-impedance state during hold acknowledge.

BUF$\overline{\text{R}}$/W [Buffer Read/Write]
For small-scale systems.

The output of this signal determines the direction of data transfer with an external bidirectional buffer. A high output causes transmission from the CPU to the external device; a low signal causes data transfer from the external device to the CPU.

BUF$\overline{\text{R}}$/W is a three-state output and enters the high-impedance state during hold acknowledge.

$\overline{\text{IO}}$/M [IO/Memory]
For small-scale systems.

The CPU generates this signal to specify either I/O access or memory access. A low-level output specifies I/O and a high-level signal specifies memory.

$\overline{\text{IO}}$/M's output is three state and becomes high impedance during hold acknowledge.

$\overline{\text{WR}}$ [Write Strobe]
For small-scale systems.

The CPU generates this strobe signal during data write to an I/O device or memory. Selection of either I/O or memory is performed by the $\overline{\text{IO}}$/M signal.

This three-state output is held high during standby mode and enters the high-impedance state during hold acknowledge.

HLDAK [Hold Acknowledge]
For small-scale systems.

The HLDAK signal is used to indicate that the CPU accepts the hold request signal (HLDRQ). When this signal is a high level, the address bus, address/data bus, the control lines become high impedance.

HLDRQ [Hold Request]
For small-scale systems.

This input signal is used by external devices to request the CPU to release the address bus, address/data bus, and the control bus.

$\overline{\text{UBE}}$ [Upper Byte Enable]
For small- and large-scale systems.

$\overline{\text{UBE}}$ indicates the use of the upper eight bits (AD_{16} -AD_8) of the address/data bus during a bus cycle. This signal is active low during T1 for read, write, and interrupt acknowledge cycles when AD_{15} - AD_8 are to be used. Bus cycles in which $\overline{\text{UBE}}$ is active are shown in the following table.

Type of Bus Operation	$\overline{\text{UBE}}$	AD_0	Number of Bus Cycles
Word at even address	0	0	1
Word at odd address	0 1	1* 0**	2
Byte at even address	1	0	1
Byte at odd address	0	1	1

Notes: * First bus cycle
** Second bus cycle

$\overline{\text{UBE}}$ is low continuously during the interrupt acknowledge state.

The three-state output is held high during standby mode and enters the high-impedance state during hold acknowledge.

A_{19}/PS_3 - A_{16}/PS_0 [Address Bus/Processor Status]
For small- and large-scale systems.

These pins are time multiplexed to operate as an address bus and as processor status signals.

When used as the address bus, these pins are the high 4 bits of the 20-bit memory address. During I/O access, all 4 bits output data 0.

The processor status signals are provided for both memory and I/O use. PS_3 is always 0 in the native mode and 1 in 8080 emulation mode. The interrupt enable flag (IE) is output on pin PS_2. Pins PS_1 and PS_0 indicate which memory segment is being accessed.

A_{17}/PS_1	A_{16}/PS_0	Segment
0	0	Data segment 1
0	1	Stack segment
1	0	Program segment
1	1	Data segment 0

The output of these pins is three state and becomes high impedance during hold acknowledge.

QS_1, QS_0 [Queue Status]

For large-scale systems.

The CPU uses these signals to allow external devices, such as the floating-point arithmetic processor chip (μPD72091), to monitor the status of the internal CPU instruction queue.

QS_1	QS_0	Instruction Queue Status
0	0	NOP (queue does not change)
0	1	First byte of instruction
1	0	Flush queue
1	1	Subsequent bytes of instruction

The instruction queue status indicated by these signals is the status when the execution unit (EXU) accesses the instruction queue. The data output from these pins is therefore valid only for one clock cycle immediately following queue access. These status signals are provided so that the floating-point processor chip can monitor the CPU's program execution status and synchronize its operation with the CPU when control is passed to it by the FPO (Floating Point Operation) instructions.

BS_2 - BS_0 [Bus Status]

For large-scale systems.

The CPU uses these status signals to allow an external bus controller to monitor what the current bus cycle is.

The external bus controller decodes these signals and generates the control signals required to perform access of the memory or I/O device.

BS_2	BS_1	BS_0	Bus Cycle
0	0	0	Interrupt acknowledge
0	0	1	I/O read
0	1	0	I/O write
0	1	1	Halt
1	0	0	Program fetch
1	0	1	Memory read
1	1	0	Memory write
1	1	1	Passive state

The output of these signals is three state and becomes high impedance during hold acknowledge.

$\overline{BUSLOCK}$ [Bus Lock]

For large-scale systems.

The CPU uses this signal to secure the bus while executing the instruction immediately following the BUSLOCK prefix instruction and during interrupt acknowledge cycles. It is a status signal to the other bus masters in a multiprocessor system inhibiting them from using the system bus during this time.

The output of this signal is three state and becomes high impedance during hold acknowledge. $\overline{BUSLOCK}$ is high during standby mode except if the HALT instruction has a BUSLOCK prefix.

$\overline{RQ}/\overline{AK_1}$, $\overline{RQ}/\overline{AK_0}$ [Hold Request/Acknowledge]

For large-scale systems.

These pins function as bus hold request inputs ($\overline{RQ}$) and as bus hold acknowledge outputs ($\overline{AK}$). $\overline{RQ}/\overline{AK_0}$ has a higher priority than $\overline{RQ}/\overline{AK_1}$.

These pins have three-state outputs with on-chip pull-up resistors which keep the pin at a high level when the output is high impedance.

V_{DD} [Power Supply]

For small- and large-scale systems.

This pin is used for the +5 V power supply.

GND [Ground]

For small- and large-scale systems.

This pin is used for ground.

IC [Internally Connected]

This pin is used for tests performed at the factory by NEC. The μPD70116 is used with this pin at ground potential.

Absolute Maximum Ratings

T_A = +25°C

Power supply voltage, V_{DD}	−0.5 V to +7.0 V
Power dissipation, PD_{MAX}	0.5 W
Input voltage, V_I	−0.5 V to V_{DD} + 0.3 V
CLK input voltage, V_K	−0.5 V to V_{DD} + 1.0 V
Output voltage, V_O	−0.5 V to V_{DD} + 0.3 V
Operating temperature, T_{OPT}	−40°C to +85°C
Storage temperature, T_{STG}	−65°C to +150°C

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

T_A = +25°C, V_{DD} = 0 V

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Input capacitance	C_I		15	pF	fc = 1 MHz
I/O capacitance	C_{IO}		15	pF	Unmeasured pins returned to 0 V

DC Characteristics

μPD70116-5, T_A = −40°C to +85°C, V_{DD} = +5 V ± 10%
μPD70116-8, μPD70116-10, T_A = −10°C to +70°C, V_{DD} = +5 V ± 5%

Parameter	Symbol		Limits Min	Limits Typ	Limits Max	Unit	Test Conditions
Input voltage high	V_{IH}		2.2		V_{DD} + 0.3	V	
Input voltage low	V_{IL}		−0.5		0.8	V	
CLK input voltage high	V_{KH}		3.9		V_{DD} + 1.0	V	
CLK input voltage low	V_{KL}		−0.5		0.6	V	
Output voltage high	V_{OH}		0.7 x V_{DD}			V	I_{OH} = −400 μA
Output voltage low	V_{OL}				0.4	V	I_{OL} = 2.5 mA
Input leakage current high	I_{LIH}				10	μA	V_I = V_{DD}
Input leakage current low	I_{LIL}				−10	μA	V_I = 0 V
Output leakage current high	I_{LOH}				10	μA	V_O = V_{DD}
Output leakage current low	I_{LOL}				−10	μA	V_O = 0 V
Supply current	I_{DD}	70116-5	30	60		mA	Normal operation
		5 MHz	5	10		mA	Standby mode
		70116-8	45	80		mA	Normal operation
		8 MHz	6	12		mA	Standby mode
		70116-10	60	100		mA	Normal operation
		10 MHz	7	14		mA	Standby mode

AC Characteristics

μPD70116-5, $T_A = -40°C$ to $+85°C$, $V_{DD} = +5\ V \pm 10\%$
μPD70116-8, μPD70116-10 $T_A = -10°C$ to $+70°C$, $V_{DD} = +5\ V \pm 5\%$

Parameter	Symbol	μPD70116-5 Min	μPD70116-5 Max	μPD70116-8 Min	μPD70116-8 Max	μPD70116-10 Min	μPD70116-10 Max	Unit	Conditions
Small/Large Scale									
Clock cycle	t_{CYK}	200	500	125	500	100	500	ns	
Clock pulse width high	t_{KKH}	69		44		41		ns	$V_{KH} = 3.0\ V$
Clock pulse width low	t_{KKL}	90		60		49		ns	$V_{KL} = 1.5\ V$
Clock rise time	t_{KR}		10		8		5	ns	1.5 V to 3.0 V
Clock fall time	t_{KF}		10		7		5	ns	3.0 V to 1.5 V
READY inactive setup to CLK↓	t_{SRYLK}	−8		−8		−10		ns	
READY inactive hold after CLK↑	t_{HKRYH}	30		20		20		ns	
READY active setup to CLK↑	t_{SRYHK}	$t_{KKL} - 8$		$t_{KKL} - 8$		$t_{KKL} - 10$		ns	
READY active hold after CLK↑	t_{HKRYL}	30		20		20		ns	
Data setup time to CLK ↓	t_{SDK}	30		20		10		ns	
Data hold time after CLK ↓	t_{HKD}	10		10		10		ns	
NMI, INT, $\overline{\text{POLL}}$ setup time to CLK ↑	t_{SIK}	30		15		15		ns	
Input rise time (except CLK)	t_{IR}		20		20		20	ns	0.8 V to 2.2 V
Input fall time (except CLK)	t_{IF}		12		12		12	ns	2.2 V to 0.8 V
Output rise time	t_{OR}		20		20		20	ns	0.8 V to 2.2 V
Output fall time	t_{OF}		12		12		12	ns	2.2 V to 0.8 V
Small Scale									
Address delay time from CLK	t_{DKA}	10	90	10	60	10	48	ns	
Address hold time from CLK	t_{HKA}	10		10		10		ns	
PS delay time from CLK ↓	t_{DKP}	10	90	10	60	10	50	ns	
PS float delay time from CLK ↑	t_{FKP}	10	80	10	60	10	50	ns	
Address setup time to ASTB ↓	t_{SAST}	$t_{KKL} - 60$		$t_{KKL} - 30$		$t_{KKL} - 30$		ns	
Address float delay time from CLK ↓	t_{FKA}	t_{HKA}	80	t_{HKA}	60	t_{HKA}	50	ns	$C_L = 100\ pF$
ASTB ↑ delay time from CLK ↓	t_{DKSTH}		80		50		40	ns	
ASTB ↓ delay time from CLK ↑	t_{DKSTL}		85		55		45	ns	
ASTB width high	t_{STST}	$t_{KKL} - 20$		$t_{KKL} - 10$		$t_{KKL} - 10$		ns	
Address hold time from ASTB ↓	t_{HSTA}	$t_{KKH} - 10$		$t_{KKH} - 10$		$t_{KKH} - 10$		ns	

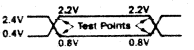
AC Characteristics (cont)

μPD70116-5, $T_A = -40°C$ to $+85°C$, $V_{DD} = +5\ V \pm 10\%$
μPD70116-8, μPD70116-10, $T_A = -10°C$ to $+70°C$, $V_{DD} = +5\ V \pm 5\%$

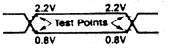
Parameter	Symbol	μPD70116-5		μPD70116-8		μPD70116-10		Unit	Conditions
		Min	Max	Min	Max	Min	Max		
Small Scale (cont)									
Control delay time from CLK	t_{DKCT}	10	110	10	65	10	55	ns	
Address float to $\overline{RD}\downarrow$	t_{AFRL}	0		0		0		ns	
$\overline{RD}\downarrow$ delay time from CLK $\downarrow$	t_{DKRL}	10	165	10	80	10	70	ns	
$\overline{RD}\uparrow$ delay time from CLK $\downarrow$	t_{DKRH}	10	150	10	80	10	60	ns	
Address delay time from $\overline{RD}\uparrow$	t_{DRHA}	$t_{CYK} - 45$		$t_{CYK} - 40$		$t_{CYK} - 35$		ns	
$\overline{RD}$ width low	t_{RR}	$2t_{CYK}-75$		$2t_{CYK}-50$		$2t_{CYK}-40$		ns	$C_L = 100$ pF
Data output delay time from CLK $\downarrow$	t_{DKD}	10	90	10	60	10	50	ns	
Data float delay time from CLK $\downarrow$	t_{FKD}	10	80	10	60	10	50	ns	
$\overline{WR}$ width low	t_{WW}	$2t_{CYK}-60$		$2t_{CYK}-40$		$2t_{CYK}-35$		ns	
HLDRQ setup time to CLK $\uparrow$	t_{SHQK}	35		20		20		ns	
HLDAK delay time from CLK $\downarrow$	t_{DKHA}	10	160	10	100	10	60	ns	
Large Scale									
Address delay time from CLK	t_{DKA}	10	90	10	60	10	48	ns	
Address hold time from CLK	t_{HKA}	10		10		10		ns	
PS delay time from CLK $\downarrow$	t_{DKP}	10	90	10	60	10	50	ns	
PS float delay time from CLK $\uparrow$	t_{FKP}	10	80	10	60	10	50	ns	
Address float delay time from CLK $\downarrow$	t_{FKA}	t_{HKA}	80	t_{HKA}	60	t_{HKA}	50	ns	
Address delay time from $\overline{RD}\uparrow$	t_{DRHA}	$t_{CYK} - 45$		$t_{CYK} - 40$		$t_{CYK} - 35$		ns	
ASTB delay time from BS $\downarrow$	t_{DBST}		15		15		15	ns	
BS $\downarrow$ delay time from CLK $\uparrow$	t_{DKBL}	10	110	10	60	10	50	ns	
BS $\uparrow$ delay time from CLK $\downarrow$	t_{DKBH}	10	130	10	65	10	50	ns	
$\overline{RD}\downarrow$ delay time from address float	t_{DAFRL}	0		0		0		ns	$C_L = 100$ pF
$\overline{RD}\downarrow$ delay time from CLK $\downarrow$	t_{DKRL}	10	165	10	80	10	70	ns	
$\overline{RD}\uparrow$ delay time from CLK $\downarrow$	t_{DKRH}	10	150	10	80	10	60	ns	
$\overline{RD}$ width low	t_{RR}	$2t_{CYK}-75$		$2t_{CYK}-50$		$2t_{CYK}-40$		ns	
Date output delay time from CLK $\downarrow$	t_{DKD}	10	90	10	60	10	50	ns	
Data float delay time from CLK $\uparrow$	t_{FKD}	10	80	10	60	10	50	ns	
$\overline{AK}$ delay time from CLK $\downarrow$	t_{DKAK}		70		50		40	ns	
$\overline{RQ}$ setup time to CLK $\uparrow$	t_{SRQK}	20		10		9		ns	
$\overline{RQ}$ hold time after CLK $\uparrow$	t_{HKRQ}	40		30		20		ns	

Timing Waveforms

AC Test Input Waveform [Except CLK]

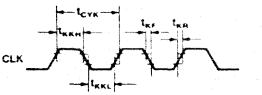


AC Output Test Points

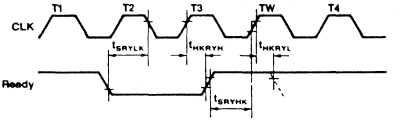


49 000247A

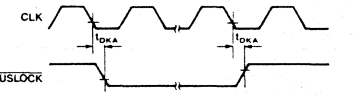
Clock Timing



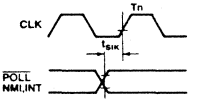
Wait [Ready] Timing



$\overline{\text{BUSLOCK}}$ Output Timing

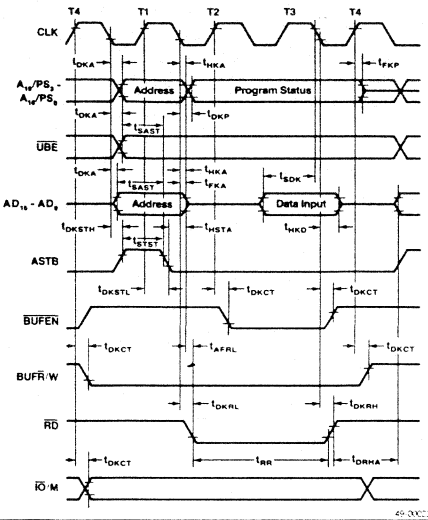


$\overline{\text{POLL}}$,NMI, INT Input Timing

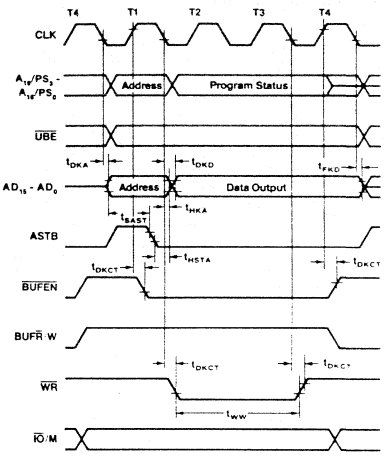


Timing Waveforms (cont)

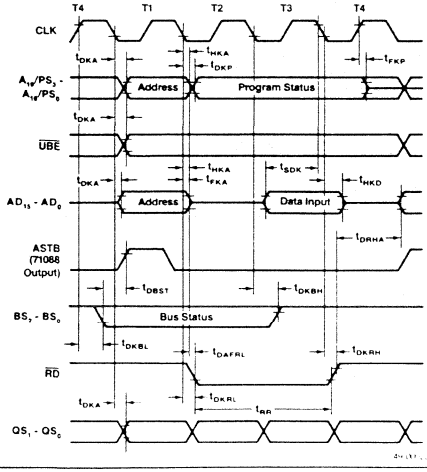
Read Timing [Small Scale]



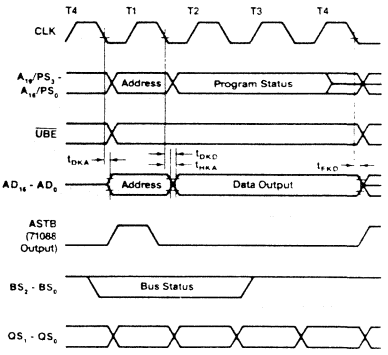
Write Timing [Small Scale]



Read Timing [Large Scale]

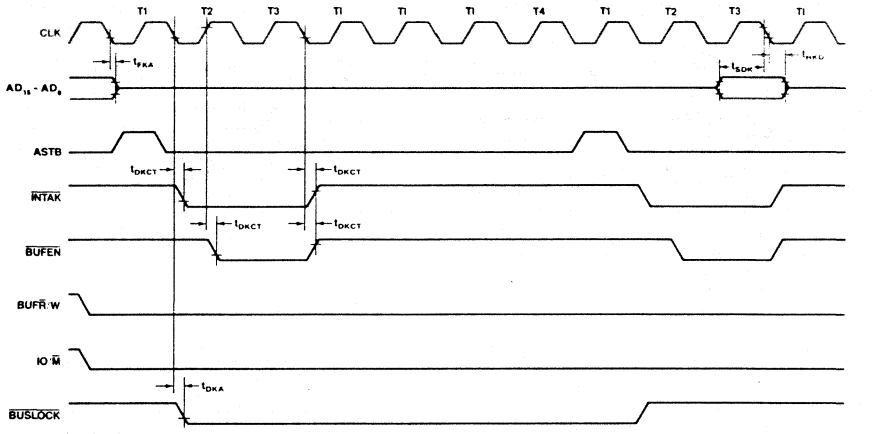


Write Timing [Large Scale]

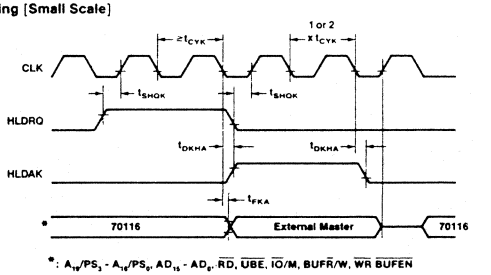


Timing Waveforms (cont)

Interrupt Acknowledge Timing



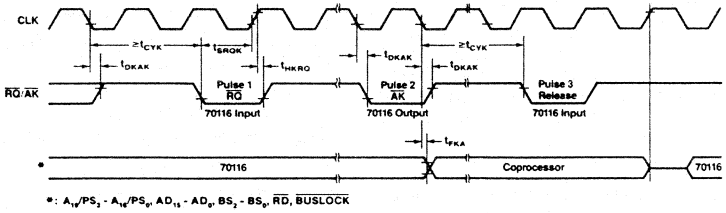
Hold Request/Acknowledge Timing [Small Scale]



*: A_{19}/PS_3 - A_{16}/PS_0, AD_{15} - AD_0, $\overline{RD}$, $\overline{UBE}$, IO/$\overline{M}$, BUFR/$\overline{W}$, $\overline{WR}$ $\overline{BUFEN}$

Timing Waveforms (cont)

Bus Request/Acknowledge Timing [Large Scale]



Register Configuration

Program Counter [PC]

The program counter is a 16-bit binary counter that contains the segment offset address of the next instruction which the EXU is to execute.

The PC increments each time the microprogram fetches an instruction from the instruction queue. A new location value is loaded into the PC each time a branch, call, return, or break instruction is executed. At this time, the contents of the PC are the same as the Prefetch Pointer (PFP).

Prefetch Pointer [PFP]

The prefetch pointer (PFP) is a 16-bit binary counter which contains a segment offset which is used to calculate a program memory address that the bus control unit (BCU) uses to prefetch the next word for the instruction queue. The contents of PFP are an offset from the PS (Program Segment) register.

The PFP is incremented each time the BCU prefetches an instruction from the program memory. A new location will be loaded into the PFP whenever a branch, call, return, or break instruction is executed. At that time the contents of the PFP will be the same as those of the PC (Program Counter).

Segment Registers [PS, SS, DS_0, and DS_1]

The memory addresses accessed by the μPD70116 are divided into 64K-byte logical segments. The starting (base) address of each segment is specified by a 16-bit segment register, and the offset from this starting address is specified by the contents of another register or by the effective address.

These are the four types of segment registers used.

Segment Register	Default Offset
PS (Program Segment)	PFP
SS (Stack Segment)	SP, effective address
DS_0 (Data Segment 0)	IX, effective address
DS_1 (Data Segment 1)	IY

General-Purpose Registers [AW, BW, CW, and DW]

There are four 16-bit general-purpose registers. Each one can be used as one 16-bit register or as two 8-bit registers by dividing them into their high and low bytes (AH, AL, BH, BL, CH, CL, DH, DL).

Each register is also used as a default register for processing specific instructions. The default assignments are:

AW: Word multiplication/division, word I/O, data conversion

AL: Byte multiplication/division, byte I/O, BCD rotation, data conversion, translation

AH: Byte multiplication/division

BW: Translation

CW: Loop control branch, repeat prefix

CL: Shift instructions, rototation instructions, BCD operations

DW: Word multiplication/division, indirect addressing I/O

Pointers [SP, BP] and Index Registers [IX, IY]

These registers serve as base pointers or index registers when accessing the memory using based addressing, indexed addressing, or based indexed addressing.

These registers can also be used for data transfer and arithmetic and logical operations in the same manner as the general-purpose registers. They cannot be used as 8-bit registers.

Also, each of these registers acts as a default register for specific operations. The default assignments are:

SP: Stack operations

IX: Block transfer (source), BCD string operations

IY: Block transfer (destination), BCD string operations

Program Status Word [PSW]

The program status word consists of the following six status and four control flags.

Status Flags

- V (Overflow)
- S (Sign)
- Z (Zero)
- AC (Auxiliary Carry)
- P (Parity)
- CY (Carry)

Control Flags

- MD (Mode)
- DIR (Direction)
- IE (Interrupt Enable)
- BRK (Break)

When the PSW is pushed on the stack, the word images of the various flags are as shown here.

PSW

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MD	1	1	1	V	DIR	IE	BRK	S	Z	0	AC	0	P	1	CY

The status flags are set and reset depending upon the result of each type of instruction executed.

Instructions are provided to set, reset, and complement the CY flag directly.

Other instructions set and reset the control flags and control the operation of the CPU.

High-Speed Execution of Instructions

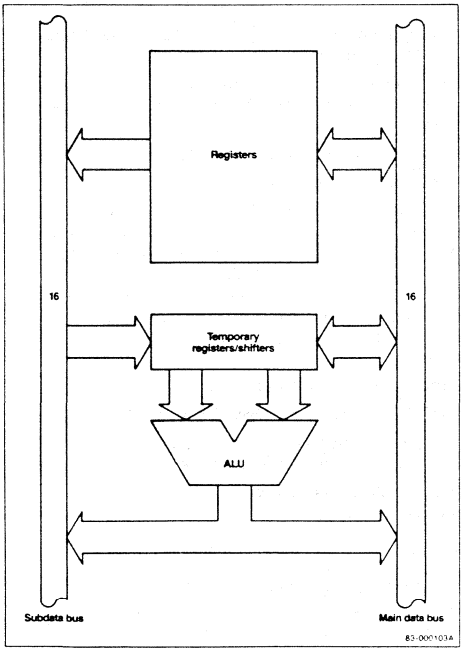
This section highlights the major architectural features that enhance the performance of the μPD70116.

- Dual data bus in EXU
- Effective address generator
- 16/32-bit temporary registers/shifters (TA, TB)
- 16-bit loop counter
- PC and PFP

Dual Data Bus Method

To reduce the number of processing steps for instruction execution, the dual data bus method has been adopted for the μPD70116 (figure 1). The two data buses (the main data bus and the subdata bus) are both 16 bits wide. For addition/subtraction and logical and comparison operations, processing time has been speeded up some 30% over single-bus systems.

Figure 1. Dual Data Buses



Example

ADD AW, BW ; AW ← AW + BW

Single Bus	Dual Bus
Step 1 TA ← AW	TA ← AW, TB ← BW
Step 2 TB ← BW	AW ← TA + TB
Step 3 AW ← TA + TB	

Effective Address Generator

This circuit (figure 2) performs high-speed processing to calculate effective addresses for accessing memory.

Calculating an effective address by the microprogramming method normally requires 5 to 12 clock cycles. This circuit requires only two clock cycles for addresses to be generated for any addressing mode. Thus, processing is several times faster.

16/32-Bit Temporary Registers/Shifters [TA, TB]

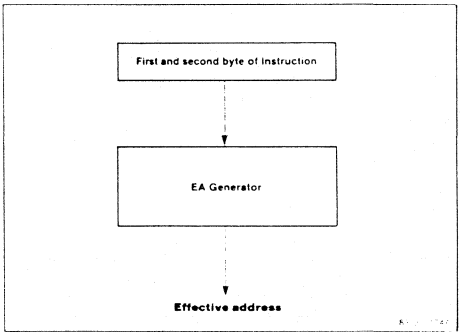
These 16-bit temporary registers/shifters (TA, TB) are provided for multiplication/division and shift/rotation instructions.

These circuits have decreased the execution time of multiplication/division instructions. In fact, these instructions can be executed about four times faster than with the microprogramming method.

TA + TB: 32-bit temporary register/shifter for multiplication and division instructions.

TB: 16-bit temporary register/shifter for shift/rotation instructions.

Figure 2. Effective Address Generator



Loop Counter [LC]

This counter is used to count the number of loops for a primitive block transfer instruction controlled by a repeat prefix instruction and the number of shifts that will be performed for a multiple bit shift/rotation instruction.

The processing performed for a multiple bit rotation of a register is shown below. The average speed is approximately doubled over the microprogram method.

Example

RORC AW, CL ; CL = 5

Microprogram method	LC method
8 + (4 x 5) = 28 clocks	7 + 5 = 12 clocks

Program Counter and Prefetch Pointer [PC and PFP]

The μPD70116 microprocessor has a program counter, (PC) which addresses the program memory location of the instruction to be executed next, and a prefetch pointer(PFP), which addresses the program memory location to be accessed next. Both functions are provided in hardware. A time saving of several clocks is realized for branch, call, return, and break instruction execution, compared with microprocessors that have only one instruction pointer.

Enhanced Instructions

In addition to the μPD8088/86 instructions, the μPD70116 has the following enhanced instructions.

Instruction	Function
PUSH imm	Pushes immediate data onto stack
PUSH R	Pushes 8 general registers onto stack
POP R	Pops 8 general registers from stack
MUL imm	Executes 16-bit multiply of register or memory contents by immediate data
SHL imm8 SHR imm8 SHRA imm8 ROL imm8 ROR imm8 ROLC imm8 RORC imm8	Shifts/rotates register or memory by immediate value
CHKIND	Checks array index against designated boundaries
INM	Moves a string from an I/O port to memory
OUTM	Moves a string from memory to an I/O port
PREPARE	Allocates an area for a stack frame and copies previous frame pointers
DISPOSE	Frees the current stack frame on a procedure exit

Enhanced Stack Operation Instructions

PUSH imm

This instruction allows immediate data to be pushed onto the stack.

PUSH R/POP R

These instructions allow the contents of the eight general registers to be pushed onto or popped from the stack with a single instruction.

Enhanced Multiplication Instructions

MUL reg16, imm16/MUL mem16, imm16

These instructions allow the contents of a register or memory location to be multiplied by immediate data.

Enhanced Shift and Rotate Instructions

SHL reg, imm8/SHR reg, imm8/SHRA reg, imm8

These instructions allow the contents of a register to be shifted by the number of bits defined by the immediate data.

ROL reg, imm8/ROR reg, imm8/ROLC reg, imm8/ RORC reg, imm8

These instructions allow the contents of a register to be rotated by the number of bits defined by the immediate data.

Check Array Boundary Instruction

CHKIND reg16, mem32

This instruction is used to verify that index values pointing to the elements of an array data structure are within the defined range. The lower limit of the array should be in memory location mem32, the upper limit in mem32 + 2. If the index value in reg16 is not between these limits when CHKIND is executed, a BRK 5 will occur. This causes a jump to the location in interrupt vector 5.

Block I/O Instructions

OUTM DW, src-block/INM dst-block, DW

These instructions are used to output or input a string to or from memory, when preceded by a repeat prefix.

Stack Frame Instructions

PREPARE imm16, imm8

This instruction is used to generate the stack frames required by block-structured languages, such as PASCAL and Ada. The stack frame consists of two areas. One area has a pointer that points to another frame which has variables that the current frame can access. The other is a local variable area for the current procedure.

DISPOSE

This instruction releases the last stack frame generated by the PREPARE instruction. It returns the stack and base pointers to the values they had before the PREPARE instruction was used to call a procedure.

Unique Instructions

In addition to the μPD8088/86 instructions and the enhanced instructions, the μPD70116 has the following unique instructions.

Instruction	Function
INS	Insert bit field
EXT	Extract bit field
ADD4S	Adds packed decimal strings
SUB4S	Subtracts one packed decimal string from another
CMP4S	Compares two packed decimal strings
ROL4	Rotates one BCD digit left through AL lower 4 bits
ROR4	Rotates one BCD digit right through AL lower 4 bits
TEST1	Tests a specified bit and sets/resets Z flag
NOT1	Inverts a specified bit
CLR1	Clears a specified bit
SET1	Sets a specified bit
REPC	Repeats next instruction until CY flag is cleared
REPNC	Repeats next instruction until CY flag is set
FPO2	Additional floating point processor call

Variable Length Bit Field Operation Instructions

This category has two instructions: INS (Insert Bit Field) and EXT (Extract Bit Field). These instructions are highly effective for computer graphics and high-level languages. They can, for example, be used for data structures such as packed arrays and record type data used in PASCAL.

INS reg8, reg8/INS reg8, imm4

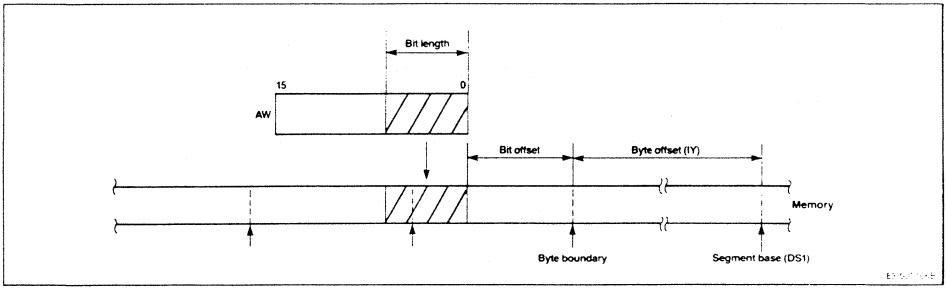
This instruction (figure 3) transfers low bits from the 16-bit AW register (the number of bits is specified by the second operand) to the memory location specified by the segment base (DS_1 register) plus the byte offset (IY register). The starting bit position within this byte is specified as an offset by the lower 4-bits of the first operand.

After each complete data transfer, the IY register and the register specified by the first operand are automatically updated to point to the next bit field.

Either immediate data or a register may specify the number of bits transferred (second operand). Because the maximum transferable bit length is 16-bits, only the lower 4-bits of the specified register (00H to 0FH) will be valid.

Bit field data may overlap the byte boundary of memory.

Figure 3. Bit Field Insertion



EXT reg8, reg8/EXT reg8, imm4

This instruction (figure 4) loads to the AW register the bit field data whose bit length is specified by the second operand of the instruction from the memory location that is specified by the DS0 segment register (segment base), the IX index register (byte offset), and the lower 4-bits of the first operand (bit offset).

After the transfer is complete, the IX register and the lower 4-bits of the first operand are automatically updated to point to the next bit field.

Either immediate data or a register may be specified for the second operand. Because the maximum transferrable bit length is 16 bits, however, only the lower 4-bits of the specified register (0H to 0FH) will be valid.

Bit field data may overlap the byte boundary of memory.

Packed BCD Operation Instructions

The instructions described here process packed BCD data either as strings (ADD4S, SUB4S, CMP4S) or byte-format operands (ROR4, ROL4). Packed BCD strings may be from 1 to 254 digits in length.

When the number of digits is even, the zero and carry flags will be set according to the result of the operation. When the number of digits is odd, the zero and carry flags may not be set correctly in this case, (CL = odd), the zero flag will not be set unless the upper 4 bits of the highest byte are all zero. The carry flag will not be set unless there is a carry out of the upper 4 bits of the highest byte. When CL is odd, the contents of the upper 4 bits of the highest byte of the result are undefined.

ADD4S

This instruction adds the packed BCD string addressed by the IX index register to the packed BCD string addressed by the IY index register, and stores the result in the string addressed by the IY register. The length of the string (number of BCD digits) is specified by the CL register, and the result of the operation will affect the overflow flag (V), the carry flag (CY), and zero flag (Z).

BCD string (IY, CL) ← BCD string (IY, CL) + BCD string (IX, CL)

SUB4S

This instruction subtracts the packed BCD string addressed by the IX index register from the packed BCD string addressed by the IY register, and stores the result in the string addressed by the IY register. The length of the string (number of BCD digits) is specified by the CL register, and the result of the operation will affect the overflow flag (V), the carry flag (CY), and zero flag (Z).

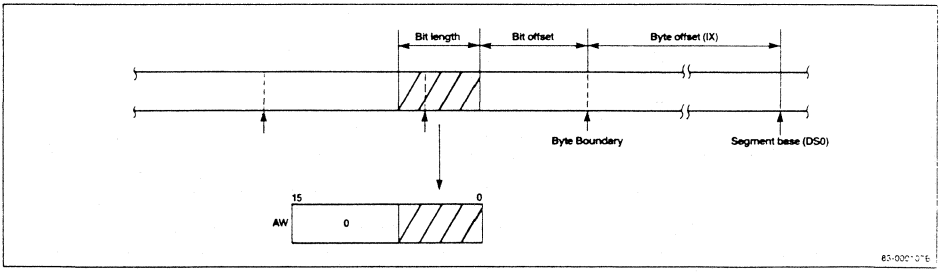
BCD string (IY, CL) ← BCD string (IY, CL) − BCD String (IX, CL)

CMP4S

This instruction performs the same operation as SUB4S except that the result is not stored and only the overflow (V), carry flags (CY) and zero flag (Z) are affected.

BCD string (IY, CL) − BCD string (IX, CL)

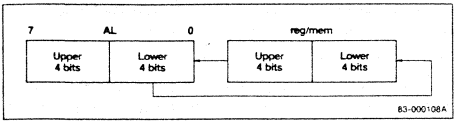
Figure 4. Bit Field Extraction



ROL4

This instruction (figure 5) treats the byte data of the register or memory operand specified by the instruction as BCD data and uses the lower 4 bits of the AL register (AL_L) to rotate that data one BCD digit to the left.

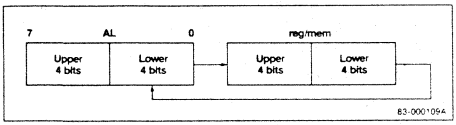
Figure 5. BCD Rotate Left (ROL4)



ROR4

This instruction (figure 6) treats the byte data of the register or memory specified by the instruction as BCD data and uses the lower 4 bits of the AL register (AL_L) to rotate that data one BCD digit to the right.

Figure 6. BCD Rotate Right (ROR4)



Bit Manipulation Instructions

TEST1

This instruction tests a specific bit in a register or memory location. If the bit is 1, the Z flag is reset to 0. If the bit is 0, the Z flag is set to 1.

NOT1

This instruction inverts a specific bit in a register or memory location.

CLR1

This instruction clears a specific bit in a register or memory location.

SET1

This instruction sets a specific bit in a register or memory location.

Repeat Prefix Instructions

REPC

This instruction causes the μPD70116 to repeat the following primitive block transfer instruction until the CY flag becomes cleared or the CW register becomes zero.

REPNC

This instruction causes the μPD70116 to repeat the following primitive block transfer instruction until the CY flag becomes set or the CW register becomes zero.

Floating Point Instruction

FPO2

This instruction is in addition to the μPD8088/86 floating point instruction, FPO1. These instructions are covered in a later section.

Mode Operation Instruction

The μPD70116 has two operating modes (figure 7). One is the native mode which executes μPD8088/86, enhanced and unique instructions. The other is the 8080 emulation mode in which the instruction set of the μPD8080AF is emulated. A mode flag (MD) is provided to select between these two modes. Native mode is selected when MD is 1 and emulation mode when MD is 0. MD is set and reset, directly and indirectly, by executing the mode manipulation instructions.

Two instructions are provided to switch operation from the native mode to the emulation mode and back.

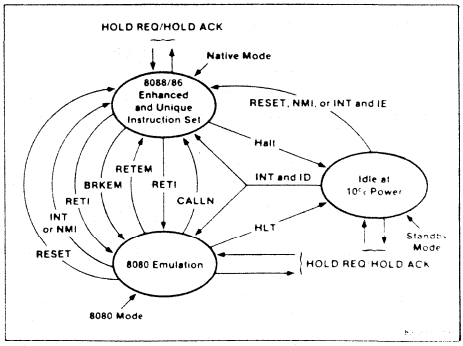
BRKEM (Break for Emulation)
RETEM (Return from Emulation)

Two instructions are used to switch from the emulation mode to the native mode and back.

CALLN (Call Native Routine)
RETI (Return from Interrupt)

The system will return from the 8080 emulation mode to the native mode when the RESET signal is present, or when an external interrupt (NMI or INT) is present.

Figure 7. V30 Modes



BRKEM imm8

This is the basic instruction used to start the 8080 emulation mode. This instruction operates exactly the same as the BRK instruction, except that BRKEM resets the mode flag (MD) to 0. PSW, PS, and PC are saved to the stack. MD is then reset and the interrupt vector specified by the operand imm8 of this command is loaded into PS and PC.

The instruction codes of the interrupt processing routine jumped to are then fetched. Then the CPU executes these codes as μPD8080AF instructions.

In 8080 emulation mode, registers and flags of the μPD8080AF are performed by the following registers and flags of the μPD70116.

	μPD8080AF	μPD70116
Registers:	A	AL
	B	CH
	C	CL
	D	DH
	E	DL
	H	BH
	L	BL
	SP	BP
	PC	PC
Flags:	C	CY
	Z	Z
	S	S
	P	P
	AC	AC

In the native mode, SP is used for the stack pointer. In the 8080 emulation mode this function is performed by BP.

This use of independent stack pointers allows independent stack areas to be secured for each mode and keeps the stack of one of the modes from being destroyed by an erroneous stack operation in the other mode.

The SP, IX, IY and AH registers and the four segment registers (PS, SS, DS_0, and DS_1) used in the native mode are not affected by operations in 8080 emulation mode.

In the 8080 emulation mode, the segment register for instructions is determined by the PS register (set automatically by the interrupt vector) and the segment register for data is the DS_0 register (set by the programmer immediately before the 8080 emulation mode is entered).

It is prohibited to nest BRKEM instructions.

RETEM [no operand]

When RETEM is executed in 8080 emulation mode (interpreted by the CPU as a μPD8080AF instruction), the CPU restores PS, PC, and PSW (as it would when returning from an interrupt processing routine), and returns to the native mode. At the same time, the contents of the mode flag (MD) which was saved to the stack by the BRKEM instruction, is restored to MD = 1. The CPU is set to the native mode.

CALLN imm8

This instruction makes it possible to call the native mode subroutines from the 8080 emulation mode. To return from subroutine to the 8080 emulation mode, the RETI instruction is used.

The processing performed when this instruction is executed in the 8080 emulation mode (it is interpreted by the CPU as μPD8080AF instruction), is similar to that performed when a BRK instruction is executed in the native mode. The imm8 operand specifies an interrupt vector type. The contents of PS, PC, and PSW are pushed on the stack and an MD flag value of 0 is saved. The mode flag is set to 1 and the interrupt vector specified by the operand is loaded into PS and PC.

RETI [no operand]

This is a general-purpose instruction used to return from interrupt routines entered by the BRK instruction or by an external interrupt in the native mode. When this instruction is executed at the end of a subroutine entered by the execution of the CALLN instruction, the operation that restores PS, PC, and PSW is exactly the same as the native mode execution. When PSW is restored, however, the 8080 emulation mode value of the mode flag (MD) is restored, the CPU is set in emulation mode, and all subsequent instructions are interpreted and executed as μPD8080AF instructions.

RETI is also used to return from an interrupt procedure initiated by an NMI or INT interrupt in the emulation mode.

Floating Point Operation Chip Instructions

FPO1 fp-op, mem

FPO2 fp-op, mem

These instructions are used for the external floating point processor. The floating point operation is passed to the floating point processor when the CPU fetches one of these instructions. From this point the CPU performs only the necessary auxiliary processing (effective address calculation, generation of physical addresses, and start-up of the memory read cycle).

The floating point processor always monitors the instructions fetched by the CPU. When it interprets one as an instruction to itself, it performs the appropriate processing. At this time, the floating point processor chip uses either the address alone or both the address and read data of the memory read cycle executed by the CPU. This difference in the data used depends on which of these instructions is executed.

Note: During the memory read cycle initiated by the CPU for FPO1 or FPO2 execution, the CPU does not accept any read data on the data bus from memory. Although the CPU generates the memory address, the data is used by the floating point processor.

Interrupt Operation

The interrupts used in the μPD70116 can be divided into two types: interrupts generated by external interrupt requests and interrupts generated by software processing. These are the classifications.

External Interrupts

(a) NMI input (nonmaskable)
(b) INT input (maskable)

Software processing

As the result of instruction execution

— When a divide error occurs during execution of the DIV or DIVU instruction
— When a memory-boundary-over error is detected by the CHKIND instruction

Conditional break instruction

— When V = 1 during execution of the BRKV instruction

Unconditional break instructions

— 1-byte break instruction: BRK3
— 2-byte break instruction: BRK imm8

Flag processing

— When stack operations are used to set the BRK flag

8080 Emulation mode instructions

— BRKEM imm8
— CALLN imm8

Starting addresses for interrupt processing routines are either determined automatically by a single location of the interrupt vector table or selected each time interrupt processing is entered.

The interrupt vector table is shown in figure 8. The table uses 1K bytes of memory addresses 000H to 3FFH and can store starting address data for a maximum of 256 vectors (4 bytes per vector).

The corresponding interrupt sources for vectors 0 to 5 are predetermined and vectors 6 to 31 are reserved. These vectors consequently cannot be used for general applications.

The BRKEM instruction and CALLN instruction (in the emulation mode) and the INT input are available for general applications for vectors 32 to 255.

A single interrupt vector is made up of 4 bytes (figure 9). The 2 bytes in the low addresses of memory are loaded into PC as the offset, and the high 2 bytes are loaded into PS as the base address. The bytes are combined in reverse order. The lower-order bytes in the vector become the most significant bytes in the PC and PS, and the higher-order bytes become the least significant bytes.

Figure 8. Interrupt Vector Table

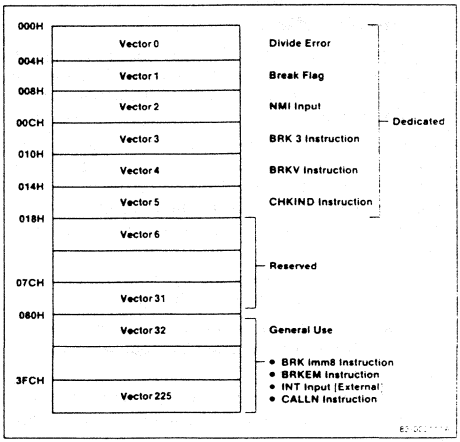
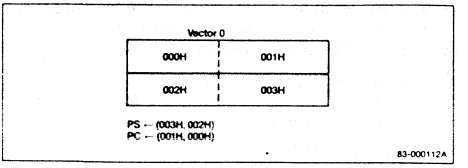


Figure 9. Interrupt Vector 0



Based on this format, the contents of each vector should be initialized at the beginning of the program.

The basic steps to jump to an interrupt processing routine are now shown.

(SP - 1, SP - 2) ← PSW
(SP - 3, SP - 4) ← PS
(SP - 5, SP - 6) ← PC
SP ← SP - 6
IE ← 0, BRK ← 0, MD ← 1
PS ← vector high bytes
PC ← vector low bytes

Standby Function

The μPD70116 has a standby mode to reduce power consumption during program wait states. This mode is set by the HALT instruction in both the native and the emulation mode.

In the standby mode, the internal clock is supplied only to those circuits related to functions required to release this mode and bus hold control functions. As a result, power consumption can be reduced to 1/10 the level of normal operation in either native or emulation mode.

The standby mode is released by inputting a RESET signal or an external interrupt (NMI, INT).

The bus hold function is effective during standby mode. The CPU returns to standby mode when the bus hold request is removed.

During standby mode, all control outputs are disabled and the addres/data bus will be at either high or low levels.

Instruction Set

Symbols

Preceding the instruction set, several tables explain symbols, abbreviations, and codes.

Clocks

In the Clocks column of the instruction set, the numbers cover these operations: instruction decoding, effective address calculation, operand fetch, and instruction execution.

Clock timings assume the instruction has been pre-fetched and is present in the six-byte instruction queue. Otherwise, add four clocks for each pair of bytes not present.

Add four clocks to the numbers given for each word transfer to an odd address.

For instructions that reference memory operands, the number on the left side of the slash (/) is for byte operands and the number on the right side is for word operands.

For conditional control transfer or branch instructions, the number on the left side of the slash is applicable if the transfer or branch takes place. The number on the right side is applicable if it does not take place.

If a range of numbers is given, the execution time depends on the operands involved.

Symbols

Symbol	Meaning
acc	Accumulator (AW or AL)
disp	Displacement (8 or 16 bits)
dmem	Direct memory address
dst	Destination operand or address
ext-disp8	16-bit displacement (sign-extension byte + 8-bit displacement)
far_label	Label within a different program segment
far_proc	Procedure within a different program segment
fp_op	Floating point instruction operation
imm	8- or 16-bit immediate operand

Symbols (cont)

Symbol	Meaning
imm3/4	3/4-bit immediate bit offset
imm8	8-bit immediate operand
imm16	16-bit immediate operand
mem	Memory field (000 to 111); 8- or 16-bit memory location
mem8	8-bit memory location
mem16	16-bit memory location
mem32	32-bit memory location
memptr16	Word containing the destination address within the current segment
memptr32	Double word containing a destination address in another segment
mod	Mode field (00 to 10)
near_label	Label within the current segment
near_proc	Procedure within the current segment
offset	Immediate offset data (16 bits)
pop_value	Number of bytes to discard from the stack
reg	Register field (000 to 111); 8- or 16-bit general-purpose register
reg8	8-bit general-purpose register
reg16	16-bit general-purpose register
regptr	16-bit register containing a destination address within the current segment
regptr16	Register containing a destination address within the current segment
seg	Immediate segment data (16 bits)
short_label	Label between −128 and +127 bytes from the end of the current instruction
sr	Segment register
src	Source operand or address
temp	Temporary register (8/16/32 bits)
tmpcy	Temporary carry flag (1 bit)
AC	Auxiliary carry flag
AH	Accumulator (high byte)
AL	Accumulator (low byte)
AND	Logical product
AW	Accumulator (16 bits)
BH	BW register (high byte)
BL	BW register (low byte)
BP	BP register
BRK	Break flag
BW	BW register (16 bits)
CH	CW register (high byte)
CL	CW register (low byte)

Symbol	Meaning
CW	CW register (16 bits)
CY	Carry flag
DH	DW register (high byte)
DIR	Direction flag
DL	DW register (low byte)
DS0	Data segment 0 register (16 bits)
DS1	Data segment 1 register (16 bits)
DW	DW register (16 bits)
IE	Interrupt enable flag
IX	Index register (source) (16 bits)
IY	Index register (destination) (16 bits)
MD	Mode flag
OR	Logical sum
P	Parity flag
PC	Program counter (16 bits)
PS	Program segment register (16 bits)
PSW	Program status word (16 bits)
R	Register set
S	Sign extend operand field S = 0 No sign extension S = 1 Sign extend immediate byte operand
S	Sign flag
SP	Stack pointer (16 bits)
SS	Stack segment register (16 bits)
V	Overflow flag
W	Word/byte field (0 to 1)
X, XXX, YYY, ZZZ	Data to identify the instruction code of the external floating point arithmetic chip
XOR	Exclusive logical sum
XXH	Two-digit hexadecimal value
XXXXH	Four-digit hexadecimal value
Z	Zero flag
( )	Values in parentheses are memory contents
←	Transfer direction
+	Addition
−	Subtraction
×	Multiplication
÷	Division
%	Modulo

Flag Operations

Symbol	Meaning
(blank)	No change
0	Cleared to 0
1	Set to 1
x	Set or cleared according to result
u	Undefined
R	Restored to previous state

Memory Addressing Modes

mem	mod = 00	mod = 01	mod = 10
000	BW + IX	BW + IX + disp8	BW + IX + disp16
001	BW + IY	BW + IY + disp8	BW + IY + disp16
010	BP + IX	BP + IX + disp8	BP + IX + disp16
011	BP + IY	BP + IY + disp8	BP + IY + disp16
100	IX	IX + disp8	IX + disp16
101	IY	IY + disp8	IY + disp16
110	Direct	BP + disp8	BP + disp16
111	BW	BW + disp8	BW + disp16

Register Selection (mod = 11)

reg	W = 0	W = 1
000	AL	AW
001	CL	CW
010	DL	DW
011	BL	BW
100	AH	SP
101	CH	BP
110	DH	IX
111	BH	IY

Segment Register Selection

sr	Segment Register
00	DS1
01	PS
10	SS
11	DS0

Instruction Set

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Data Transfer Instructions																									
MOV	reg, reg	1	0	0	0	1	0	1	W	1	1		reg			reg		2	2						
	mem, reg	1	0	0	0	1	0	0	W	mod			reg			mem		9	2-4						
	reg, mem	1	0	0	0	1	0	1	W	mod			reg			mem		11	2-4						
	mem, imm	1	1	0	0	0	1	1	W	mod			reg			mem		11	3-6						
	reg, imm	1	0	1	1	W		reg										4	2-3						
	acc, dmem	1	0	1	0	0	0	0	W									10	3						
	dmem, acc	1	0	1	0	0	0	1	W									9	3						
	sr, reg16	1	0	0	0	1	1	1	0	1	1	0	sr			reg		2	2						
	sr, mem16	1	0	0	0	1	1	1	0	mod		0	sr			mem		11	2-4						
	reg16, sr	1	0	0	0	1	1	0	0	1	1	0	sr			reg		2	2						
	mem16, sr	1	0	0	0	1	1	0	0	mod		0	sr			mem		10	2-4						
	DS0, reg16, mem32	1	1	0	0	0	1	0	1	mod			reg			mem		18	2-4						
	DS1, reg16, mem32	1	1	0	0	0	1	0	0	mod			reg			mem		18	2-4						
	AH, PSW	1	0	0	1	1	1	1	1									2	1						
	PSW, AH	1	0	0	1	1	1	1	0									3	1	x	x		x	x	x
LDEA	reg16, mem16	1	0	0	0	1	1	0	1	mod			reg			mem		4	2-4						
TRANS	src_table	1	1	0	1	0	1	1	1									9	1						
XCH	reg, reg	1	0	0	0	0	1	1	W	1	1		reg			reg		3	2						
	mem, reg	1	0	0	0	0	1	1	W	mod			reg			mem		16	2-4						
	AW, reg16	1	0	0	1	0		reg										3	1						

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Repeat Prefixes																									
REPC		0	1	1	0	0	1	0	1									2	1						
REPNC		0	1	1	0	0	1	0	0									2	1						
REP REPE REPZ		1	1	1	1	0	0	1	1									2	1						
REPNE REPNZ		1	1	1	1	0	0	1	0									2	1						
Block Transfer Instructions																									
MOVBK	dst, src	1	0	1	0	0	1	0	W									11 + 8n	1						
CMPBK	dst, src	1	0	1	0	0	1	1	W									7 + 14n	1	x	x	x	x	x	x
CMPM	dst	1	0	1	0	1	1	1	W									7 + 10n	1	x	x	x	x	x	x
LDM	src	1	0	1	0	1	1	0	W									7 + 9n	1						
STM	dst	1	0	1	0	1	0	1	W									7 + 4n	1						
										n = number of transfers															
I/O Instructions																									
IN	acc, imm8	1	1	1	0	0	1	0	W									9	2						
	acc, DW	1	1	1	0	1	1	0	W									8	1						
OUT	imm8, acc	1	1	1	0	0	1	1	W									8	2						
	DW, acc	1	1	1	0	1	1	1	W									8	1						
INM	dst, DW	0	1	1	0	1	1	0	W									9 + 8n	1						
OUTM	DW, src	0	1	1	0	1	1	1	W									9 + 8n	1						
										n = number of transfers															
BCD Instructions																									
ADJBA		0	0	1	1	0	1	1	1									3	1	x	x	u	u	u	u
ADJ4A		0	0	1	0	0	1	1	1									3	1	x	x	u	x	x	x
ADJBS		0	0	1	1	1	1	1	1									7	1	x	x	u	u	u	u
ADJ4S		0	0	1	0	1	1	1	1									7	1	x	x	u	x	x	x
ADD4S	dst, src	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	0	7 + 19n	2	u	x	u	u	u	x
SUB4S	dst, src	0	0	0	0	1	1	1	1	0	0	1	0	0	0	1	0	7 + 19n	2	u	x	u	u	u	x
CMP4S	dst, src	0	0	0	0	1	1	1	1	0	0	1	0	0	1	1	0	7 + 19n	2	u	x	u	u	u	x
ROL4	reg8	0 1	0 1	0 0	0 0	1 0	1 reg	1	1	0	0	1	0	1	0	0	0	25	3						
	mem8	0 mod	0	0	0	1 0	1 0	1	1 mem	0	0	1	0	1	0	0	0	28	3-5						
ROR4	reg8	0 1	0 1	0 0	0 0	1 0	1 reg	1	1	0	0	1	0	1	0	1	0	29	3						
	mem8	0 mod	0	0	0	1 0	1 0	1	1 mem	0	0	1	0	1	0	1	0	33	3-5						
										n = number of BCD digits divided by 2															

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Data Type Conversion Instructions																									
CVTBD		1	1	0	1	0	1	0	0	0	0	0	0	1	0	1	0	15	2	u	u	u	x	x	x
CVTDB		1	1	0	1	0	1	0	1	0	0	0	0	1	0	1	0	7	2	u	u	u	x	x	x
CVTBW		1	0	0	1	1	0	0	0									2	1						
CVTWL		1	0	0	1	1	0	0	1									4-5	1						
Arithmetic Instructions																									
ADD	reg, reg	0	0	0	0	0	0	1	W	1	1	reg				reg		2	2	x	x	x	x	x	x
	mem, reg	0	0	0	0	0	0	0	W	mod		reg				mem		16	2-4	x	x	x	x	x	x
	reg, mem	0	0	0	0	0	0	1	W	mod		reg				mem		11	2-4	x	x	x	x	x	x
	reg, imm	1	0	0	0	0	0	S	W	1	1	0	0	0	reg			4	3-4	x	x	x	x	x	x
	mem, imm	1	0	0	0	0	0	S	W	mod		0	0	0	mem			18	3-6	x	x	x	x	x	x
	acc, imm	0	0	0	0	0	1	0	W									4	2-3	x	x	x	x	x	x
ADDC	reg, reg	0	0	0	1	0	0	1	W	1	1	reg				reg		2	2	x	x	x	x	x	x
	mem, reg	0	0	0	1	0	0	0	W	mod		reg				mem		16	2-4	x	x	x	x	x	x
	reg, mem	0	0	0	1	0	0	1	W	mod		reg				mem		11	2-4	x	x	x	x	x	x
	reg, imm	1	0	0	0	0	0	S	W	1	1	0	1	0	reg			4	3-4	x	x	x	x	x	x
	mem, imm	1	0	0	0	0	0	S	W	mod		0	1	0	mem			18	3-6	x	x	x	x	x	x
	acc, imm	0	0	0	1	0	1	0	W									4	2-3	x	x	x	x	x	x
SUB	reg, reg	0	0	1	0	1	0	1	W	1	1	reg				reg		2	2	x	x	x	x	x	x
	mem, reg	0	0	1	0	1	0	0	W	mod		reg				mem		16	2-4	x	x	x	x	x	x
	reg, mem	0	0	1	0	1	0	1	W	mod		reg				mem		11	2-4	x	x	x	x	x	x
	reg, imm	1	0	0	0	0	0	S	W	1	1	1	0	1	reg			4	3-4	x	x	x	x	x	x
	mem, imm	1	0	0	0	0	0	S	W	mod		1	0	1	mem			18	3-6	x	x	x	x	x	x
	acc, imm	0	0	1	0	1	1	0	W									4	2-3	x	x	x	x	x	x
SUBC	reg, reg	0	0	0	1	1	0	1	W	1	1	reg				reg		2	2	x	x	x	x	x	x
	mem, reg	0	0	0	1	1	0	0	W	mod		reg				mem		16	2-4	x	x	x	x	x	x
	reg, mem	0	0	0	1	1	0	1	W	mod		reg				mem		11	2-4	x	x	x	x	x	x
	reg, imm	1	0	0	0	0	0	S	W	1	1	0	1	1	reg			4	3-4	x	x	x	x	x	x
	mem, imm	1	0	0	0	0	0	S	W	mod		0	1	1	mem			18	3-6	x	x	x	x	x	x
	acc, imm	0	0	0	1	1	1	0	W									4	2-3	x	x	x	x	x	x
INC	reg8	1	1	1	1	1	1	1	0	1	1	0	0	0	reg			2	2	x		x	x	x	x
	mem	1	1	1	1	1	1	1	W	mod		0	0	0	mem			16	2-4	x		x	x	x	x
	reg16	0	1	0	0	0	reg											2	1	x		x	x	x	x
DEC	reg8	1	1	1	1	1	1	1	0	1	1	0	0	1	reg			2	2	x		x	x	x	x
	mem	1	1	1	1	1	1	1	W	mod		0	0	1	mem			16	2-4	x		x	x	x	x
	reg16	0	1	0	0	1	reg											2	1	x		x	x	x	x
MULU	reg	1	1	1	1	0	1	1	W	1	1	1	0	0	reg			21-30	2	u	x	x	u	u	u
	mem	1	1	1	1	0	1	1	W	mod		1	0	0	mem			27-36	2-4	u	x	x	u	u	u

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Arithmetic Instructions (cont)																									
MUL	reg	1	1	1	1	0	1	1	W	1	1	1	0	1		reg		33-47	2	U	X	X	U	U	U
	mem	1	1	1	1	0	1	1	W	mod			1	0	1	mem		39-53	2-4	U	X	X	U	U	U
	reg16,reg16,imm8	0	1	1	0	1	0	1	1	1	1		reg			reg		28-34	3	U	X	X	U	U	U
	reg16,mem16,imm8	0	1	1	0	1	0	1	1	mod			reg			mem		34-40	3-5	U	X	X	U	U	U
	reg16,reg16,imm16	0	1	1	0	1	0	0	1	1	1		reg			reg		36-42	4	U	X	X	U	U	U
	reg16,mem16,imm16	0	1	1	0	1	0	0	1	mod			reg			mem		46-48	4-6	U	X	X	U	U	U
DIVU	reg	1	1	1	1	0	1	1	W	1	1	1	1	0		reg		19-25	2	U	U	U	U	U	U
	mem	1	1	1	1	0	1	1	W	mod			1	1	0	mem		25-31	2-4	U	U	U	U	U	U
DIV	reg	1	1	1	1	0	1	1	W	1	1	1	1	1		reg		29-43	2	U	U	U	U	U	U
	mem	1	1	1	1	0	1	1	W	mod			1	1	1	mem		35-49	2-4	U	U	U	U	U	U
Comparison Instructions																									
CMP	reg, reg	0	0	1	1	1	0	1	W	1	1		reg			reg		2	2	X	X	X	X	X	X
	mem, reg	0	0	1	1	1	0	0	W	mod			reg			mem		11	2-4	X	X	X	X	X	X
	reg, mem	0	0	1	1	1	0	1	W	mod			reg			mem		11	2-4	X	X	X	X	X	X
	reg, imm	1	0	0	0	0	0	S	W	1	1	1	1	1		reg		4	3-4	X	X	X	X	X	X
	mem, imm	1	0	0	0	0	0	S	W	mod			1	1	1	mem		13	3-6	X	X	X	X	X	X
	acc, imm	0	0	1	1	1	1	0	W									4	2-3	X	X	X	X	X	X
Logical Instructions																									
NOT	reg	1	1	1	1	0	1	1	W	1	1	0	1	0		reg		2	2						
	mem	1	1	1	1	0	1	1	W	mod			0	1	0	mem		16	2-4						
NEG	reg	1	1	1	1	0	1	1	W	1	1	0	1	1		reg		2	2	X	X	X	X	X	X
	mem	1	1	1	1	0	1	1	W	mod			0	1	1	mem		16	2-4	X	X	X	X	X	X
TEST	reg, reg	1	0	0	0	0	1	0	W	1	1		reg			reg		2	2	U	0	0	X	X	X
	mem, reg	1	0	0	0	0	1	0	W	mod			reg			mem		10	2-4	U	0	0	X	X	X
	reg, imm	1	1	1	1	0	1	1	W	1	1	0	0	0		reg		4	3-4	U	0	0	X	X	X
	mem, imm	1	1	1	1	0	1	1	W	mod			0	0	0	mem		11	3-6	U	0	0	X	X	X
	acc, imm	1	0	1	0	1	0	0	W									4	2-3	U	0	0	X	X	X
AND	reg, reg	0	0	1	0	0	0	1	W	1	1		reg			reg		2	2	U	0	0	X	X	X
	mem, reg	0	0	1	0	0	0	0	W	mod			reg			mem		16	2-4	U	0	0	X	X	X
	reg, mem	0	0	1	0	0	0	1	W	mod			reg			mem		11	2-4	U	0	0	X	X	X
	reg, imm	1	0	0	0	0	0	0	W	1	1	1	0	0		reg		4	3-4	U	0	0	X	X	X
	mem, imm	1	0	0	0	0	0	0	W	mod			1	0	0	mem		18	3-6	U	0	0	X	X	X
	acc, imm	0	0	1	0	0	1	0	W									4	2-3	U	0	0	X	X	X
OR	reg, reg	0	0	0	0	1	0	1	W	1	1		reg			reg		2	2	U	0	0	X	X	X
	mem, reg	0	0	0	0	1	0	0	W	mod			reg			mem		16	2-4	U	0	0	X	X	X
	reg, mem	0	0	0	0	1	0	1	W	mod			reg			mem		11	2-4	U	0	0	X	X	X
	reg, imm	1	0	0	0	0	0	0	W	1	1	0	0	1		reg		4	3-4	U	0	0	X	X	X
	mem, imm	1	0	0	0	0	0	0	W	mod			0	0	1	mem		18	3-6	U	0	0	X	X	X
	acc, imm	0	0	1	0	0	1	0	W									4	2-3	U	0	0	X	X	X

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Logical Instructions (cont)																									
XOR	reg, reg	0	0	1	1	0	0	1	W	1	1		reg			reg		2	2	u	0	0	x	x	x
	mem, reg	0	0	1	1	0	0	0	W	mod			reg			mem		16	2-4	u	0	0	x	x	x
	reg, mem	0	0	1	1	0	0	1	W	mod			reg			mem		11	2-4	u	0	0	x	x	x
	reg, imm	1	0	0	0	0	0	0	W	1	1	1	1	0		reg		4	3-4	u	0	0	x	x	x
	mem, imm	1	0	0	0	0	0	0	W	mod			1	1	0	mem		18	3-6	u	0	0	x	x	x
	acc, imm	0	0	1	0	0	1	0	W									4	2-3	u	0	0	x	x	x
Bit Manipulation Instructions																									
INS	reg8, reg8	0	0	0	0	1	1	1	1	0	0	1	1	0	0	0	1	31-117	3						
		1	1		reg				reg																
	reg8, imm8	0	0	0	0	1	1	1	1	0	0	1	1	1	0	0	1	31-117	4						
		1	1	0	0	0		reg																	
EXT	reg8, reg8	0	0	0	0	1	1	1	1	0	0	1	1	0	0	1	1	26-55	3						
		1	1		reg				reg																
	reg8, imm8	0	0	0	0	1	1	1	1	0	0	1	1	1	0	1	1	26-55	4						
		1	1	0	0	0		reg																	
TEST1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	0	W	3	3	u	0	0	u	u	x
		1	1	0	0	0		reg																	
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	0	W	12	3-5	u	0	0	u	u	x
		mod		0	0	0		mem																	
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	0	W	4	4	u	0	0	u	u	x
		1	1	0	0	0		reg																	
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	0	W	13	4-6	u	0	0	u	u	x
		mod		0	0	0		mem																	
SET1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	0	W	4	3						
		1	1	0	0	0		reg																	
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	0	W	13	3-5						
		mod		0	0	0		mem																	
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	0	W	5	4						
		1	1	0	0	0		reg																	
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	0	W	14	4-6						
		mod		0	0	0		mem																	
	CY	1	1	1	1	1	0	0	1									2	1		1				
	DIR	1	1	1	1	1	1	0	1									2	1						
CLR1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	1	W	5	3						
		1	1	0	0	0		reg																	
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	1	W	14	3-5						
		mod		0	0	0		mem																	
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1	W	6	4						
		1	1	0	0	0		reg																	
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1	W	15	4-6						
		mod		0	0	0		mem																	
	CY	1	1	1	1	1	0	0	0									2	1		0				
	DIR	1	1	1	1	1	1	0	0									2	1						

Instruction Set (cont)

Mnemonic	Operands	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Bit Manipulation Instructions (cont)																									
NOT1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	1	W	4	3						
		1	1	0	0	0	reg																		
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	1	W	18	3-5						
		mod		0	0	0	mem																		
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	1	W	5	4						
		1	1	0	0	0	reg																		
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	1	W	19	4-6						
		mod		0	0	0	mem																		
	CY	1	1	1	1	0	1	0	1									2	1		x				
Shift/Rotate Instructions																									
SHL	reg, 1	1	1	0	1	0	0	0	W	1	1	1	0	0	reg			2	2	u	x	x	x	x	x
	mem, 1	1	1	0	1	0	0	0	W	mod			1	0	0	mem		16	2-4	u	x	x	x	x	x
	reg, CL	1	1	0	1	0	0	1	W	1	1	1	0	0	reg			7 + n	2	u	x	u	x	x	x
	mem, CL	1	1	0	1	0	0	1	W	mod			1	0	0	mem		19 + n	2-4	u	x	u	x	x	x
	reg, imm8	1	1	0	0	0	0	0	W	1	1	1	0	0	reg			7 + n	3	u	x	u	x	x	x
	mem, imm8	1	1	0	0	0	0	0	W	mod			1	0	0	mem		19 + n	3-5	u	x	u	x	x	x
SHR	reg, 1	1	1	0	1	0	0	0	W	1	1	1	0	1	reg			2	2	u	x	x	x	x	x
	mem, 1	1	1	0	1	0	0	0	W	mod			1	0	1	mem		16	2-4	u	x	x	x	x	x
	reg, CL	1	1	0	1	0	0	1	W	1	1	1	0	1	reg			7 + n	2	u	x	u	x	x	x
	mem, CL	1	1	0	1	0	0	1	W	mod			1	0	1	mem		19 + n	2-4	u	x	u	x	x	x
	reg, imm8	1	1	0	0	0	0	0	W	1	1	1	0	1	reg			7 + n	3	u	x	u	x	x	x
	mem, imm8	1	1	0	0	0	0	0	W	mod			1	0	1	mem		19 + n	3-5	u	x	u	x	x	x
										n = number of shifts															
SHRA	reg, 1	1	1	0	1	0	0	0	W	1	1	1	1	1	reg			2	2	u	x	0	x	x	x
	mem, 1	1	1	0	1	0	0	0	W	mod			1	1	1	mem		16	2-4	u	x	0	x	x	x
	reg, CL	1	1	0	1	0	0	1	W	1	1	1	1	1	reg			7 + n	2	u	x	u	x	x	x
	mem, CL	1	1	0	1	0	0	1	W	mod			1	1	1	mem		19 + n	2-4	u	x	u	x	x	x
	reg, imm8	1	1	0	0	0	0	0	W	1	1	1	1	1	reg			7 + n	3	u	x	u	x	x	x
	mem, imm8	1	1	0	0	0	0	0	W	mod			1	1	1	mem		19 + n	3-5	u	x	u	x	x	x
ROL	reg, 1	1	1	0	1	0	0	0	W	1	1	0	0	0	reg			2	2		x	x			
	mem, 1	1	1	0	1	0	0	0	W	mod			0	0	0	mem		16	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	0	0	reg			7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod			0	0	0	mem		19 + n	2-4		x	u			
	reg, imm	1	1	0	0	0	0	0	W	1	1	0	0	0	reg			7 + n	3		x	u			
	mem, imm	1	1	0	0	0	0	0	W	mod			0	0	0	mem		19 + n	3-5		x	u			
ROR	reg, 1	1	1	0	1	0	0	0	W	1	1	0	0	1	reg			2	2		x	u			
	mem, 1	1	1	0	1	0	0	0	W	mod			0	0	1	mem		16	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	0	1	reg			7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod			0	0	1	mem		19 + n	2-4		x	u			
	reg, imm8	1	1	0	0	0	0	0	W	1	1	0	0	1	reg			7 + n	3		x	u			
	mem, imm8	1	1	0	0	0	0	0	W	mod			0	0	1	mem		19 + n	3-5		x	u			

Instruction Set (cont)

Mnemonic	Operands	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Shift/Rotate Instructions (cont)																									
ROLC	reg, 1	1	1	0	1	0	0	0	W	1	1	0	1	0	reg			2	2		x	x			
	mem, 1	1	1	0	1	0	0	0	W	mod			0	1	0	mem		16	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	1	0	reg			7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod			0	1	0	mem		19 + n	2-4		x	u			
	reg, imm8	1	1	0	0	0	0	0	W	1	1	0	1	0	reg			7 + n	3		x	u			
	mem, imm8	1	1	0	0	0	0	0	W	mod			0	1	0	mem		19 + n	3-5		x	u			
RORC	reg, 1	1	1	0	1	0	0	0	W	1	1	0	1	1	reg			2	2		x	x			
	mem, 1	1	1	0	1	0	0	0	W	mod			0	1	1	mem		16	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	1	1	reg			7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod			0	1	1	mem		19 + n	2-4		x	u			
	reg, imm8	1	1	0	0	0	0	0	W	1	1	0	1	1	reg			7 + n	3		x	u			
	mem, imm8	1	1	0	0	0	0	0	W	mod			0	1	1	mem		19 + n	3-5		x	u			
										n = number of shifts															
Stack Manipulation Instructions																									
PUSH	mem16	1	1	1	1	1	1	1	1	mod			1	1	0	mem		18	2-4						
	reg16	0	1	0	1	0	reg											8	1						
	sr	0	0	0	sr		1	1	0									8	1						
	PSW	1	0	0	1	1	1	0	0									8	1						
	R	0	1	1	0	0	0	0	0									35	1						
	imm	0	1	1	0	1	0	S	0									7-8	2-3						
POP	mem16	1	0	0	0	1	1	1	1	mod			0	0	0	mem		17	2-4						
	reg16	0	1	0	1	1	reg											8	1						
	sr	0	0	0	sr		1	1	1									8	1						
	PSW	1	0	0	1	1	1	0	1									8	1	R	R	R	R	R	R
	R	0	1	1	0	0	0	0	1									43	1						
PREPARE	imm16, imm8	1	1	0	0	1	0	0	0	*imm8 = 0 : 12 imm8 > 1 : 19 + 8 (imm8 − 1)								*	4						
DISPOSE		1	1	0	0	1	0	0	1									6	1						
Control Transfer Instructions																									
CALL	near_proc	1	1	1	0	1	0	0	0									16	3						
	regptr	1	1	1	1	1	1	1	1	1	1	0	1	0	reg			14	1						
	memptr16	1	1	1	1	1	1	1	1	mod			0	1	0	mem		23	2-4						
	far_proc	1	0	0	1	1	0	1	0									21	5						
	memptr32	1	1	1	1	1	1	1	1	mod			0	1	1	mem		31	2-4						
RET		1	1	0	0	0	0	1	1									15	1						
	pop_value	1	1	0	0	0	0	1	0									20	3						
		1	1	0	0	1	0	1	1									21	1						
	pop_value	1	1	0	0	1	0	1	0									24	3						

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Control Transfer Instructions (cont)																									
BR	near_label	1	1	1	0	1	0	0	1									13	3						
	short_label	1	1	1	0	1	0	0	1									12	2						
	reg	1	1	1	1	1	1	1	1	1	1	1	0	0	reg			11	2						
	memptr16	1	1	1	1	1	1	1	1	mod		1	0	0	mem			20	2-4						
	far_label	1	1	1	0	1	0	1	0									15	5						
	memptr32	1	1	1	1	1	1	1	1	mod		1	0	1	mem			27	2-4						
BV	near_label	0	1	1	1	0	0	0	0									14/4	2						
BNV	near_label	0	1	1	1	0	0	0	1									14/4	2						
BC, BL	near_label	0	1	1	1	0	0	1	0									14/4	2						
BNC, BNL	near_label	0	1	1	1	0	0	1	1									14/4	2						
BE, BZ	near_label	0	1	1	1	0	1	0	0									14/4	2						
BNE, BNZ	near_label	0	1	1	1	0	1	0	1									14/4	2						
BNH	near_label	0	1	1	1	0	1	1	0									14/4	2						
BH	near_label	0	1	1	1	0	1	1	1									14/4	2						
BN	near_label	0	1	1	1	1	0	0	0									14/4	2						
BP	near_label	0	1	1	1	1	0	0	1									14/4	2						
BPE	near_label	0	1	1	1	1	0	1	0									14/4	2						
BPO	near_label	0	1	1	1	1	0	1	1									14/4	2						
BLT	near_label	0	1	1	1	1	1	0	0									14/4	2						
BGE	near_label	0	1	1	1	1	1	0	1									14/4	2						
BLE	near_label	0	1	1	1	1	1	1	0									14/4	2						
BGT	near_label	0	1	1	1	1	1	1	1									14/4	2						
DBNZNE	near_label	1	1	1	0	0	0	0	0									14/5	2						
DBNZE	near_label	1	1	1	0	0	0	0	1									14/5	2						
DBNZ	near_label	1	1	1	0	0	0	1	0									13/5	2						
BCWZ	near_label	1	1	1	0	0	0	1	1									13/5	2						
Interrupt Instructions																									
BRK	3	1	1	0	0	1	1	0	0									38	1						
	imm8	1	1	0	0	1	1	0	1									38	2						
BRKV	imm8	1	1	0	0	1	1	1	1									40/3	1						
RETI		1	1	0	0	1	1	1	0									27	1	R	R	R	R	R	R
CHKIND	reg16, mem32	0	1	1	0	0	0	1	0	mod			reg			mem		53-56/18	2-4						
BRKEM	imm8	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	38	3						

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
CPU Control Instructions																									
HALT		1	1	1	1	0	1	0	0									2	1						
BUSLOCK		1	1	1	1	0	0	0	0									2	1						
FPO1	fp_op	1	1	0	1	1	X	X	X	1	1	Y	Y	Y	Z	Z	Z	2	2						
	fp_op, mem	1	1	0	1	1	X	X	X	mod		Y	Y	Y	mem			11	2-4						
FPO2	fp_op	0	1	1	0	0	1	1	X	1	1	Y	Y	Y	Z	Z	Z	2	2						
	fp_op, mem	0	1	1	0	0	1	1	X	mod		Y	Y	Y	mem			11	2-4						
POLL		1	0	0	1	1	0	1	1	n = number of times $\overline{\text{POLL}}$ pin is sampled								2 + 5n	1						
NOP		1	0	0	1	0	0	0	0									3	1						
DI		1	1	1	1	1	0	1	0									2	1						
EI		1	1	1	1	1	0	1	1									2	1						
8080 Instruction Set Enhancements																									
RETEM		1	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	27	2	R	R	R	R	R	R
CALLN	imm8	1	1	1	0	1	1	0	1	1	1	1	0	1	1	0	1	38	3						

μPD70208 (V40™) 8/16-BIT, HIGH-INTEGRATION CMOS MICROPROCESSOR

Description

The μPD70208 (V40™) is a high-performance, low-power 16-bit microprocessor integrating a number of commonly used peripherals to dramatically reduce the size of microprocessor systems. The CMOS construction makes the μPD70208 ideal for the design of portable computers, instrumentation, and process control equipment.

The μPD70208 contains a powerful instruction set that is compatible with the μPD70108/μPD70116 (V20™/V30™) and μPD8086/μPD8088 instruction sets. Instruction set support includes a wide range of arithmetic, logical, and control operations as well as bit manipulation, BCD arithmetic, and high-speed block transfer instructions. The μPD70208 can also execute the entire μPD8080AF instruction set using the 8080 emulation mode. Also available is the μPD70216 (V50™), identical to the μPD70208 but with a 16-bit external data bus.

Features

- ☐ V20/V30 instruction set compatible
- ☐ Minimum instruction execution time: 250 ns (at 8 MHz)
- ☐ Direct addressing of 1M bytes of memory
- ☐ Powerful set of addressing modes
- ☐ 14 16-bit registers
- ☐ On-chip peripherals including
  - — Clock generator
  - — Bus interface
  - — Bus arbitration
  - — Programmable wait state generator
  - — DRAM refresh control
  - — Three 16-bit timer/counters
  - — Asynchronous serial I/O control
  - — Eight-input interrupt control
  - — Four-channel DMA control
- ☐ Hardware effective address calculation logic
- ☐ Maskable and nonmaskable interrupts
- ☐ μPD72191 Floating Point Processor interface
- ☐ IEEE 796 compatible bus interface
- ☐ Low-power standby mode
- ☐ Low-power CMOS technology

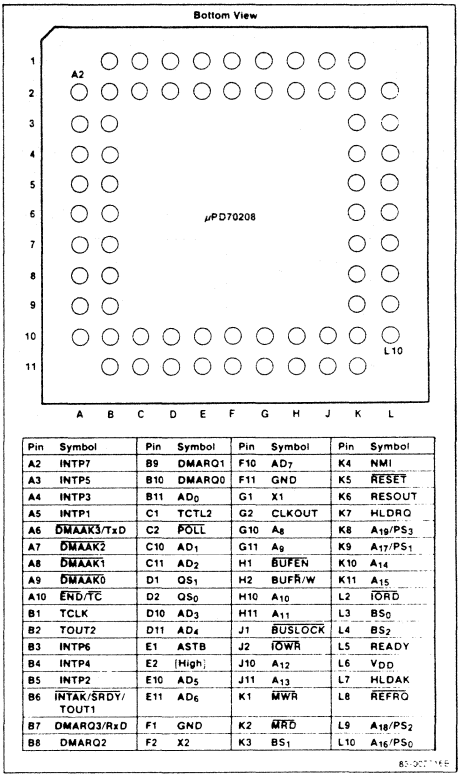
V20, V30, V40, and V50 are trademarks of NEC Corporation.

Ordering Information

Part Number	Package	Maximum Frequency
μPD70208R-8	68-pin PGA	8 MHz
μPD70208L-8	68-pin PLCC	8 MHz
μPD70208G-8	80-pin plastic miniflat	8 MHz

Pin Configurations

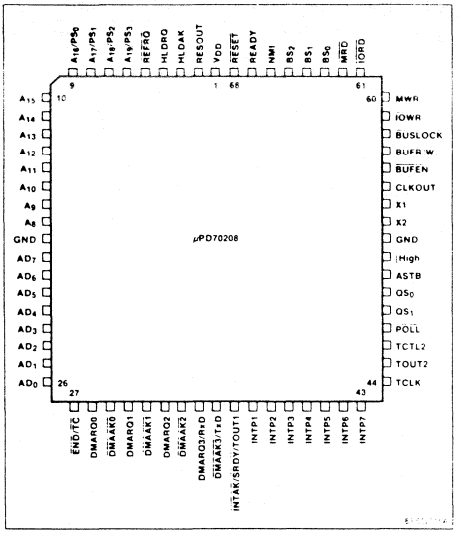
68-Pin PGA



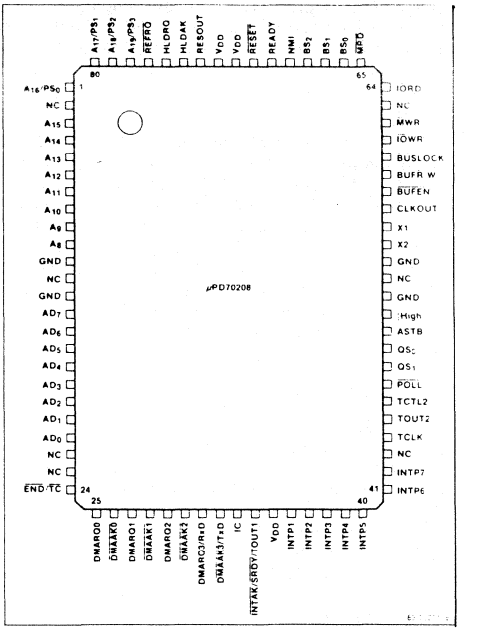
Pin	Symbol	Pin	Symbol	Pin	Symbol	Pin	Symbol
A2	INTP7	B9	DMARQ1	F10	AD_7	K4	NMI
A3	INTP5	B10	DMARQ0	F11	GND	K5	$\overline{RESET}$
A4	INTP3	B11	AD_0	G1	X1	K6	RESOUT
A5	INTP1	C1	TCTL2	G2	CLKOUT	K7	HLDRQ
A6	$\overline{DMAAK3}$/TxD	C2	$\overline{POLL}$	G10	A_8	K8	A_{19}/PS_3
A7	$\overline{DMAAK2}$	C10	AD_1	G11	A_9	K9	A_{17}/PS_1
A8	$\overline{DMAAK1}$	C11	AD_2	H1	$\overline{BUFEN}$	K10	A_{14}
A9	$\overline{DMAAK0}$	D1	QS_1	H2	BUFR/W	K11	A_{15}
A10	$\overline{END}$/$\overline{TC}$	D2	QS_0	H10	A_{10}	L2	$\overline{IORD}$
B1	TCLK	D10	AD_3	H11	A_{11}	L3	BS_0
B2	TOUT2	D11	AD_4	J1	$\overline{BUSLOCK}$	L4	BS_2
B3	INTP6	E1	ASTB	J2	$\overline{IOWR}$	L5	READY
B4	INTP4	E2	(High)	J10	A_{12}	L6	V_{DD}
B5	INTP2	E10	AD_5	J11	A_{13}	L7	HLDAK
B6	$\overline{INTAK}$/$\overline{SRDY}$/TOUT1	E11	AD_6	K1	$\overline{MWR}$	L8	$\overline{REFRQ}$
B7	DMARQ3/RxD	F1	GND	K2	$\overline{MRD}$	L9	A_{18}/PS_2
B8	DMARQ2	F2	X2	K3	BS_1	L10	A_{16}/PS_0

Pin Configurations (cont)

68-Pin PLCC



80-Pin Plastic Miniflat



Pin Identification

Symbol	Function
A_{19}-A_{16}/PS_3-PS_0	Multiplexed address/processor status outputs
A_{15}-A_8	Address bus outputs
AD_7-AD_0	Multiplexed address/data bus
ASTB	Address strobe output
$\overline{BUFEN}$	Data bus transceiver enable output
$BUFR/\overline{W}$	Data bus transceiver direction output
$\overline{BUSLOCK}$	Buslock output
BS_2-BS_0	Bus status outputs
CLKOUT	System clock output
$\overline{DMAAK0}$	DMA channel 0 acknowledge output
$\overline{DMAAK1}$	DMA channel 1 acknowledge output
$\overline{DMAAK2}$	DMA channel 2 acknowledge output
$\overline{DMAAK3}$/TxD	DMA channel 3 acknowledge output/Serial transmit data output
DMARQ0	DMA channel 0 request input
DMARQ1	DMA channel 1 request input
DMARQ2	DMA channel 2 request input
DMARQ3/RxD	DMA channel 3 request input/Serial receive data input
$\overline{END}/\overline{TC}$	End input/Terminal count output
GND	Ground
High	High-level output except during hold acknowledge when it is placed in the high-impedance state
HLDAK	Hold acknowledge output
HLDRQ	Hold request input
IC	Internal connection; leave unconnected
$\overline{INTAK}$/TOUT1/$\overline{SRDY}$	Interrupt acknowledge output/Timer/counter 1 output/Serial ready output
INTP1-INTP7	Interrupt request inputs
$\overline{IORD}$	I/O read strobe output
$\overline{IOWR}$	I/O write strobe output
$\overline{MRD}$	Memory read strobe output
$\overline{MWR}$	Memory write strobe output
NC	No connection
NMI	Nonmaskable interrupt input
$\overline{POLL}$	Poll input
QS_1-QS_0	CPU queue status outputs
READY	Ready input
$\overline{REFRQ}$	Refresh request output
$\overline{RESET}$	Reset input
RESOUT	Synchronized reset output
TCLK	Timer/counter external clock input
TCTL2	Timer/counter 2 control input
TOUT2	Timer/counter 2 output
V_{DD}	+5 V power supply input
X1, X2	Crystal/external clock inputs

Pin Functions

A_{19}-A_{16}/PS_3-PS_0 [Address/Status Bus]

These three-state output pins contain the upper 4 bits of the 20-bit address during T1 and processor status information during T2, T3, Tw, and T4. During T1 of a memory read or write cycle, these pins contain the upper 4 bits of the 20-bit address. These pins are forced low during T1 of an I/O bus cycle.

Processor status is output during T2, T3, Tw, and T4 of both memory and I/O bus cycles. PS_3 is zero during any CPU native mode bus cycle. During any DMA, refresh, or 8080 emulation mode bus cycle, PS_3 outputs a high level. PS_2 outputs the contents of the interrupt enable (IE) flag in the CPU PSW register. PS_1 and PS_0 indicate the segment register used to form the physical address of a CPU bus cycle as follows:

PS_1	PS_0	Segment
0	0	Data segment 1 (DS1)
0	1	Stack segment (SS)
1	0	Program segment (PS)
1	1	Data segment 0 (DS0)

These pins are in the high-impedance state during hold acknowledge.

A_{15}-A_8 [Address Bus]

These three-state pins form the active-high address bus. During any CPU, DMA, or refresh bus cycle, A_{15}-A_8 output the middle 8 bits of the 20-bit memory or I/O address. The A_{15}-A_8 pins enter the high-impedance state during hold acknowledge or an internal interrupt acknowledge bus cycle. During a slave interrupt acknowledge bus cycle, A_{10}-A_8 contain the address of the slave interrupt controller.

AD_7-AD_0 [Address/Data Bus]

These three-state pins form the active-high, time-multiplexed address/data bus. During T1 of a bus cycle, AD_7-AD_0 output the lower 8 bits of the 20-bit memory or I/O address. During the T2, T3, Tw, and T4 states, AD_7-AD_0 form the 8-bit bidirectional data bus.

The AD_7-AD_0 pins enter the high-impedance state during hold acknowledge or internal interrupt acknowledge bus cycles or while $\overline{RESET}$ is asserted.

ASTB [Address Strobe]

This active-high output is used to latch the address from the multiplexed address bus in an external address latch during T1 of a bus cycle. ASTB is held at a low level during hold acknowledge.

$\overline{\text{BUFEN}}$ [Buffer Enable]

$\overline{\text{BUFEN}}$ is an active-low output for enabling an external data bus transceiver during a bus cycle. $\overline{\text{BUFEN}}$ is asserted during T2 through T4 of a read cycle, T2 through T3 of a slave interrupt acknowledge cycle, and T1 through T4 of a write cycle. $\overline{\text{BUFEN}}$ is not asserted when the bus cycle corresponds to an internal peripheral, DMA, refresh, or internal interrupt acknowledge cycle. $\overline{\text{BUFEN}}$ enters the high-impedance state during hold acknowledge.

BUF$\overline{\text{R}}$/W [Buffer Read/Write]

BUF$\overline{\text{R}}$/W is a three-state, active-low output used to control the direction of an external data bus transceiver. A high level indicates the μPD70208 will perform a write cycle and a low level indicates a read cycle. BUF$\overline{\text{R}}$/W enters the high-impedance state during hold acknowledge.

$\overline{\text{BUSLOCK}}$

This active-low output provides a means for the CPU to indicate to an external bus arbiter that the bus cycles of the next instruction are to be kept contiguous. $\overline{\text{BUSLOCK}}$ is asserted for the duration of the instruction following the BUSLOCK prefix. $\overline{\text{BUSLOCK}}$ is also asserted during interrupt acknowledge cycles and enters the high-impedance state during hold acknowledge. While $\overline{\text{BUSLOCK}}$ is asserted, DMAU, RCU, and external bus requests are disabled.

BS_2-BS_0 [Bus Status]

Outputs BS_2-BS_0 indicate the type of bus cycle being performed as follows.

BS_2	BS_1	BS_0	Bus Cycle
0	0	0	Interrupt acknowledge
0	0	1	I/O read
0	1	0	I/O write
0	1	1	Halt
1	0	0	Instruction fetch
1	0	1	Memory read (1)
1	1	0	Memory write (2)
1	1	1	Passive state

Note:

(1) Memory read bus cycles include CPU, DMA read, DMA verify and refresh bus cycles.

(2) Memory write bus cycles include CPU and DMA write bus cycles.

BS_2-BS_0 are three-state outputs and are high impedance during hold acknowledge.

CLKOUT

The CLKOUT output is used to generate all internal timing for the μPD70208. CLKOUT has a 50-percent duty cycle at half the frequency of the input clock source.

$\overline{\text{DMAAK0}}$-$\overline{\text{DMAAK2}}$ [DMA Acknowledge]

This set of outputs contains the DMA acknowledge signals for channels 0-2 from the internal DMA controller and indicate that the peripheral can perform the requested transfer.

$\overline{\text{DMAAK3}}$/TxD [DMA Acknowledge 3]/[Serial Transmit Data]

Two output signals multiplexed on this pin are selected by the PF field of the on-chip peripheral connection register.

- $\overline{\text{DMAAK3}}$ is an active-low output and enables an external DMA peripheral to perform the requested DMA transfer for channel 3.
- TxD is the serial output from the serial control unit.

DMARQ0-DMARQ2 [DMA Request]

These synchronized inputs are used by external peripherals to request DMA service for channels 0-2 from the internal DMA controller.

DMARQ3/RxD [DMA Request 3]/[Serial Receive Data]

Two input signals multiplexed on this pin are selected by the PF field of the on-chip peripheral connection register.

- DMARQ3 is used by an external peripheral to request a DMA transfer cycle for channel 3.
- RxD is the serial input to the serial control unit.

$\overline{END}/\overline{TC}$ [End/Terminal Count]

This active-low bidirectional pin controls the termination of a DMA service. Assertion of $\overline{END}$ by external hardware during DMA service causes the service to terminate. When a DMA channel reaches its terminal count, the DMAU asserts $\overline{TC}$, indicating the programmed operation has completed.

$\overline{END}/\overline{TC}$ is an open-drain I/O pin, and requires an external 2.2-kΩ pull-up resistor.

HLDAK [Hold Acknowledge]

When an external bus requester has become the highest priority requester, the internal bus arbiter will assert the HLDAK output indicating the address, data, and control buses have entered a high-impedance state and are available for use by the external bus master.

Should the internal DMAU or RCU (demand mode) request the bus, the bus arbiter will drive HLDAK low. When this occurs, the external bus master should complete the current bus cycle and negate the HLDRQ signal. This allows the bus arbiter to reassign the bus to the higher priority requester.

HLDRQ [Hold Request]

This active-high signal is asserted by an external bus master requesting to use the local address, data, and control buses. The HLDRQ input is used by the internal bus arbiter, which gives control of the buses to the highest priority bus requester in the following order.

Bus Master	Priority
RCU	Highest (demand mode)
DMAU	•
HLDRQ	•
CPU	•
RCU	Lowest (normal operation)

$\overline{INTAK}$/TOUT1/$\overline{SRDY}$ [Interrupt Acknowledge]/[Timer 1 Output]/[Serial Ready]

Three output signals multiplexed on this pin are selected by the PF field of the on-chip peripheral connection register.

- $\overline{INTAK}$ is an interrupt acknowledge signal used to cascade external slave μPD71059 Interrupt Controllers. $\overline{INTAK}$ is asserted during T2, T3, and Tw states of an interrupt acknowledge cycle.
- TOUT1 is the output of timer/counter 1.
- $\overline{SRDY}$ is an active-low output and indicates that the serial control unit is ready to receive the next character.

INTP1-INTP7 [Peripheral Interrupts]

INTP1-INTP7 accept either rising-edge or high-level triggered asynchronous interrupt requests from external peripherals. These INTP1-INTP7 inputs are internally synchronized and prioritized by the interrupt control unit, which requests the CPU to perform an interrupt acknowledge bus cycle. External interrupt controllers such as the μPD71059 can be cascaded to increase the number of vectored interrupts.

These interrupt inputs cause the CPU to exit both the standby and 8080 emulation modes.

INTP1-INTP7 contain internal pull-up resistors and may be left unconnected.

$\overline{IORD}$ [I/O Read]

This three-state pin outputs an active-low I/O read strobe during T2, T3, and Tw of an I/O read bus cycle. Both CPU I/O read and DMA write bus cycles assert $\overline{IORD}$. $\overline{IORD}$ is not asserted when the bus cycle corresponds to an internal peripheral. It enters the high-impedance state during hold acknowledge.

$\overline{IOWR}$ [I/O Write]

This three-state pin outputs an active-low I/O write strobe during T2, T3, and Tw of a CPU I/O write or an extended DMA read cycle and during T3 and Tw of a DMA read bus cycle. $\overline{IOWR}$ is not asserted when the bus cycle corresponds to an internal peripheral. It enters the high-impedance state during hold acknowledge.

$\overline{MRD}$ [Memory Read Strobe]

This three-state pin outputs an active-low memory read strobe during T2, T3, and Tw of a memory read bus cycle. CPU memory read, DMA read, and refresh bus cycles all assert $\overline{MRD}$. $\overline{MRD}$ enters the high-impedance state during hold acknowledge.

$\overline{MWR}$ [Memory Write Strobe]

This three-state pin outputs an active-low memory write strobe during T2, T3, and Tw of a CPU memory write or DMA extended write bus cycle and during T3 and Tw of a DMA normal write bus cycle. $\overline{MWR}$ enters the high-impedance state during hold acknowledge.

NMI [Nonmaskable Interrupt]

The NMI pin is a rising-edge-triggered interrupt input that cannot be masked by software. NMI is sampled by CPU logic each clock cycle and when found valid for five or more CLKOUT cycles, the NMI interrupt is accepted. The CPU will process the NMI interrupt immediately after the current instruction finishes execution by fetching the segment and offset of the NMI handler from interrupt vector 2. The NMI interrupt causes the CPU to exit both the standby and 8080 emulation modes. The NMI input takes precedence over the maskable interrupt inputs.

$\overline{POLL}$ [Poll]

The active-low $\overline{POLL}$ input is used to synchronize the operation of external devices with the CPU. During execution of the POLL instruction, the CPU checks the $\overline{POLL}$ input state every five clocks until $\overline{POLL}$ is once again asserted.

QS_1-QS_0 [Queue Status]

The QS_1 and QS_0 outputs maintain instruction synchronization between the μPD70208 CPU and external devices such as the μPD72191 Floating Point Processor. These outputs are interpreted as follows.

QS_1	QS_0	Instruction Queue Status
0	0	No operation
0	1	First byte of instruction fetched
1	0	Flush queue contents
1	1	Subsequent byte of instruction fetched

Queue status is valid for one clock cycle after the CPU has accessed the instruction queue.

READY [Ready]

This active-high input synchronizes external memory and peripheral devices with the μPD70208. Slow memory and I/O devices can lengthen a bus cycle by negating the READY input and forcing the BIU to insert Tw states. READY must be negated prior to the rising edge of CLKOUT during the T2 state to guarantee recognition. When READY is once again asserted and recognized by the BIU, the BIU will proceed to the T4 state.

The READY input operates in parallel with the internal μPD70208 wait control unit and can be used to insert more than three wait states into a bus cycle.

$\overline{REFRQ}$ [Refresh Request]

$\overline{REFRQ}$ is an active-low output indicating the current bus cycle is a memory refresh operation. $\overline{REFRQ}$ is used to disable memory address decode logic and refresh dynamic memories. The 9-bit refresh row address is placed on A_8-A_0 during a refresh bus cycle.

$\overline{RESET}$ [Reset]

The $\overline{RESET}$ input is used to force the μPD70208 to a known state by resetting the CPU and on-chip peripherals. $\overline{RESET}$ must be asserted for a minimum of four clocks to guarantee recognition. After $\overline{RESET}$ has been released, the CPU will start program execution from address FFFF0H.

$\overline{RESET}$ will release the CPU from the low-power standby mode and force it to the native mode.

RESOUT [Reset Output]

This active-high output is available to perform a system-wide reset function. Reset is internally synchronized with CLKOUT and output on the RESOUT pin.

TCLK

TCLK is an external clock source for the timer control unit. The three timer/counters can be programmed to operate with either the TCLK input or a prescaled CLKOUT input.

TCTL2

TCTL2 is the control input for timer/counter 2.

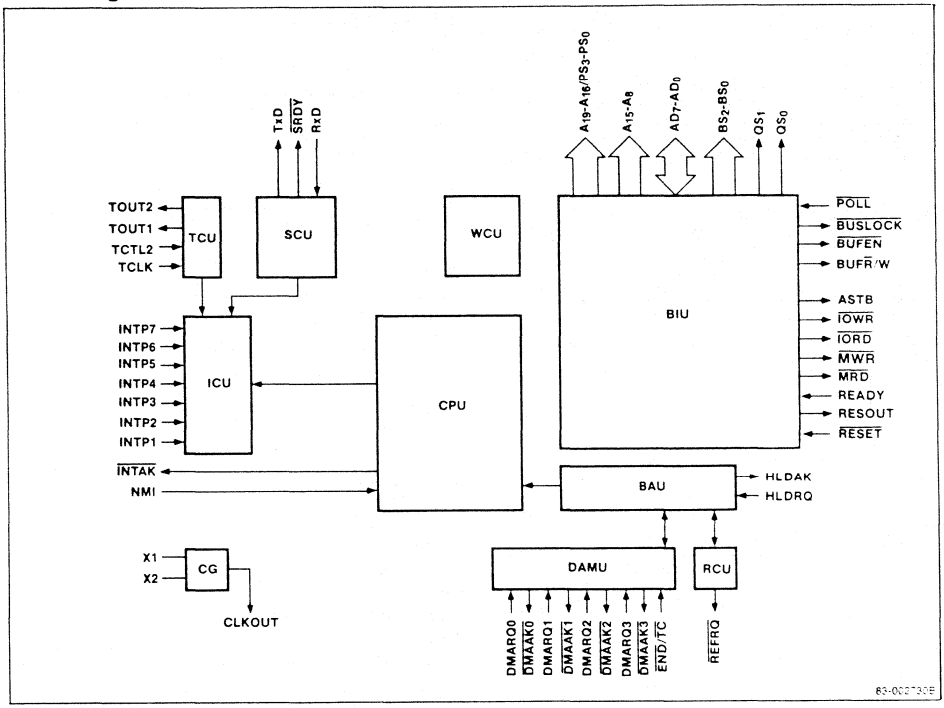
TOUT2

TOUT2 is the output of timer/counter 2.

X1, X2 [Clock Inputs]

These pins accept either a parallel resonant, fundamental mode crystal or an external oscillator input with a frequency twice the desired operating frequency.

Block Diagram



Absolute Maximum Ratings

$T_A = +25°C$

Power supply voltage, V_{DD}	−0.5 to +7.0 V
Input voltage, V_I	−0.5 to V_{DD} + 0.3 V
CLK input voltage, V_K	−0.5 to V_{DD} + 1.0 V
Output voltage, V_O	−0.5 to V_{DD} + 0.3 V
Operating temperature, T_{OPT}	−10 to +70°C
Storage temperature, T_{STG}	−65 to +150°C

Comment: Exposing the device to stresses above those listed in the Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

$T_A = -10$ to +70°C; $V_{DD} = +5$ V ±10%

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Input voltage, high	V_{IH}	2.2	V_{DD} + 0.3	V	
Input voltage, low	V_{IL}	−0.5	0.8	V	
X1, X2 input voltage, high	V_{KH}	3.9	V_{DD} + 1.0	V	
X1, X2 input voltage, low	V_{KL}	−0.5	0.6	V	
Output voltage, high	V_{OH}	0.7 V_{DD}		V	$I_{OH} = -400\ \mu A$
Output voltage, low	V_{OL}		0.4	V	$I_{OL} = 2.5$ mA
Input leakage current, high	I_{LIH}		10	μA	$V_I = V_{DD}$
Input leakage current, low	I_{LIPL}		−300	μA	$V_I = 0$ V, INTP input pins
	I_{LIL}		−10	μA	$V_I = 0$ V, other input pins
Output leakage current, high	I_{LOH}		10	μA	$V_O = V_{DD}$
Output leakage current, low	I_{LOL}		−10	μA	$V_O = 0$ V
Supply current	I_{DD}		90 20	mA mA	Normal mode Standby mode

Capacitance

$T_A = +25°C$, $V_{DD} = 0$ V

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Input capacitance	C_I		15	pF	$f_C = 1$ MHz; unmeasured pins are returned to 0 V.
Output capacitance	C_O		15	pF	

AC Characteristics

$T_A = -10$ to +70°C; $V_{DD} = +5$ V ±10%; $C_L = 100$ pF

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
External clock input cycle time	t_{CYX}	62	250	ns	
External clock pulse width, high	t_{XXH}	20		ns	$V_{KH} = 3.0$ V
External clock pulse width, low	t_{XXL}	20		ns	$V_{KL} = 1.5$ V
External clock rise time	t_{XR}		10	ns	1.5 → 3.0 V
External clock fall time	t_{XF}		10	ns	3.0 → 1.5 V
CLKOUT cycle time	t_{CYK}	124	500	ns	
CLKOUT pulse width, high	t_{KKH}	0.5 t_{CYK} − 7		ns	$V_{KH} = 3.0$ V
CLKOUT pulse width, low	t_{KKL}	0.5 t_{CYK} − 7		ns	$V_{KL} = 1.5$ V
CLKOUT rise time	t_{KR}		7	ns	1.5 → 3.0 V
CLKOUT fall time	t_{KF}		7	ns	3.0 → 1.5 V
CLKOUT delay time from external clock	t_{DXK}		55	ns	
Input rise time (except external clock)	t_{IR}		20	ns	0.8 → 2.2 V
Input fall time (except external clock)	t_{IF}		12	ns	2.2 → 0.8 V
Output rise time (except CLKOUT)	t_{OR}		20	ns	0.8 → 2.2 V
Output fall time (except CLKOUT)	t_{OF}		12	ns	2.2 → 0.8 V
$\overline{RESET}$ setup time to CLKOUT↓	t_{SRESK}	25		ns	
$\overline{RESET}$ hold time after CLKOUT↓	t_{HKRES}	35		ns	
RESOUT delay time from CLKOUT↓	t_{DKRES}	5	60	ns	
READY inactive setup time to CLKOUT↑	t_{SRYLK}	15		ns	
READY inactive hold time after CLKOUT↑	t_{HKRYL}	25		ns	
READY active setup time to CLKOUT↑	t_{SRYHK}	15		ns	
READY active hold time after CLKOUT↑	t_{HKRYH}	25		ns	
NMI, $\overline{POLL}$ setup time to CLKOUT↑	t_{SIK}	15		ns	

AC Characteristics (cont)

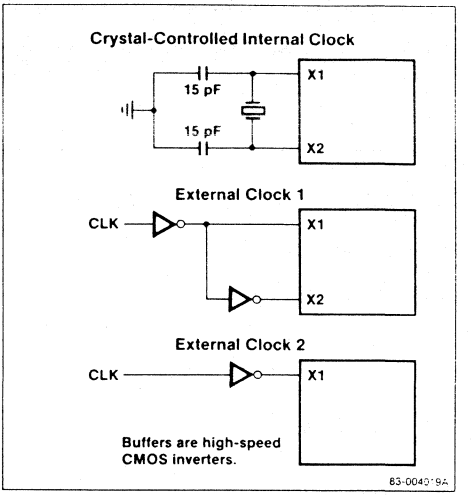
Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Data setup time to CLKOUT↓	t_{SDK}	20		ns	
Data hold time after CLKOUT↓	t_{HKD}	15		ns	
Address delay time from CLKOUT↓	t_{DKA}	10	60	ns	
Address hold time after CLKOUT↓	t_{HKA}	10		ns	
PS delay time from CLKOUT↓	t_{DKP}	10	60	ns	
PS float delay time from CLKOUT↑	t_{FKP}	10	60	ns	
Address setup time to ASTB↓	t_{SAST}	$t_{KKL} - 30$		ns	
Address float delay time from CLKOUT↓	t_{FKA}	t_{HKA}	60	ns	
ASTB↑ delay time from CLKOUT↓	t_{DKSTH}		50	ns	
ASTB↓ delay time from CLKOUT↑	t_{DKSTL}		55	ns	
ASTB pulse width, high	t_{STST}	$t_{KKL} - 10$		ns	
Address hold time after ASTB↓	t_{HSTA}	$t_{KKH} - 10$		ns	
Control delay time from CLKOUT	t_{DKCT}	15	60	ns	
$\overline{RD}$↓ delay time from address float	t_{DAFRL}	0		ns	
$\overline{RD}$↓ delay time from CLKOUT↓	t_{DKRL}	10	70	ns	
$\overline{RD}$↑ delay time from CLKOUT↓	t_{DKRH}	15	60	ns	
Address delay time from CLKOUT	t_{DRHA}	$t_{CYK} - 40$		ns	
$\overline{RD}$ pulse width, low	t_{RR}	$2t_{CYK} - 50$		ns	
BUF$\overline{R}$/W delay from BUFEN↑	t_{DBECT}	$t_{KKL} - 20$		ns	Read cycle
	t_{DWCT}	$t_{KKL} - 20$		ns	Write cycle
Data output delay time from CLKOUT↓	t_{DKD}	10	60	ns	
Data float delay time from CLKOUT↓	t_{FKD}	10	60	ns	
$\overline{WR}$ pulse width, low	t_{WW}	$2t_{CYK} - 40$		ns	
BS↓ delay time from CLKOUT↑	t_{DKBL}	10	60	ns	
BS↑ delay time from CLKOUT↓	t_{DKBH}	10	65	ns	

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
HLDRQ setup time to CLKOUT↑	t_{SHQK}	20		ns	
HLDAK delay time from CLKOUT↓	t_{DKHA}	10	100	ns	
Address drive delay time from CLKOUT↓	t_{DKA2}	t_{CYK}		ns	
$\overline{DMAAK}$ delay time from CLKOUT↑	t_{DKDAL}	10	70	ns	
$\overline{DMAAK}$ delay time from CLKOUT↓	t_{DKDAH}	10	115	ns	Cascade mode
$\overline{WR}$ pulse width, low (DMA cycle)	t_{WW1}	$2t_{CYK} - 40$		ns	DMA extended write cycle
$\overline{WR}$ pulse width, low (DMA cycle)	t_{WW2}	$t_{CYK} - 40$		ns	DMA normal write cycle
$\overline{TC}$ output delay time from CLKOUT↑	t_{DKTCL}		60	ns	
$\overline{TC}$ off delay time from CLKOUT↑	t_{DKTCF}		60	ns	
$\overline{TC}$ pulse width, low	t_{TCTCL}	$t_{CYK} - 15$		ns	
$\overline{TC}$ pullup delay time from CLKOUT↑	t_{DKTCH}		$t_{KKH} + t_{CYK} - 10$	ns	
$\overline{END}$ setup time to CLKOUT↑	t_{SEDK}	35		ns	
$\overline{END}$ pulse width, low	t_{EDEDL}	100		ns	
DMARQ setup time to CLKOUT↑	t_{SDQK}	35		ns	
INTPn pulse width, low	t_{IPIPL}	100		ns	
RxD setup time to SCU internal clock↓	t_{SRX}	1		μs	
RxD hold time after SCU internal clock↓	t_{HRX}	1		μs	
$\overline{SRDY}$ delay time from CLKOUT↓	t_{DKSR}		150	ns	
TxD delay time from TOUT1↓	t_{DTX}		500	ns	
TCTL2 setup time from CLKOUT↓	t_{SGK}	50		ns	
TCTL setup time to TCLK↑	t_{SGTK}	50		ns	
TCTL2 hold time after CLKOUT↓	t_{HKG}	100		ns	
TCTL2 hold time after TCLK↑	t_{HTKG}	50		ns	
TCTL2 pulse width, high	t_{GGH}	50		ns	

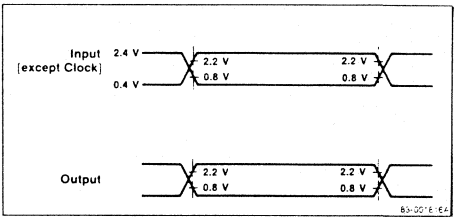
AC Characteristics (cont)

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
TCTL2 pulse width, low	t_{GGL}	50		ns	
TOUT output delay time from CLKOUT↓	t_{DKTO}		200	ns	
TOUT output delay time from TCLK↓	t_{DTKTO}		150	ns	
TOUT output delay time from TCTL2↓	t_{DGTO}		120	ns	
TCLK rise time	t_{TKR}		25	ns	
TCLK fall time	t_{TKF}		25	ns	
TCLK pulse width, high	t_{TKTKH}	50		ns	
TCLK pulse width, low	t_{TKTKL}	50		ns	
TCLK cycle time	t_{CYTK}	124	Dc	ns	
RD↓, WR↓ delay from DMAAK↓	t_{DDARW}	t_{KKH} − 30		ns	
DMAAK↑ delay from RD↑	t_{DRHDAH}	t_{KKL} − 30		ns	
RD↑ delay from WR↑	t_{DWHRH}	5		ns	

Clock Input Configurations

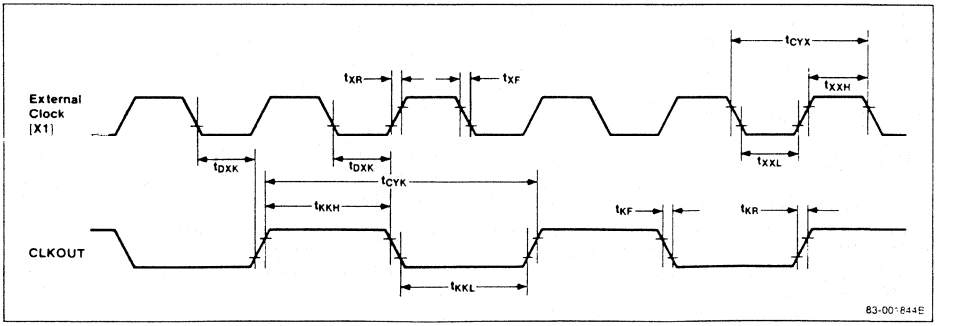


Timing Measurement Points



Timing Waveforms

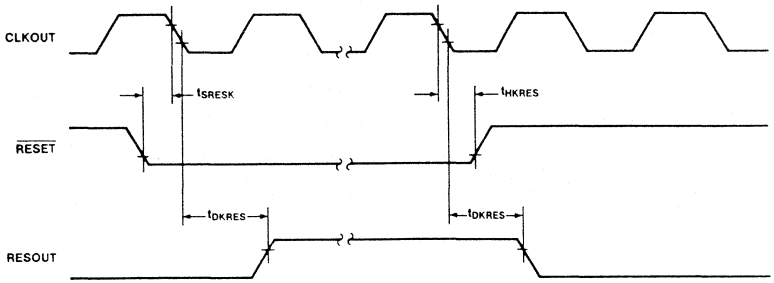
Clock Timing



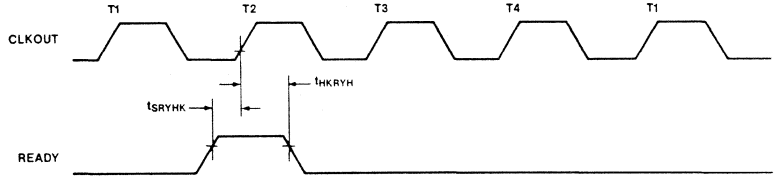
Timing Waveforms (cont)

Reset and Ready Timing

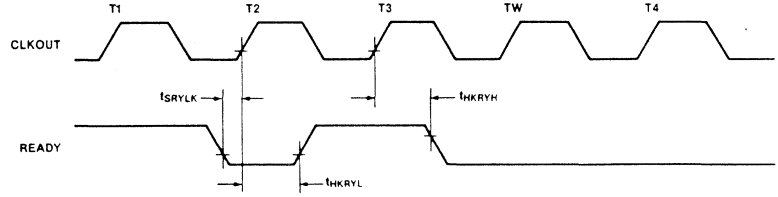
Reset Timing



Ready Timing, No Wait States

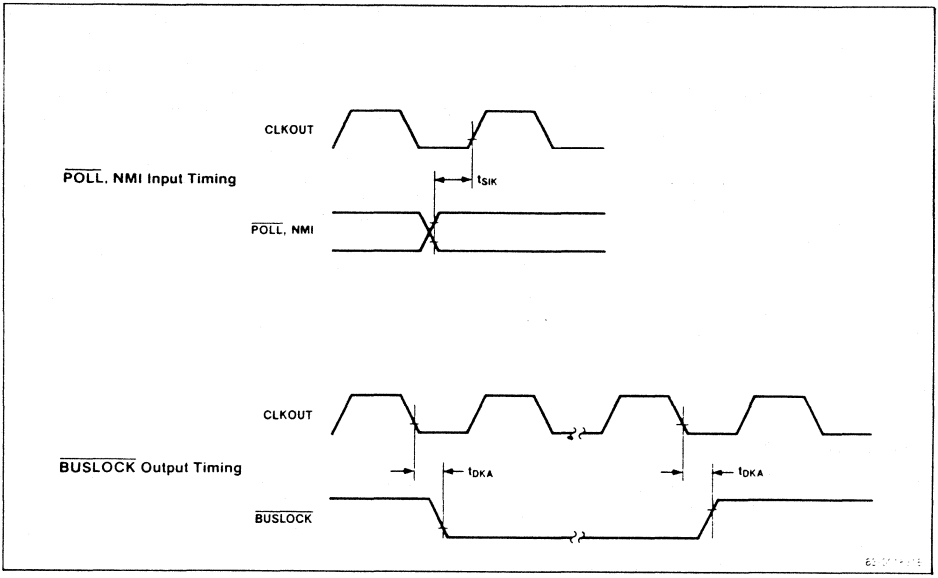


Ready Timng, Wait States



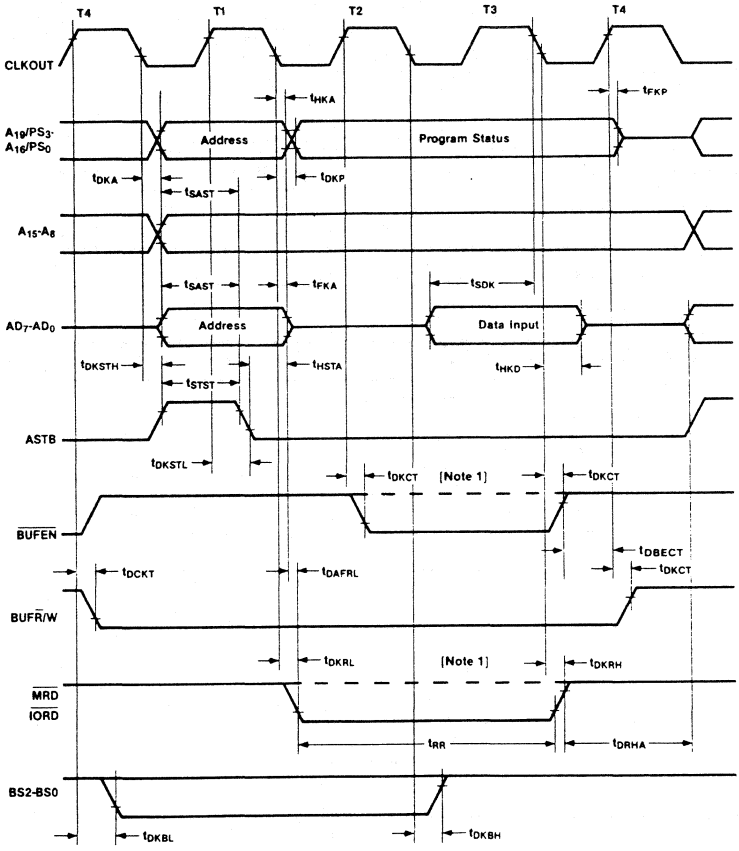
Timing Waveforms (cont)

Poll, NMI, and Buslock Timing



Timing Waveforms (cont)

Read Timing

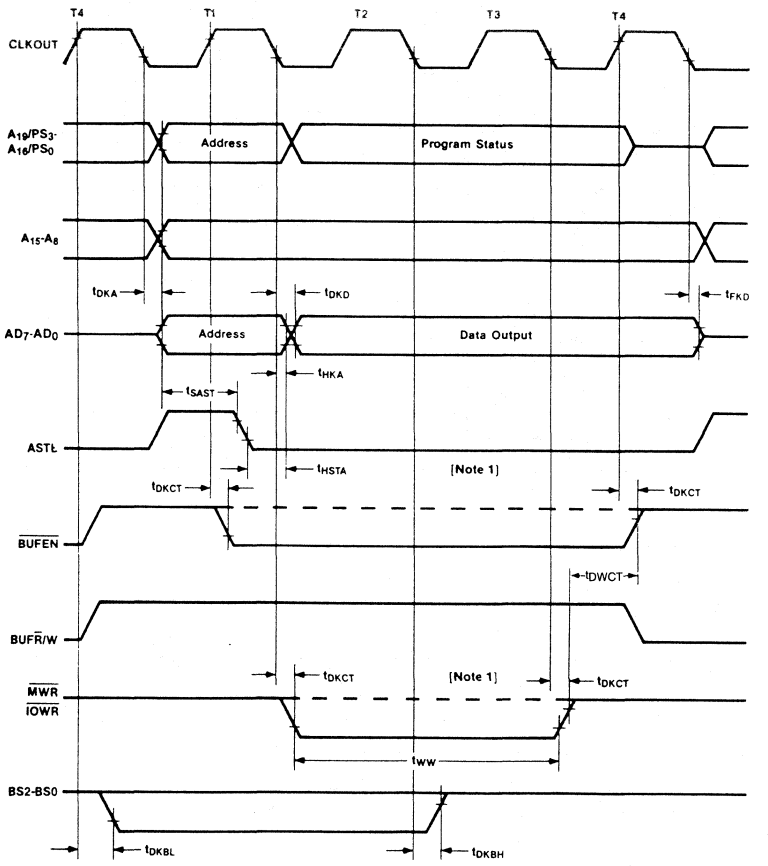


Note:
[1] Except internal I/O accesses.

83-001646E

Timing Waveforms (cont)

Write Timing

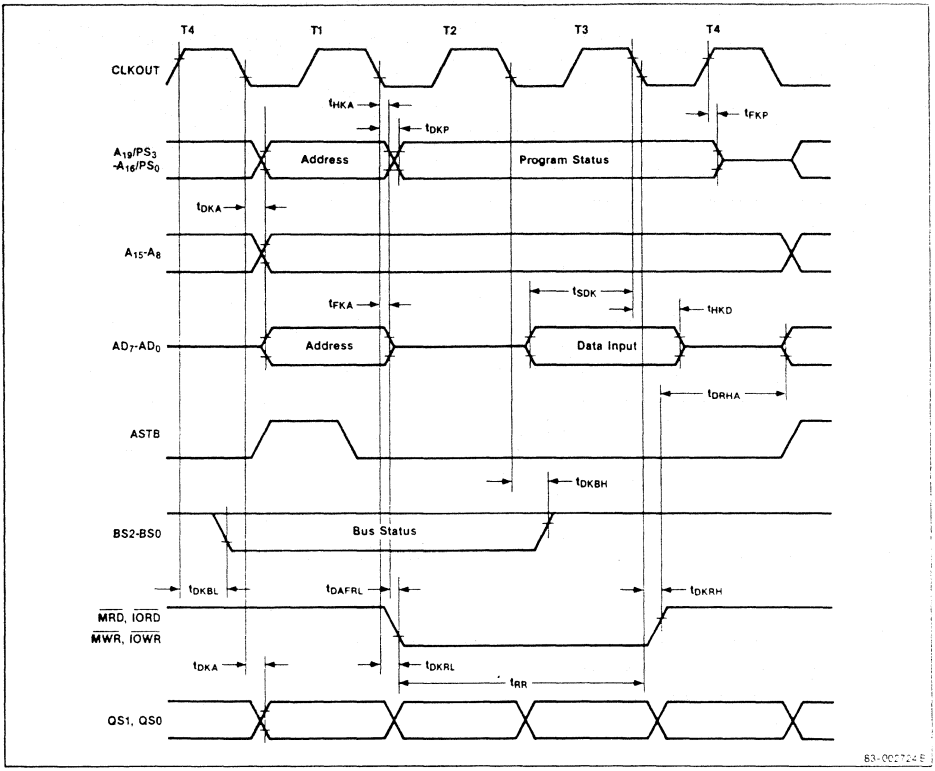


Note:
[1] Except internal I/O accesses.

83-001846 B

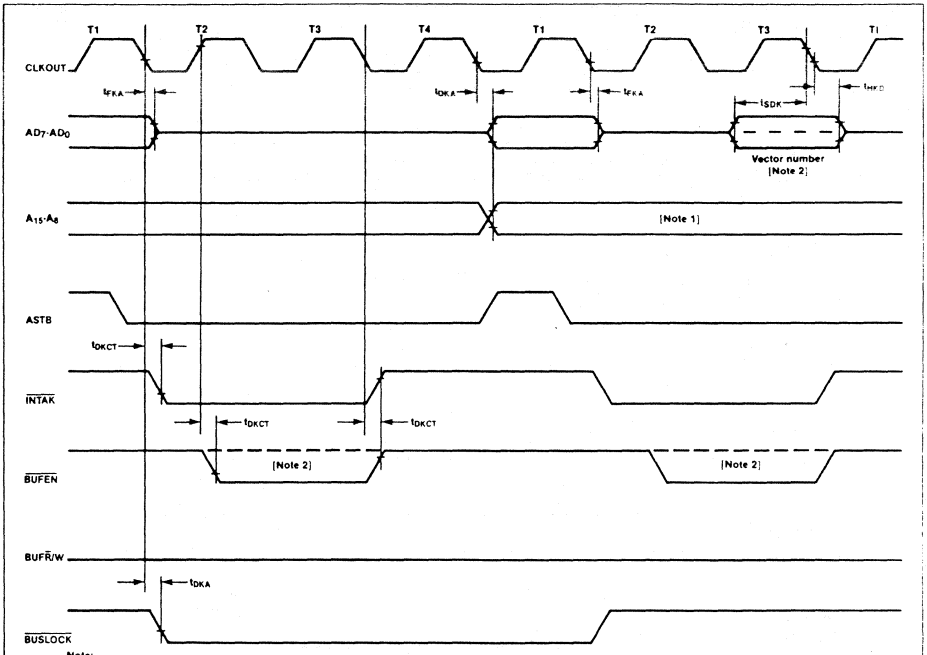
Timing Waveforms (cont)

Status Timing



Timing Waveforms (cont)

Interrupt Acknowledge Timing



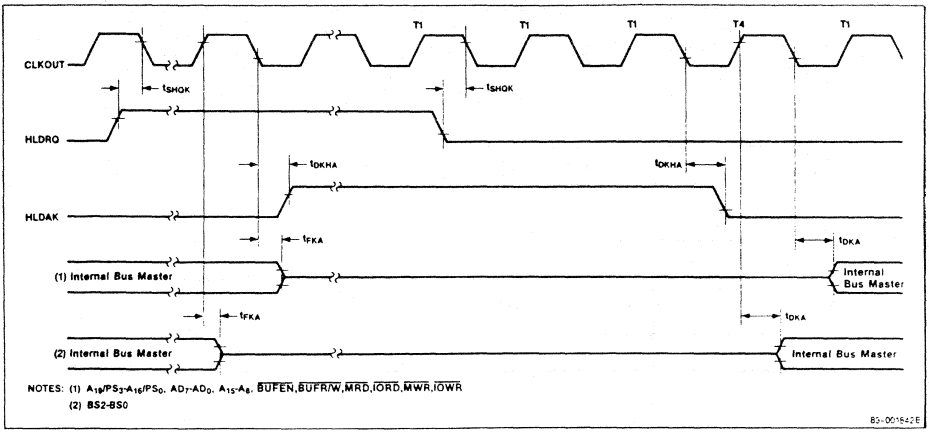
Note:

[1] Slave address when interrupt from external μPD71059. Undefined when internal ICU interrupt.

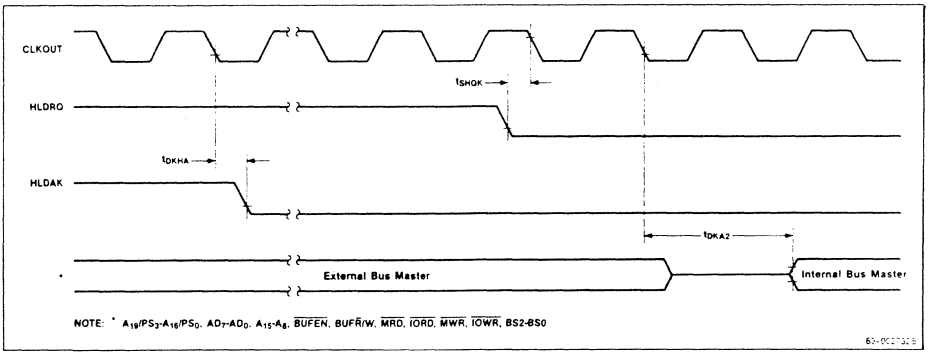
[2] Solid line when interrupt from external μPD71059. Dash line when internal ICU interrupt.

Timing Waveforms (cont)

Timing, Normal Operation

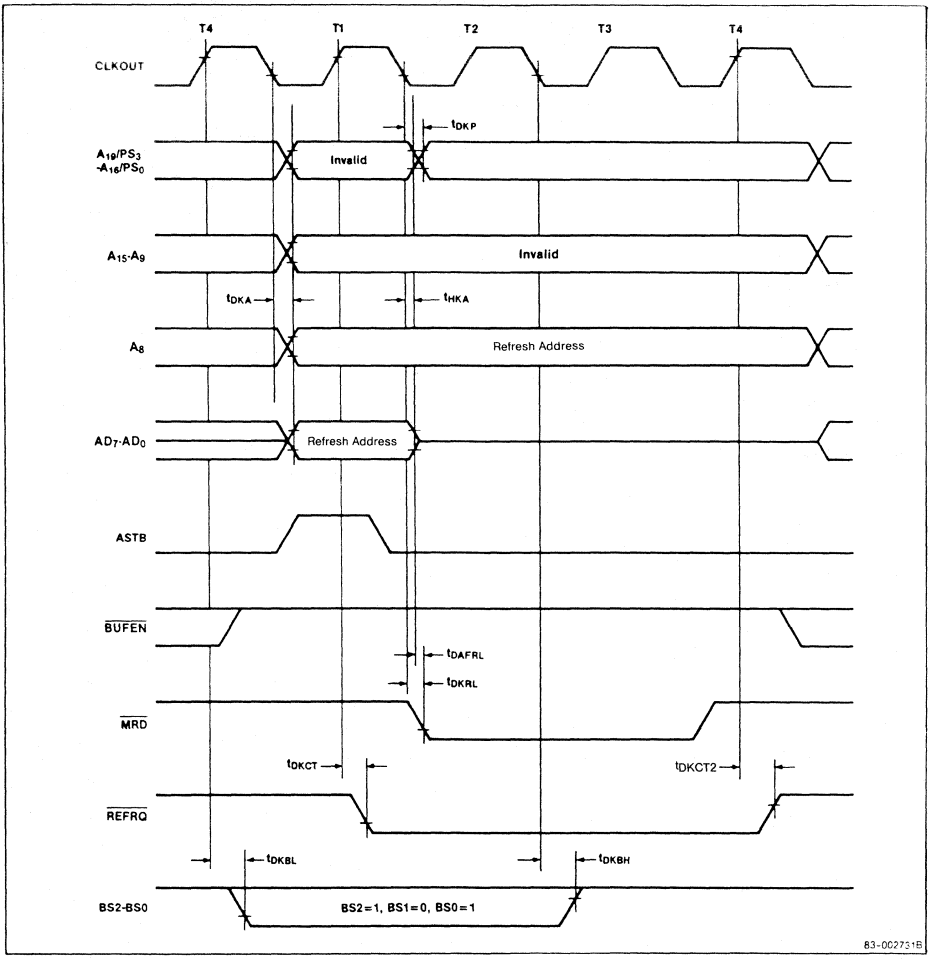


Timing, Bus Wait



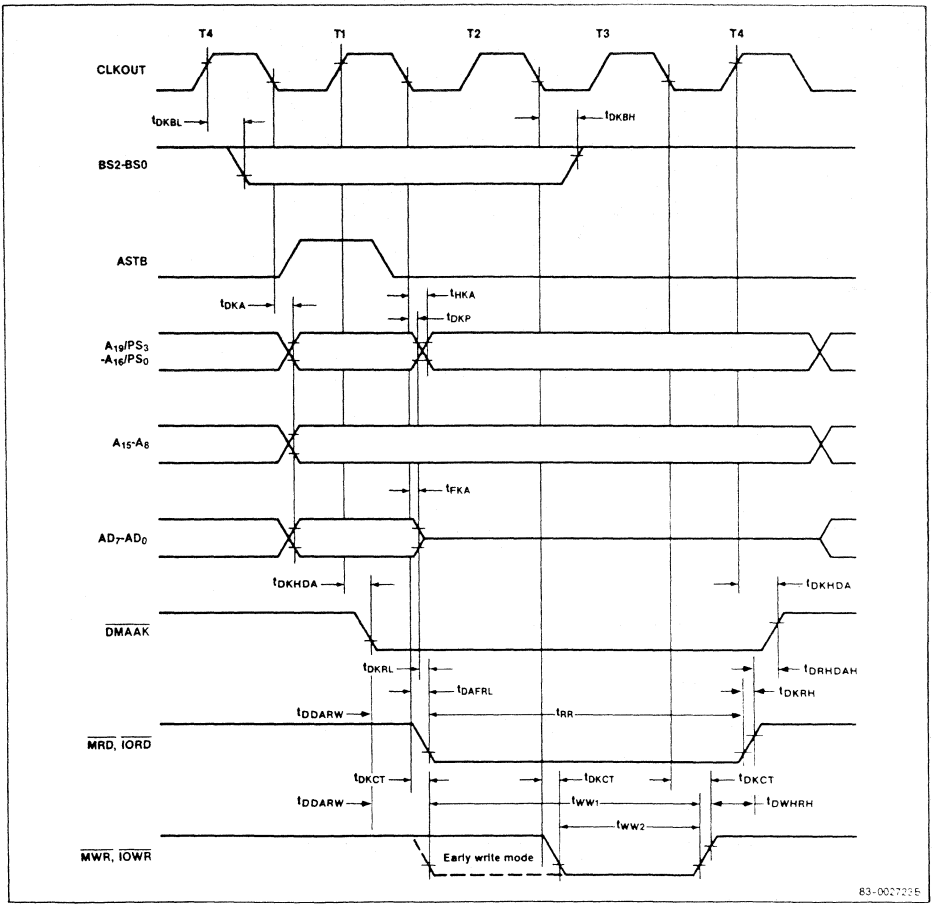
Timing Waveforms (cont)

Refresh Timing



Timing Waveforms (cont)

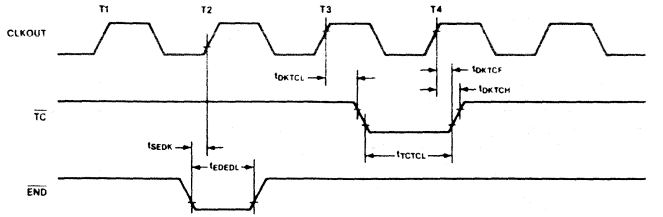
DMAU, DMA Transfer Timing



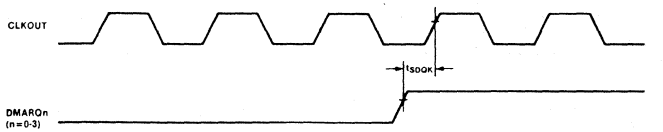
Timing Waveforms (cont)

DMA Timing

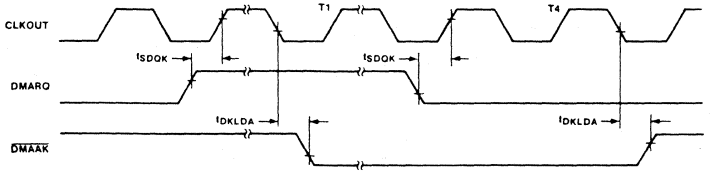
$\overline{END}/\overline{TC}$ Timing



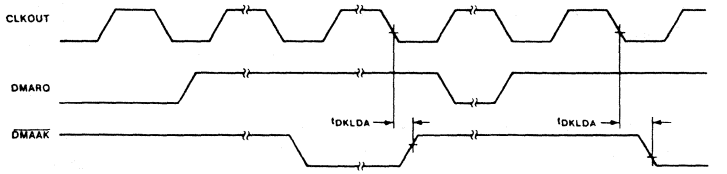
DMA Request Timing



Cascade Mode, Normal Operation

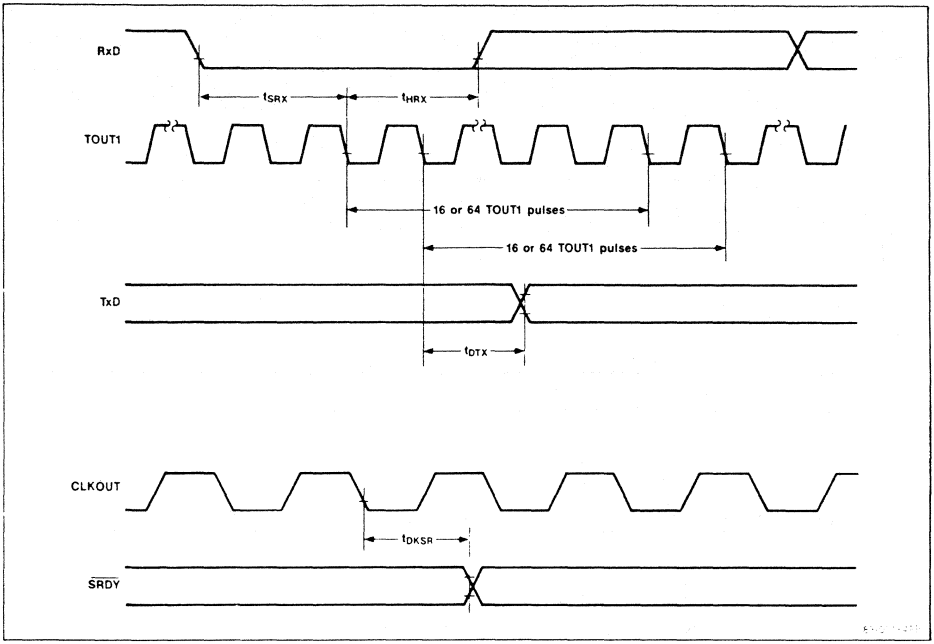


Cascade Mode, Refresh Cycle Insertion

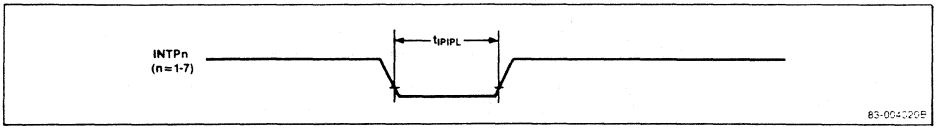


Timing Waveforms (cont)

SCU Timing

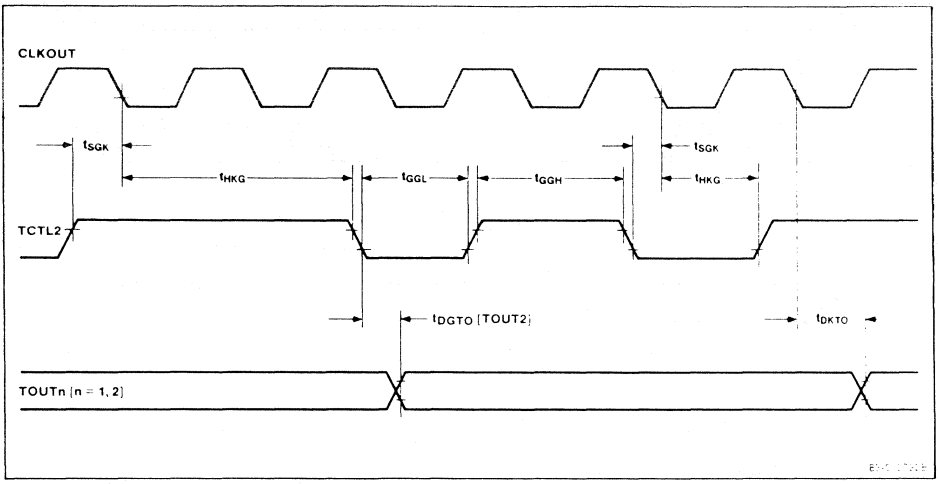


ICU Timing

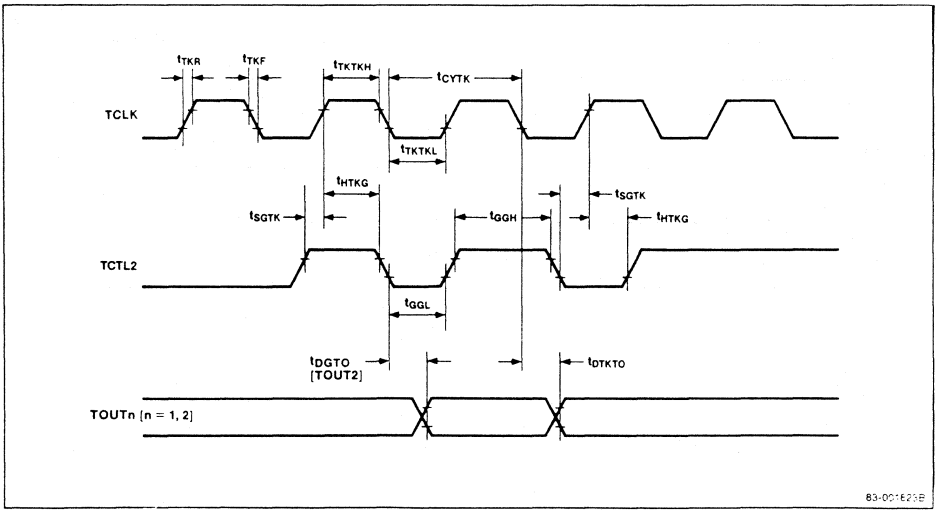


Timing Waveforms (cont)

TCU, Internal Clock Source



TCU Timing, TCLK Source



Functional Description

Refer to the μPD70208 block diagram for an overview of the ten major functional blocks listed below.

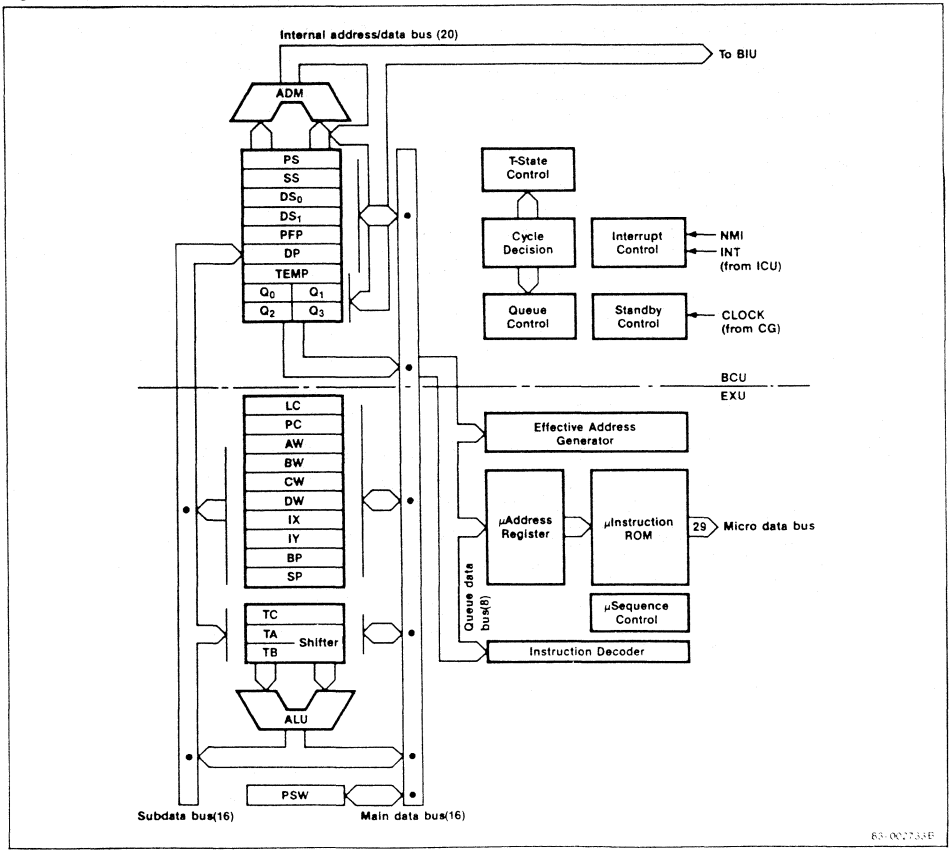
- Central processing unit (CPU)
- Clock generator (CG)
- Bus interface unit (BIU)
- Bus arbitration unit (BAU)
- Refresh control unit (RCU)
- Wait control unit (WCU)
- Timer/counter unit (TCU)
- Serial control unit (SCU)
- Interrupt control unit (ICU)
- DMA control unit (DMAU)

Central Processing Unit

The μPD70208 CPU functions similarly to the CPU of the μPD70108 CMOS microprocessor. However, because the μPD70208 has internal peripheral devices, its bus architecture has been modified to permit sharing the bus with internal peripherals. The μPD70208 CPU is object code compatible with both the μPD70108/μPD70116 and the μPD8086/μPD8088 microprocessors.

Figure 1 is the μPD70208 CPU block diagram. A listing of the μPD70208 instruction set is at the end of this data sheet.

Figure 1. μPD70208 CPU Block Diagram



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Register Configuration

Program Counter [PC]. The program counter is a 16-bit binary counter that contains the program segment offset of the next instruction to be executed. The PC is incremented each time the microprogram fetches an instruction from the instruction queue. The contents of the PC are replaced whenever a branch, call, return, or break instruction is executed and during interrupt processing. At this time, the contents of the PC are the same as the prefetch pointer (PFP).

Prefetch Pointer [PFP]. The prefetch pointer is a 16-bit binary counter that contains the program segment offset of the next instruction to be fetched for the instruction queue. Because instruction queue prefetch is independent of instruction execution, the contents of the PFP and PC are not always identical. The PFP is updated each time the bus interface unit (BIU) fetches an instruction for the instruction queue. The contents of the PFP are replaced whenever a branch, call, return or break instruction is executed and during interrupt processing. At this time, the contents of the PFP and PC are the same.

Segment Registers [PS, SS, DS_0, DS_1]. The μPD70208 memory address space is divided into 64K-byte logical segments. A memory address is determined by the sum of a 20-bit base address (obtained from a segment register) and a 16-bit offset known as the effective address (EA). I/O address space is not segmented and no segment register is used. The four segment registers are program segment (PS), stack segment (SS), data segment 0 (DS_0), and data segment 1 (DS_1). The following table lists their offsets and overrides.

Default Segment Register	Offset	Override
PS	PFP register	Invalid
SS	SP register	Invalid
SS	Effective address (BP-based)	PS, DS_0, DS_1
DS_0	Effective address (non BP-based)	PS, SS, DS_1
DS_0	IX register (1)	PS, SS, DS_1
DS_1	IY register (2)	Invalid

Note:

(1) Includes source block transfer, output, BCD string, and bit field extraction.

(2) Includes destination block transfer, input, BCD string, and bit field insertion.

General-Purpose Registers. The μPD70208 CPU contains four 16-bit general-purpose registers (AW, BW, CW, DW), each of which can be used as a pair of 8-bit registers by dividing into upper and lower bytes (AH, AL, BH, BL, CH, CL, DH, DL). General-purpose registers may also be specified implicitly in an instruction. The implicit assignments are:

- AW — Word multiplication/division, word I/O, data conversion
- AL — Byte multiplication/division, byte I/O, BCD rotation, data conversion, translation
- AH — Byte multiplication/division
- BW — Translation
- CW — Loop control, repeat prefix
- CL — Shift/rotate bit counts, BCD operations
- DW — Word multiplication/division, indirect I/O addressing

Pointer [SP, BP] and Index Registers [IX, IY]. These registers serve as base pointers or index registers when accessing memory using one of the base, indexed, or base indexed addressing modes. Pointer and index registers can also be used as operands for word data transfer, arithmetic, and logical instructions. These registers are implicitly selected by certain instructions as follows.

- SP — Stack operations, interrupts
- IX — Source block transfer, BCD string operations, bit field extraction
- IY — Destination block transfer, BCD string operations, bit field insertion

Program Status Word [PSW]

The program status word consists of six status flags and four control flags.

Status Flags

- V (Overflow)
- S (Sign)
- Z (Zero)
- AC (Auxiliary Carry)
- P (Parity)
- CY (Carry)

Control Flags

- MD (Mode)
- DIR (Direction)
- IE (Interrupt Enable)
- BRK (Break)

When pushed onto the stack, the word image of the PSW is as follows:

15							8
MD	1	1	1	V	DIR	IE	BRK

7							0
S	Z	0	AC	0	P	1	CY

The status flags are set and cleared automatically depending upon the result of the previous instruction execution. Instructions are provided to set, clear, and complement certain status and control flags. Other flags can be manipulated by using the POP PSW instruction.

Between execution of the BRKEM and RETEM instructions, the native mode RETI and POP PSW instructions can modify the MD bit. Care must be exercised by emulation mode programs to prevent inadvertent alteration of this bit.

CPU Architectural Features

The major architectural features of the μPD70208 CPU are:

- Dual data buses
- Effective address generator
- Loop counter
- PC and PFP

Dual Data Buses. To increase performance, dual data buses (figure 2) have been employed in the CPU to fetch operands in parallel and avoid the bottleneck of a single bus. For two-operand instructions and effective address calculations, the dual data bus approach is 30 percent faster than single-bus systems.

Effective Address Generator. Effective address (EA) calculation requires only two clocks regardless of the addressing mode complexity due to the hardware effective address generator (figure 3). When compared with microprogrammed methods, the hardware approach saves between 3 and 10 clock cycles during effective address calculation.

Figure 2. Dual Data Buses

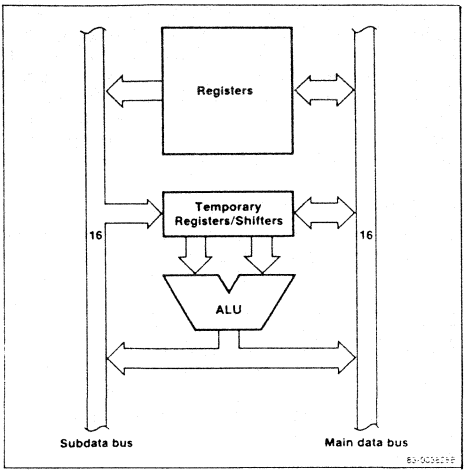
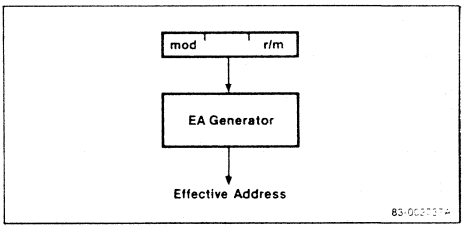


Figure 3. Effective Address Generator



Loop Counter and Shifters. A dedicated loop counter is used to count the iterations of block transfer and multiple shift instructions. This logic offers a significant performance advantage over architectures that control block transfers and multiple shifts using microprogramming. Dedicated shift registers also speed up the execution of the multiply and divide instructions. Compared with microprogrammed methods, multiply and divide instructions execute approximately four times faster.

Program Counter and Prefetch Pointer. The functions of instruction execution and queue prefetch are decoupled in the μPD70208. By avoiding a single-instruction pointer and providing separate PC and PFP registers, the execution time of control transfers and the interrupt response latency can be minimized. Several clocks are saved by avoiding the need to readjust an instruction pointer to account for prefetching before computing the new destination address.

Enhanced Instruction Set

In addition to the μPD8086/88 instruction set, the μPD70208 has added the following enhanced instructions.

Instruction	Function
PUSH imm	Push immediate data onto stack
PUSH R	Push all general registers onto stack
POP R	Pop all general registers from stack
MUL imm	Multiply register/memory by immediate data
SHL imm8	Shift/rotate by immediate count
SHR imm8	
SHRA imm8	
ROL imm8	
ROR imm8	
ROLC imm8	
RORC imm8	
CHKIND	Check array index
INM	Input multiple
OUTM	Output multiple
PREPARE	Prepare new stack frame
DISPOSE	Dispose current stack frame

Unique Instruction Set

In addition to the μPD70208 enhanced instruction set, the following unique instructions are supported.

Instruction	Function
INS	Insert bit field
EXT	Extract bit field
ADD4S	BCD string addition
SUB4S	BCD string subtraction
CMP4S	BCD string comparison
ROL4	Rotate BCD digit left
ROR4	Rotate BCD digit right
TEST1	Test bit
SET1	Set bit
CLR1	Clear bit
NOT1	Complement bit
REPC	Repeat while carry set
REPNC	Repeat while carry cleared
FPO2	Floating point operation 2

Bit Fields. Bit fields are data structures that range in length from 1 to 16 bits. Two separate operations on bit fields, insertion and extraction, with no restrictions on the position of the bit field in memory are supported. Separate segment, byte offset, and bit offset registers are used for bit field insertion and extraction. Because of their power and flexibility, these instructions are highly effective for graphics, high-level languages, and data packing/unpacking applications.

Insert bit field (INS) copies the bit field of specified length (0 = 1 bit, 15 = 16 bits) from the AW register to the bit field addressed by DS1:IY:reg8 (figure 4). The bit field length can be located in any byte register or supplied as an immediate value. The value in reg8 is a bit field offset. A content of 0 selects bit 0 and 15 selects bit 15 of the word DS0:IX points to. Following execution, the IY and bit offset register are updated to point to the start of the next bit field.

Bit field extraction (EXT) copies the bit field of specified length (0 = 1 bit, 15 = 16 bits) from the bit field addressed by DS0:IX:reg8 to the AW register (figure 5). If the bit field is less than 16 bits, it is right justified with a zero fill. The bit field length can be located in any byte register or supplied as immediate data. The value in reg8 is a bit field offset. A content of 0 selects bit 0 and 15 selects bit 15 of the word DS0:IX points to. Following execution, the IX and bit offset register are updated to point to the start of the next bit field.

Packed BCD Strings. These instructions are provided to efficiently manipulate packed BCD data as strings (length from 1 to 254 digits) or as a byte data type with a single instruction.

BCD string arithmetic is supported by the ADD4S, SUB4S, and CMP4S instructions. These instructions allow the source string (addressed by DS0:IX) and the destination string (addressed by DS1:IY) to be manipulated with a single instruction. When the number of BCD digits is even, the Z and CY flags are set according to the result of the operation. If the number of digits is odd, the Z flag will not be correctly set unless the upper 4 bits of the result are zero. The CY flag will not be correctly set unless there is a carry out of the upper 4 bits of the result.

The two BCD rotate instructions (ROR4, ROL4) perform rotation of a single BCD digit in the lower half of the AL register through the register or memory operand.

Bit Manipulation. Four bit manipulation instructions have been added to the μPD70208 instruction set. The ability to test, set, clear, or complement a single bit in a register or memory operand increases code readability as well as performance over the logical operations traditionally used to manipulate bit data.

Figure 4. Bit Field Insertion

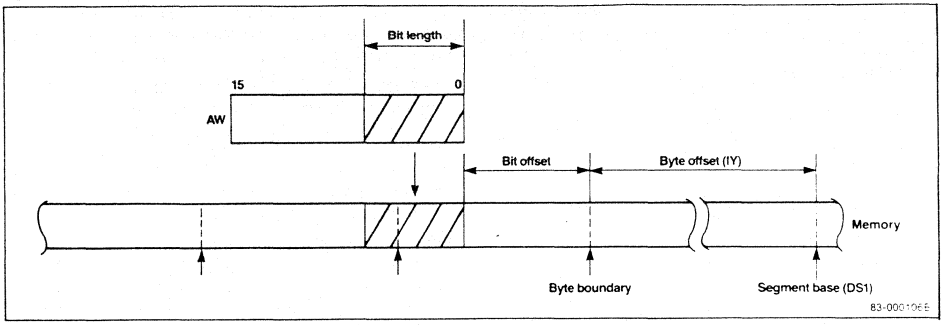
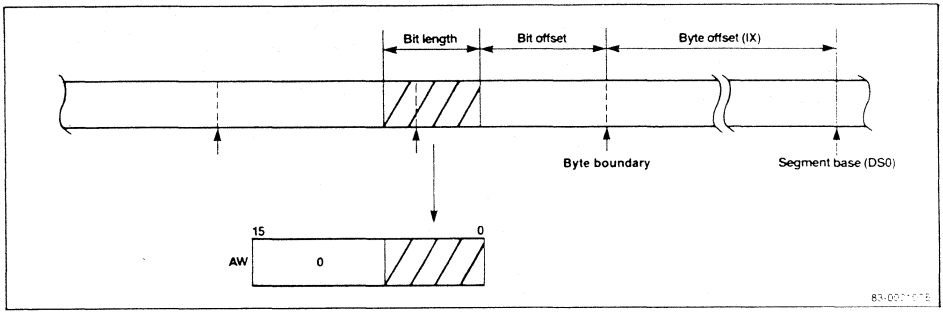


Figure 5. Bit Field Extraction



Repeat Prefixes. Two repeat prefixes (REPC, REPNC) allow conditional block transfer instructions to use the state of the CY flag as a terminating condition. The use of these prefixes allows inequalities to be used when working on ordered data, increasing the performance of searching and sorting algorithms.

Floating Point Operation Instructions. Two floating point operation (FPO) instruction types are recognized by the μPD70208 CPU. These instructions are detected by the CPU, which performs any auxiliary processing such as effective address calculation and the initial bus cycle if specified by the instruction. It is the responsibility of the external coprocessor to latch the address information and data (if a read cycle) from the bus and complete the execution of the instruction.

8080 Emulation Mode. The μPD70208 CPU can operate in either of two modes; see figure 6. Native mode allows the execution of the μPD8086/88, enhanced and unique instructions. The other operating mode is 8080 emulation mode, which allows the entire μPD8080AF instruction set to be executed. A mode (MD) flag is provided to distinguish between the two operating modes. Native mode is active when MD is 1 and 8080 emulation mode is active when MD is 0.

Two instructions are provided to switch from native to 8080 emulation mode and return back. Break for emulation (BRKEM) operates similarly to a BRK instruction, except that after the PSW has been pushed on the native mode stack, the MD flag is cleared.

During 8080 emulation mode, the registers and flags of the 8080 are mapped onto the native mode registers and flags as shown below. Note that PS, SS, DS_0, DS_1, IX, IY, AH, and the upper half of the PSW registers are inaccessible to 8080 programs.

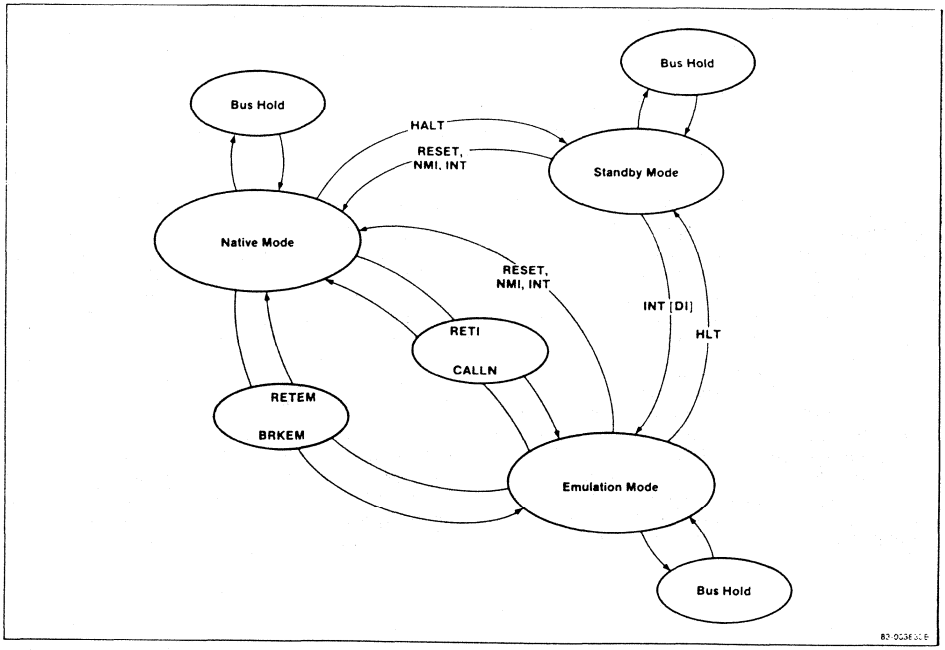
	μPD8080AF	μPD70208
Registers	A	AL
	B	CH
	C	CL
	D	DH
	E	DL
	H	BH
	L	BL
	SP	BP
	PC	PC
Flags	C	CY
	Z	Z
	S	S
	P	P
	AC	AC

During 8080 emulation mode, the BP register functions as the 8080 stack pointer. The use of separate stack pointers prevents inadvertent damage to the native stack pointer by emulation mode programs.

The 8080 emulation mode PC is combined with the PS register to form the 20-bit physical address. All emulation mode data references use DS0 as the segment register. For compatibility with older 8080 software these registers must be equal. By using different segment register contents, separate 64K-byte code and data spaces are possible.

Either an NMI or maskable interrupt will cause the 8080 emulation mode to be suspended. The CPU pushes the PS, PC, and PSW registers on the native mode stack, sets the MD bit (indicating native mode), and enters the specified interrupt handler. When the return from interrupt (RETI) instruction is executed, the PS, PC, and PSW (containing MD=0) are popped from the native stack and execution in 8080 emulation mode continues. Reset will also force a return to native mode.

Figure 6. μPD70208 Modes



The 8080 emulation mode programs also have the capability to invoke native mode interrupt handlers by means of the call native (CALLN) instruction. This instruction operates the same as the BRK instruction except that the saved PSW indicates 8080 emulation mode.

To exit 8080 emulation mode, the return from emulation (RETEM) instruction pops the PS, PC, and PSW from the native mode stack and execution continues with the instruction following the BRKEM instruction. Nesting of 8080 emulation modes is prohibited.

Interrupt Operation

The μPD70208 supports a number of external interrupts and software exceptions. External interrupts are events asynchronous to program execution. On the other hand, exceptions always occur as a result of program execution.

The two types of external interrupts are:

- Nonmaskable interrupt (NMI)
- Maskable interrupt (INT)

The six software exceptions are:

- Divide error (DIV, DIVU instructions)
- Array bound error (CHKIND instruction)
- Break on overflow (BRKV instruction)
- Break (BRK, BRK3 instructions)
- Single step (BRK bit in PSW set)
- Mode switch (BRKEM, CALLN instructions)

Interrupt vectors are determined automatically for exceptions and the NMI interrupt or supplied by hardware for maskable interrupts. The 256 interrupt vectors are stored in a table (figure 7) located at address 00000H. Vectors 0 to 5 are predetermined and vectors 6 to 31 are reserved. Interrupt vectors 32 to 255 are available for use by application software.

Each vector is made up of two words. The word located at the lower address contains the new PC for the interrupt handler. The word at the next-higher address is the new PS value for the interrupt handler. These must be initialized by software at the start of a program.

Standby Mode

The μPD70208 CPU has a low-power standby mode, which can dramatically reduce power consumption during idle periods. Standby mode is entered by simply executing a native or 8080 emulation HALT instruction; no external hardware is required. All other peripherals such as the timer/counter unit, refresh control unit, and DMA control unit continue to operate as programmed.

During standby mode, the clock is distributed only to the circuits required to release the standby mode. When a RESET, NMI, or INT event is detected, the standby mode is released. Both NMI and unmaskable interrupts are processed before control returns to the instruction following the HALT. In the case of the INT input being masked, execution will begin with the instruction immediately following the HALT instruction without an intervening interrupt acknowledge bus cycle. When maskable interrupts are again enabled, the interrupt will be serviced.

Output signal states in the standby mode are listed below.

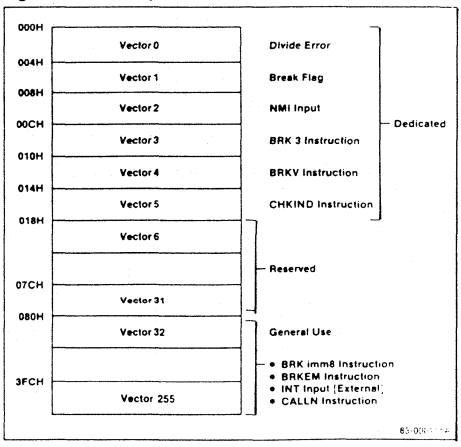
Output Signal	Status in Standby Mode
$\overline{INTAK}$, $\overline{BUFEN}$, $\overline{MRD}$, $\overline{MWR}$, $\overline{IOWR}$, $\overline{IORD}$	High level
BS_2-BS_0 (Note 2)	High level
QS_1-QS_0, ASTB	Low level
$\overline{BUSLOCK}$	High level (low level if the HALT instruction follows the BUSLOCK prefix)
$BUF\overline{R}/W$, A_{19}-A_{16}/PS_3-PS_0, A_{15}-A_8, AD_7-AD_0	High or low level

Note:

(1) Output pin states during refresh and DMA bus cycles will be as defined for those operations.

(2) Halt status is presented prior to entering the passive state.

Figure 7. Interrupt Vector Table



Clock Generator

The clock generator (CG) generates a clock signal half the frequency of a parallel-resonant, fundamental mode crystal connected to pins X1 and X2. Figure 8 shows the recommended circuit configuration. Capacitors C1 and C2 are required for frequency stability. Their values can be calculated from the load capacitance (CL) specified by the crystal manufacturer.

$$C1 = C2 = 2\ (CL - CS)$$

CS is any stray capacitance in parallel with the crystal, such as the μPD70208 input capacitance.

External clock sources (figure 9) are also accommodated by applying the external clock to the X1 pin and its complement to the X2 pin. The CG distributes the clock to the CLKOUT pin and to each functional block of the μPD70208. The generated clock signal has a 50-percent duty cycle.

Bus Interface Unit

The bus interface unit (BIU) controls the external address, data, and control buses for the three internal bus masters: CPU, DMA control unit (DMAU), and refresh control unit (RCU). The BIU is also responsible for synchronization of the $\overline{\text{RESET}}$ and READY inputs with the clock. The synchronized reset signal is used internally by the μPD70208 and provided externally at the RESOUT pin as a system-wide reset. The synchronized READY signal is combined with the output of the wait control unit (WCU) and is distributed internally to the CPU, DMAU, and RCU. Figure 10 shows the synchronization of $\overline{\text{RESET}}$ and READY.

Figure 8. Crystal Configuration

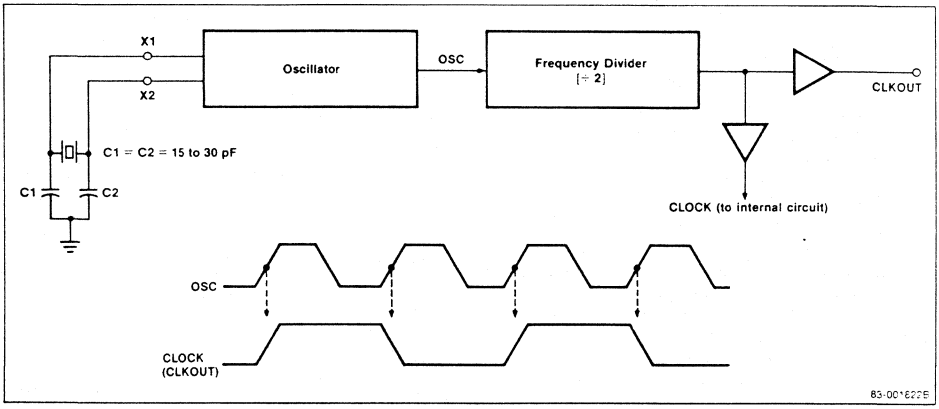
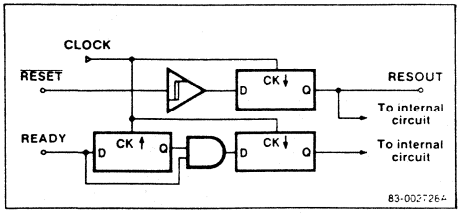


Figure 10. $\overline{\text{RESET}}$/READY Synchronization



Bus Arbitration Unit

The bus arbitration unit (BAU) arbitrates the local bus between the internal CPU, DMAU, and RCU bus requesters and an external bus master. The BAU bus priorities from the highest priority requester to the lowest are:

RCU (Demand mode)
DMAU
HLDRQ
CPU
RCU (Normal mode)

Note that RCU requests the bus at either the highest or lowest priority depending on the status of the refresh request queue. Bus masters other than the CPU are prohibited from using the bus when the CPU is executing an instruction containing a BUSLOCK prefix. Therefore, caution should be exercised when using the BUSLOCK prefix with instructions having a long execution time.

If a bus master with higher priority than the current bus master requests the bus, the BAU inactivates the current bus master's acknowledge signal. When the BAU sees the bus request from the current master go inactive, the BAU gives control of the bus to the higher priority bus master. The BAU performs bus switching between internal bus masters without the introduction of idle bus cycles, enhancing system throughput.

System I/O Area

The I/O address space from addresses FF00H to FFFFH is reserved for use as the system I/O area. Located in this area are the 12 μPD70208 registers that determine the I/O addressing, enable/disable peripherals, and control pin multiplexing.

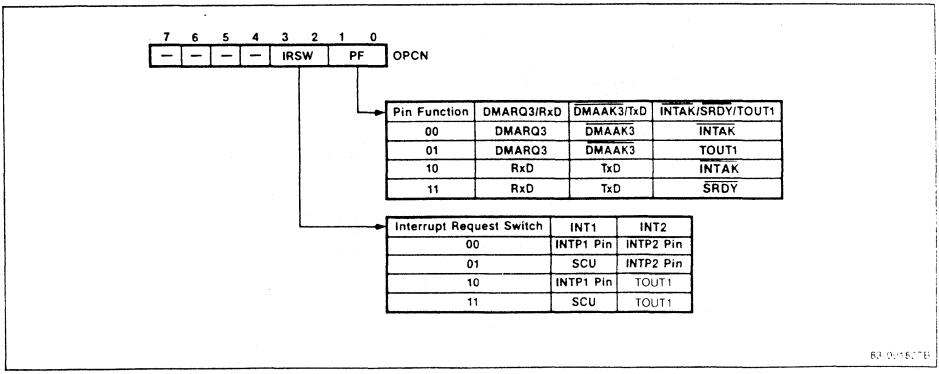
I/O Address	Register	Operation
FFFFH	Reserved	—
FFFEH	OPCN	Read/Write
FFFDH	OPSEL	Read/Write
FFFCH	OPHA	Read/Write
FFFBH	DULA	Read/Write
FFFAH	IULA	Read/Write
FFF9H	TULAL	Read/Write
FFF8H	SULA	Read/Write
FFF7H	Reserved	—
FFF6H	WCY2	Read/Write
FFF5H	WCY1	Read/Write
FFF4H	WMB	Read/Write
FFF3H	Reserved	—
FFF2H	RFC	Read/Write
FFF1H	Reserved	—
FFF0H	TCKS	Read/Write

On-Chip Peripheral Connection Register

The on-chip peripheral connection (OPCN) register controls multiplexing of the μPD70208 multiplexed pins. Figure 11 shows the format of the OPCN register. The interrupt request switch (IRSW) field controls multiplexing of ICU interrupt inputs INT1 and INT2. The output of an internal peripheral or an external interrupt source can be selected as the INT1 and INT2 inputs to the ICU.

The pin function (PF) field in the OPCN selects one of four possible states for the DMARQ3/RxD, $\overline{\text{DMAAK3}}$/TxD, and $\overline{\text{INTAK}}$/$\overline{\text{SRDY}}$/TOUT1 pins. Bit 0 of the

Figure 11. OPCN Register Format

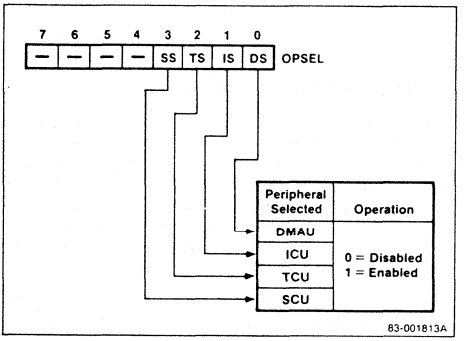


OPCN controls the function of the INTAK/SRDY/TOUT1 pin. If cleared, INTAK will appear on this output pin. If bit 0 is set, either TOUT1 or SRDY will appear at the output depending on the state of bit 1. If bit 1 is cleared, DMA channel 3 I/O signals will appear on the DMARQ3/RxD and DMAAK3/TxD pins. If the SCU is to be used, bit 1 of the PF field must be set.

On-Chip Peripheral Selection Register

The on-chip peripheral selection (OPSEL) register is used to enable or disable the μPD70208 internal peripherals. Figure 12 shows the format of the OPSEL register. Any of the four (DMAU, TCU, ICU, SCU) peripherals can be independently enabled or disabled by setting or clearing the appropriate OPSEL bit.

Figure 12. OPSEL Register Format



Internal Peripheral Relocation Registers

The five internal peripheral relocation registers (figure 13) are used to fix the I/O addresses of the DMAU, ICU, TCU, and SCU. The on-chip peripheral high-address (OPHA) register is common to all four internal peripherals and fixes the high-order byte of the 16-bit I/O address. The individual DMAU low-address (DULA) register, ICU low-address (IULA) register, TCU low-address (TULA) register, and the SCU low-address (SULA) register select the low-order byte of the I/O addresses for the DMAU, ICU, TCU, and SCU peripherals.

The contents of the OPHA register are:

OPHA

7							0
A_{15}	A_{14}	A_{13}	A_{12}	A_{11}	A_{10}	A_9	A_8

The formats for the individual internal peripheral registers appear below. Since address checking is not performed, do not overlap two peripheral I/O address spaces.

DULA

7							0
A_7	A_6	A_5	A_4	—	—	—	—

IULA

7							0
A_7	A_6	A_5	A_4	A_3	A_2	—	—

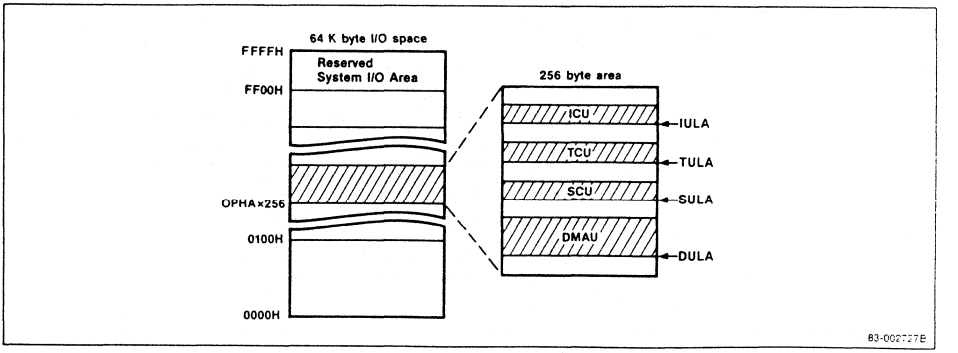
TULA

7							0
A_7	A_6	A_5	A_4	A_3	A_2	—	—

SULA

7							0
A_7	A_6	A_5	A_4	A_3	A_2	—	—

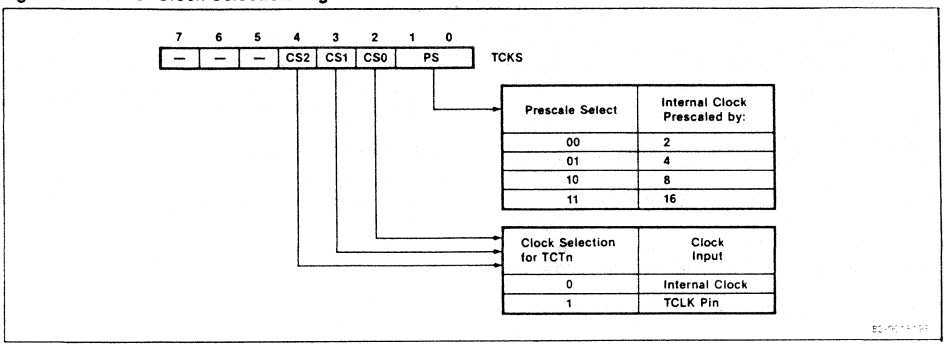
Figure 13. μPD70208 Peripheral Relocation



Timer Clock Selection Register

The timer clock selection (TCKS) register selects the clock source for each of the timer/counters as well as the divisor for the internal clock prescaler. Figure 14 shows the format of the TCKS register. The clock source for each timer/counter is independently selected from either the prescaled CLKOUT signal or from an external clock source (TCLK). The internal clock is derived from the CLKOUT signal and can be divided by 2, 4, 8, or 16 before being presented to the clock select logic.

Figure 14. Timer Clock Selection Register



Refresh Control Unit

The refresh control unit (RCU) refreshes external dynamic RAM devices by outputting a 9-bit row address on address lines A_8-A_0 and performing a memory read bus cycle. External logic can distinguish a refresh bus cycle by monitoring the refresh request ($\overline{REFRQ}$) pin. Following each refresh bus cycle, the refresh row counter is incremented.

The refresh control (RFC) register in the system I/O area contains two fields. The refresh enable field enables or disables the refreshing function. The refresh timer (RTM) field selects a refresh interval to match the dynamic memory refresh requirements. Figure 15 shows the format for the RFC register.

To minimize the impact of refresh on the system bus bandwidth, the μPD70208 utilizes a refresh request queue to store refresh requests and perform refresh bus cycles in otherwise idle bus cycles.

The RCU normally requests the bus as the lowest-priority bus requester (normal mode). However, if seven refresh requests are allowed to accumulate in the RCU refresh request queue, the RCU will change to the highest-priority bus requester (demand mode). The RCU will then perform back-to-back refresh cycles until three requests remain in the queue. This guarantees the integrity of the DRAM system while maximizing performance.

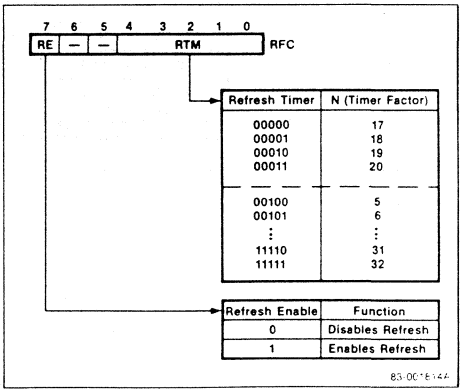
The refresh count interval can be calculated as follows:

Refresh interval = 8 x N x t_{CYK}

where N is the timer factor selected by the RTM field.

When the μPD70208 is reset, the RE field in the RFC register is unaffected and the RTM field is set to 01000 (N = 9). No refresh bus cycles occur while $\overline{RESET}$ is asserted.

Figure 15. Refresh Control Register



Wait Control Unit

The wait control unit (WCU) inserts from zero to three wait states into a bus cycle in order to compensate for the varying access times of memory and I/O devices. The number of wait states for CPU, DMAU, and RCU bus cycles is separately programmable. In addition, the memory address space is divided into three independent partitions to accommodate a wide range of system designs. $\overline{\text{RESET}}$ initializes the WCU to insert three wait states in all bus cycles. This allows operation with slow memory and peripheral devices before the initialization of the WCU registers.

The three system I/O area registers that control the WCU are wait cycle 1 (WCY1), wait cycle 2 (WCY2), and wait state memory boundary (WMB). The WCU always inserts wait states corresponding to the wait count programmed in WCY1 or WCY2 registers into a bus cycle, regardless of the state of the external READY input. After the programmed number of wait states occurs, the WCU will insert Tw states as long as the READY pin remains inactive. When READY is again asserted, the bus cycle continues with T4 as the next cycle. The μPD70208 internal peripherals never require wait states; four clock cycles will terminate an internal peripheral bus cycle.

CPU Wait States

The WMB register divides the 1M-byte memory address space into three independent partitions: lower, middle, and upper. Figure 16 shows the WMB register format.

Initialization software can then set the number of wait states for each memory partition and the I/O partition via the WCY1 register (figure 17).

DMA and Refresh Wait States

The WCY2 register (figure 18) specifies the number of wait states to be automatically inserted in DMA and refresh bus cycles.

Figure 16. Wait State Memory Boundary Register

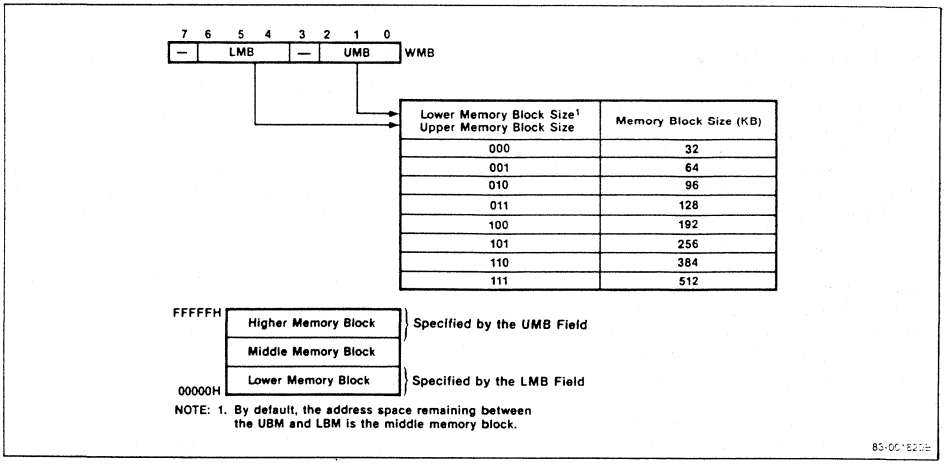


Figure 17. Wait Cycle 1 Register

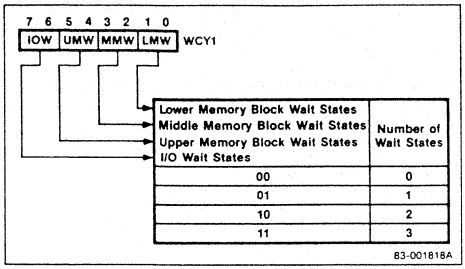
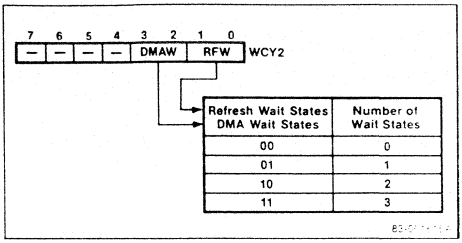


Figure 18. Wait Cycle 2 Register



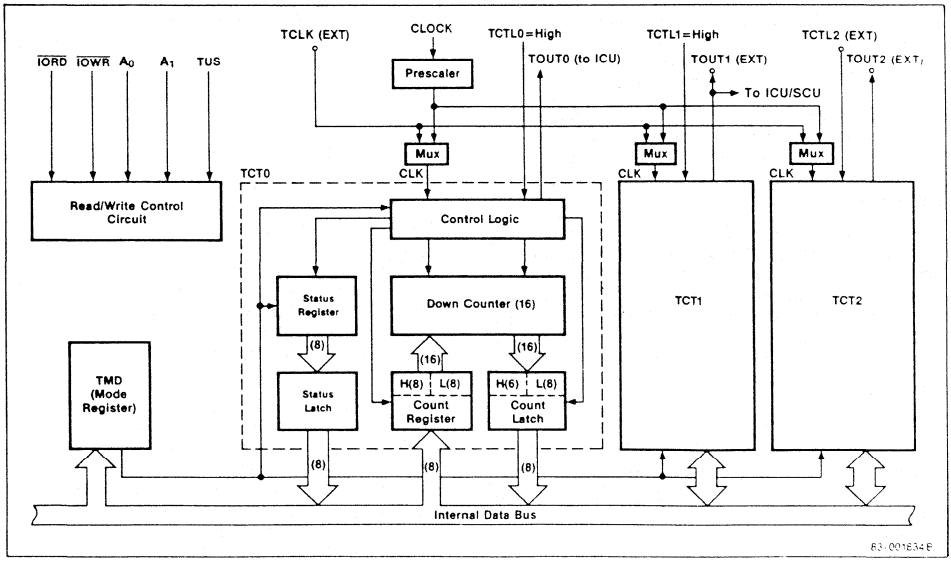
Timer/Counter Unit

The timer/counter unit (TCU) provides a set of three independent 16-bit timer/counters. The output signal of timer/counter 0 is hardwired internally as an interrupt source. The output of timer/counter 1 is available internally as an interrupt source, used as a baud rate generator, or used as an external output. The timer/counter 2 output is available as an external output. Due to mode restrictions, the TCU is a subset of the μPD71054 Programmable Timer/Counter. Figure 19 shows the internal block diagram of the TCU.

The TCU has the following features:

- Three 16-bit timer/counters
- Six programmable count modes
- Binary/BCD counting
- Multiple latch command
- Choice of two clock sources

Figure 19. TCU Block Diagram



Because $\overline{RESET}$ leaves the TCU in an uninitialized state, each timer/counter must be initialized by specifying an operating mode and a count. Once programmed, a timer/counter will continue to operate in that mode until another mode is selected. When the count has been written to the counter and transferred to the down counter, a new count operation starts. Both the current count and the counter status can be read while count operations are in progress.

TCU Commands

The TCU is programmed by issuing I/O instructions to the I/O port addresses programmed in the OPHA and TULA registers. The individual TCU registers are selected by address bits A_1 and A_0 as follows.

A_1	A_0	Register	Operation
0	0	TCTQ TST0	Read/Write Read
0	1	TCT1 TST1	Read/Write Read
1	0	TCT2 TST2	Read/Write Read
1	1	TMD	Write

The timer mode (TMD) register selects the operating mode for each timer/counter and issues the latch command for one or more timer/counters. Figure 20 shows the format for the TMD register.

Writes to the timer/counter 2-0 (TCT2-TCT0) registers stores the new count in the appropriate timer/counter. The count latch command is used before reading count data in order to latch the current count and prevent inaccuracies.

The timer status 2-0 (TST2-TST0) registers contain status information for the specified counter (figure 21). The latch command is used to latch the appropriate counter status before reading status information. If both status and counter data are latched for a counter, the first read operation returns the status data and subsequent read operations obtain the count data.

Count Modes

There are six programmable timer/counter modes. The timing waveforms for these modes are in figure 22.

Mode 0 [Interrupt on End of Count]. In this mode, TOUT changes from the low to high level when the specified count is reached. This mode is available on all timer/counters.

Mode 1 [Retriggerable One-Shot]. In mode 1, a low-level one-shot pulse, triggered by TCTL2 is output from the TOUT2 pin. This mode is available only on timer/counter 2.

Mode 2 [Rate Generator]. In mode 2, TOUT cyclically goes low for one clock period when the counter reaches the 0001H count. A counter in this mode operates as a frequency divider. All timer/counters can operate using mode 2.

Mode 3 [Square-Wave Generator]. Mode 3 is a frequency divider similar to mode 2, but the output has a symmetrical duty cycle. This mode is available on all three timer/counters. For counts of N = 2, use mode 2.

Mode 4 [Software-Triggered Strobe]. In mode 4, when the specified count is reached, TOUT goes low for the duration of one clock pulse. Mode 4 is available on all timer/counters.

Mode 5 [Hardware-Triggered Strobe]. Mode 5 is similar to mode 4 except that operation is triggered by the TCTL2 input and can be retriggered. This mode is available only on timer/counter 2.

Serial Control Unit

The serial control unit (SCU) is a single asynchronous serial channel that performs serial communication between the μPD70208 and an external serial device. The SCU is similar to the μPD71051 Serial Control Unit except for the lack of synchronous communication protocols. Figure 23 is the block diagram of the SCU.

The SCU has the following features.

- Full-duplex asynchronous serial controller
- Clock rate divisor (x16, x64)
- Baud rates to 38.4 kb/s supported
- 7-, 8-bit character lengths
- 1-, 2-bit stop bit lengths
- Break transmission and detection
- Full-duplex, double-buffered transmitter/receiver
- Even, odd, or no parity
- Parity, overrun, and framing error detection
- Receiver full and transmitter empty interrupts

The SCU contains four separately addressable registers for reading/writing data, reading status, and controlling operation of the SCU. The serial receive buffer (SRB) and the serial transmit buffer (STB) store the incoming and outgoing character data. The serial status (SST) register allows software to determine the current state of both the transmitter and receiver. The serial command (SCM) and serial mode (SMD) registers determine the operating mode of the SCU while the serial interrupt mask (SIMK) register allows software control of the SCU receive and transmit interrupts.

Figure 20. Timer Mode Register

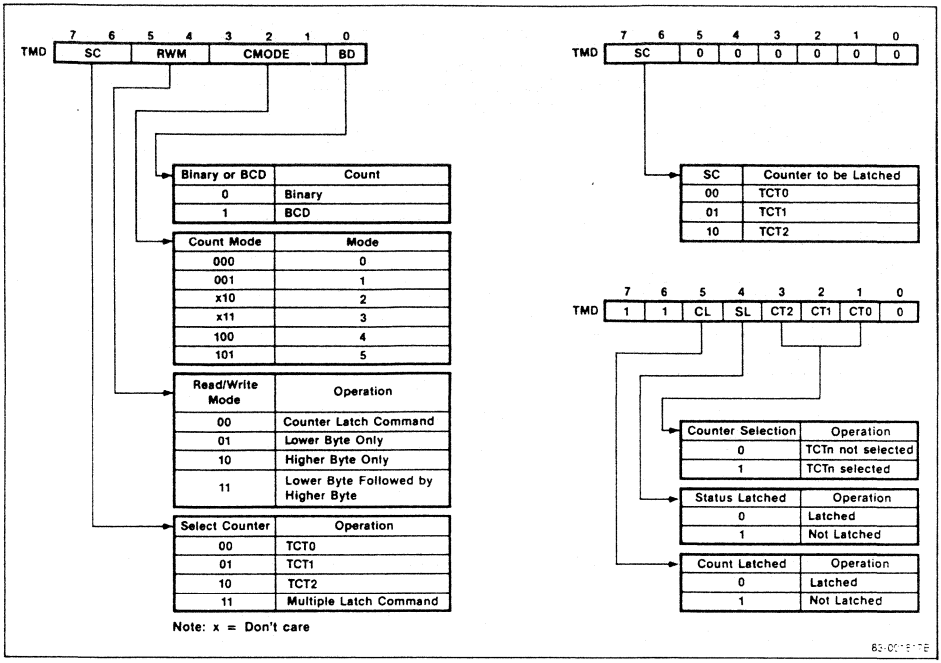


Figure 21. TCU Status Register

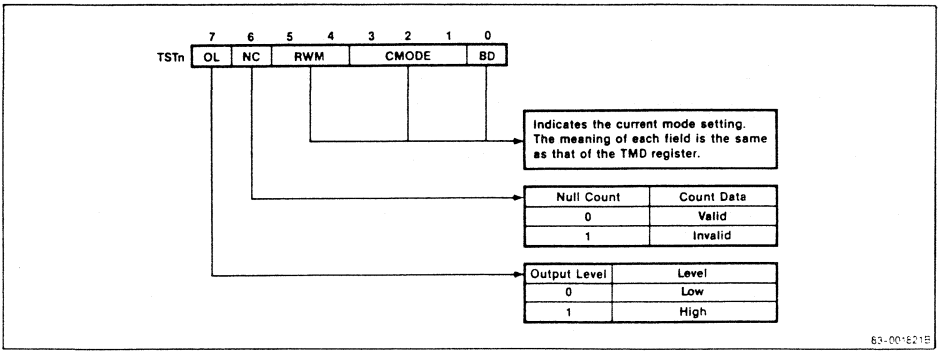


Figure 22. TCU Waveforms (Sheet 1 of 3)

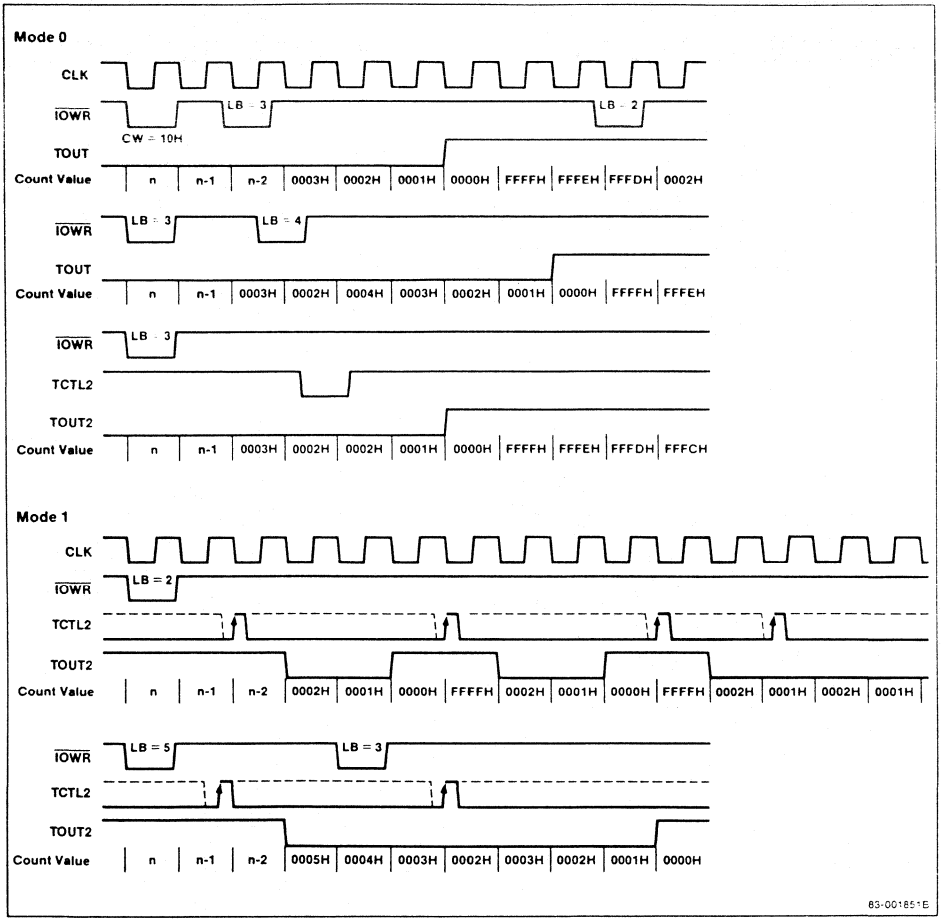


Figure 22. TCU Waveforms (Sheet 2 of 3)

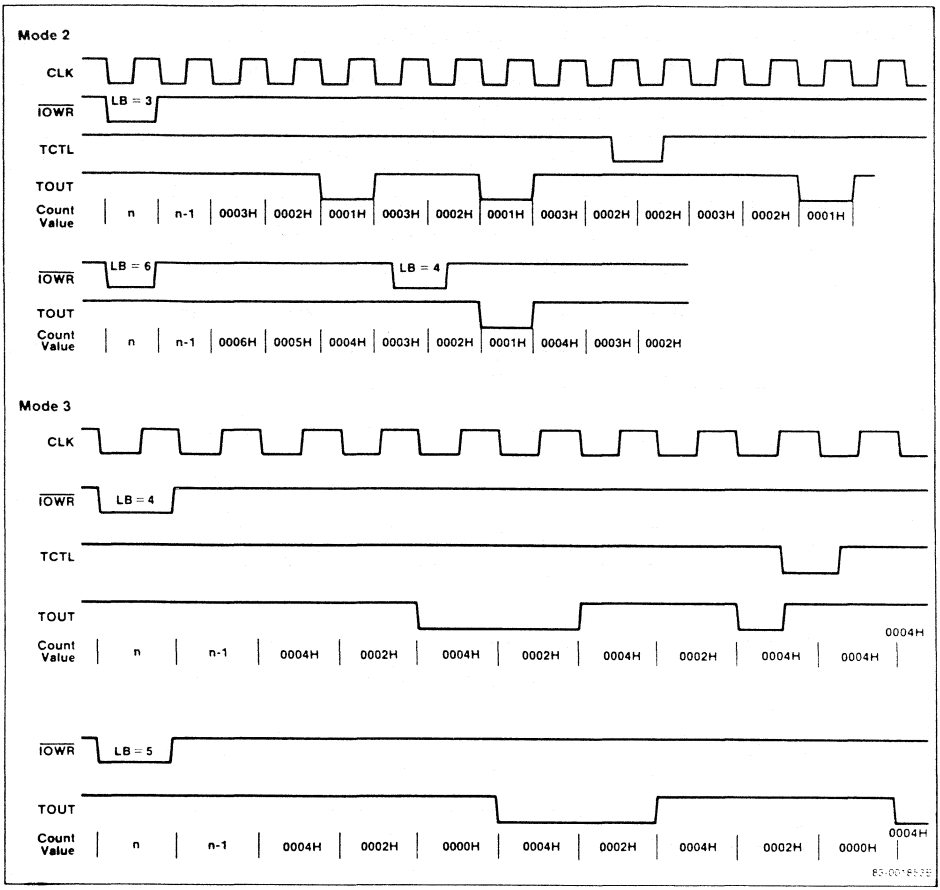


Figure 22. TCU Waveforms (Sheet 3 of 3)

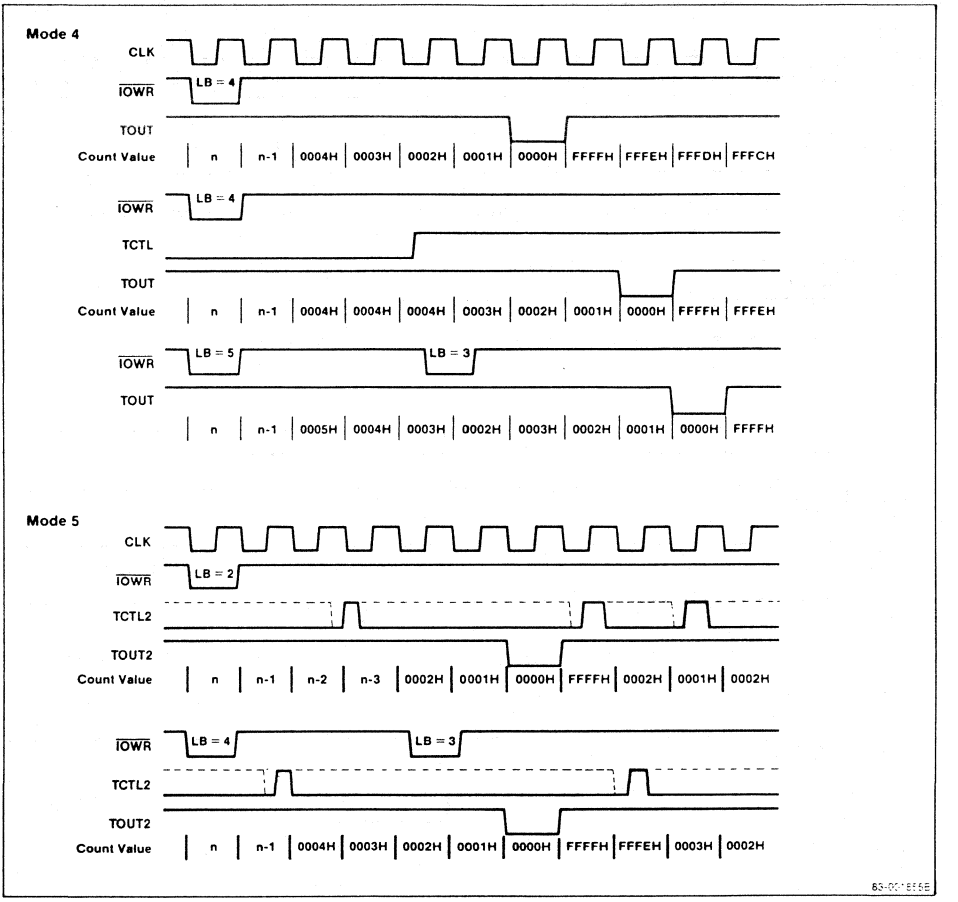
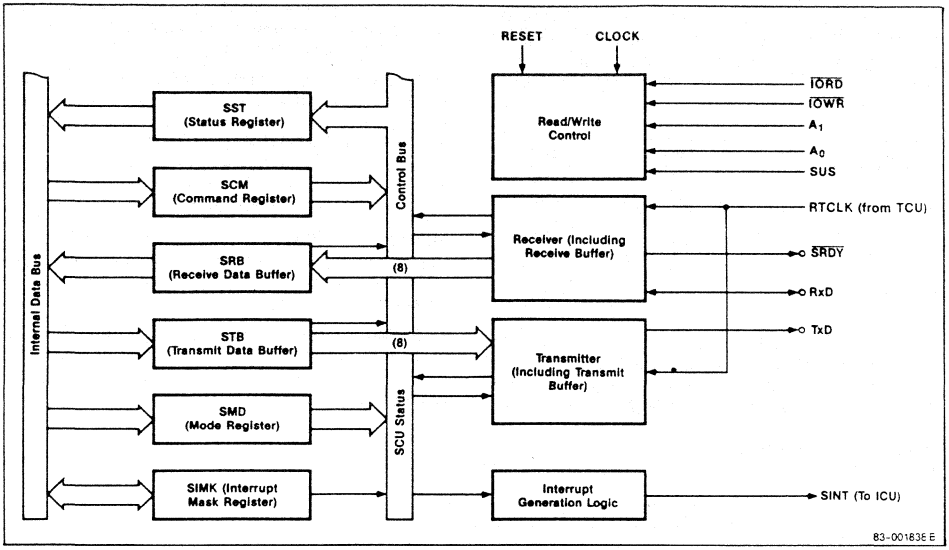


Figure 23. SCU Block Diagram



Receiver Operation

While the RxD pin is high, the SCU is in an idle state. A transition on RxD from high to low indicates the start of a new serial data reception. When a complete character has been received, it is transferred to the SRB; the receive buffer ready (RBRDY) bit in the SST register is set and (if unmasked) an interrupt is generated. The SST also latches any parity, overrun, or framing errors at this time.

The receiver detects a break condition when a null character with zero parity is received. The BRK bit is set for as long as the subsequent receive data is low and resets when RxD returns to a high level. The MRDY bit (SCM) and RBRDY (SST) are gated to form the output $\overline{SRDY}$. $\overline{SRDY}$ prevents overruns from occurring when the program is unable to process the input data. Software can control MRDY to prevent data from being sent from the remote transmitter while RBRDY can prevent the immediate overrun of a received character.

Transmitter Operation

TxD is kept high while the STB register is empty. When the transmitter is enabled and a character is written to the STB register, the data is converted to serial format and output on the TxD pin. The start bit indicates the start of the transmission and is followed by the character stream (LSB to MSB) and an optional parity bit. One or two stop bits are then appended, depending on the programmed mode. When the character has been transferred from the STB, the TRBDY bit in the SST is set and if unmasked, a transmit buffer empty interrupt is generated.

Serial data can be transmitted and received by polling the SST register and checking the TBRDY or RBRDY flags. Data can also be transmitted and received by SCU-generated interrupts to the interrupt control unit. The SCU generates an interrupt in either of these conditions:

(1) The receiver is enabled, the SRB is full, and receive interrupts are unmasked.

(2) The transmitter is enabled, the STB is empty, and transmit interrupts are unmasked.

SCU Registers and Commands

I/O instructions to the I/O addresses selected by the OPHA and SULA registers are used to read/write the SCU registers. Address bits A_1 and A_0 and the read/write lines select one of the six internal registers as follows:

A_1	A_0	Register	Operation
0	0	SRB	Read
		STB	Write
0	1	SST	Read
		SCM	Write
1	0	SMD	Write
1	1	SIMK	Read/Write

The SRB and STB are 8-bit registers. When the character length is 7 bits, the lower 7 bits of the SRB register are valid and bit 7 is cleared to 0. If programmed for 7-bit characters, bit 7 of the STB is ignored.

The SST register (figure 24) contains the status of the transmit and receive data buffers and the error flags. Error flags are persistent. Once an error flag is set, it remains set until a clear error flags command is issued.

Figure 25 shows the SCM and SMD registers. The SCM register stores the command word that controls transmission, reception, error flag reset, break transmission, and the state of the $\overline{SRDY}$ pin. The SMD register stores the mode word that determines serial characteristics such as baud rate divisor, parity, character length, and stop bit length.

Initialization software should first program the SMD register followed by the SCM register. Unlike the μPD71051, the SMD register can be modified at any time without resetting the SCU.

The SIMK register (figure 26) controls the occurrence of RBRDY and TBRDY interrupts. When an interrupt is masked, it is prevented from propagating to the interrupt control unit.

Figure 24. SST Register

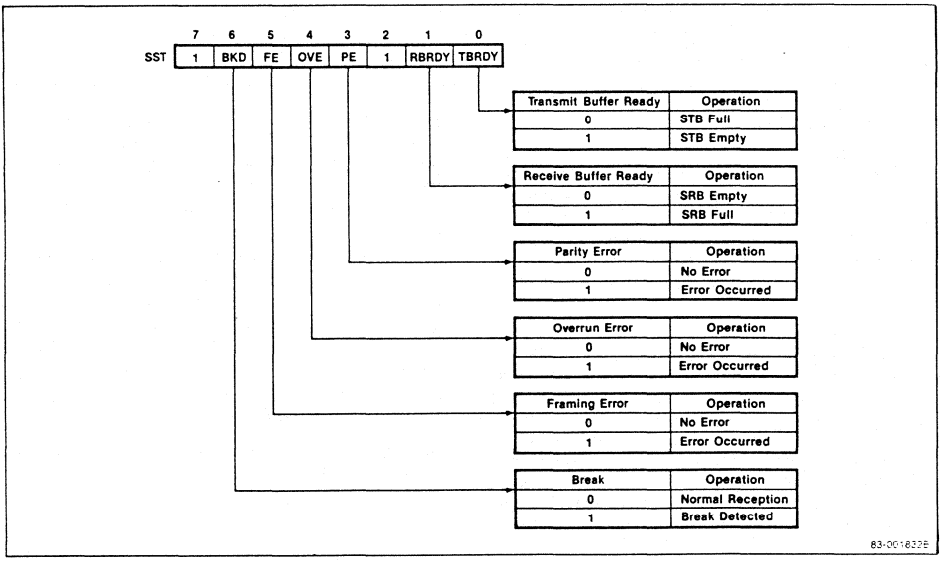
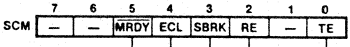


Figure 25. SCM and SMD Registers

SCM Register



Transmitter Enabled	Operation
0	Transmitter Disabled
1	Transmitter Enabled

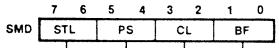
Receiver Enabled	Operation
0	Receiver Disabled
1	Receiver Enabled

Send Break	Operation
0	Normal Operation
1	TxD = 0 (Break)

Error Clear	Operation
0	No Operation
1	Error Flag Clear

$\overline{\text{MRDY}}$	Mask Ready
0	$\overline{\text{SRDY}}$ = 1 (Mask)
1	Normal Operation of $\overline{\text{SRDY}}$ Output

SMD Register



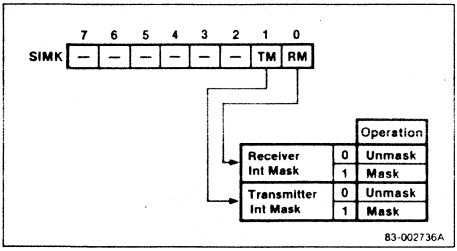
Baud Rate Factor	Operation
0-	Illegal
10	RTCLK Frequency ÷ 16
11	RTCLK Frequency ÷ 64

Character Length	Operation
0-	Illegal
10	7 Bit Characters
11	8 Bit Characters

Parity Select	Operation
-0	No Parity
01	Odd Parity
11	Even Parity

Stop Bit Length	Operation
-0	Illegal
01	1 Stop Bit
11	2 Stop Bits

Figure 26. SIMK Register



Interrupt Control Unit

The interrupt control unit (ICU) is a programmable interrupt controller equivalent to the μPD71059. The ICU arbitrates up to eight interrupt inputs, generates a CPU interrupt request, and outputs the interrupt vector number on the internal data bus during an interrupt acknowledge cycle. Cascading up to seven external slave μPD71059s permits the μPD70208 to support up to 56 interrupt sources. Figure 27 is the block diagram for the ICU.

The ICU has the following features:

- Eight interrupt request inputs
- Cascadable with μPD71059 Interrupt Controllers
- Programmable edge- or level-triggered interrupts (TCU, edge-triggered interrupts only)
- Individually maskable interrupt requests
- Programmable interrupt request priority
- Polling mode

ICU Registers

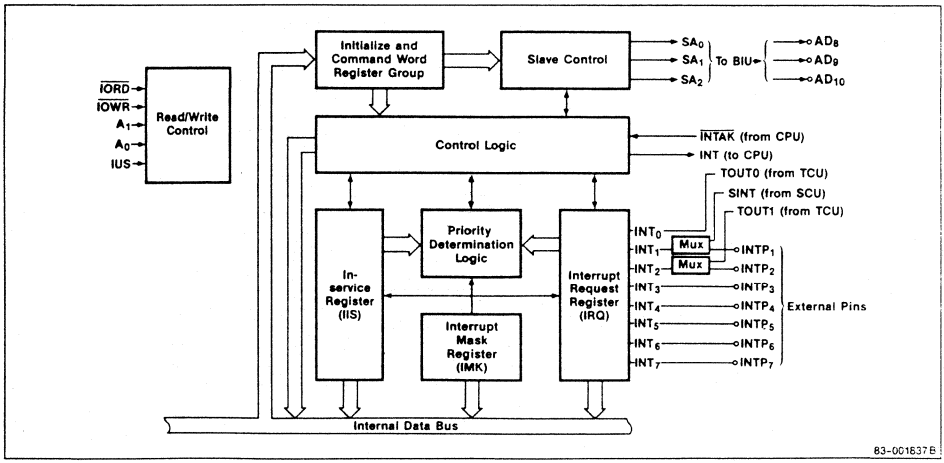
Use I/O instructions to the I/O addresses selected by the OPHA and IULA registers to read from and write to the ICU registers. Address bit A_0 and the command word selects an ICU internal register.

	A_0	Other Condition	Operation
Read	0	IMD selects IRQ	CPU ← IRQ data
	0	IMD selects IIS	CPU ← IIS data
	0	Polling phase	CPU ← Polling data
	1	—	CPU ← IMKW
Write	0	D4 = 1	CPU → IIW1
	0	D4 = 0 and D3 = 0	CPU → IPFW
	0	D4 = 0 and D3 = 1	CPU → IMDW
	1	During initialization	CPU → IIW2
	1		CPU → IIW3
	1		CPU → IIW4
	1	After initialization	CPU → IMKW

Note:

(1) In polling phase, polling data has priority over the contents of the IRQ or IIS register when read.

Figure 27. ICU Block Diagram



Initializing the ICU

The ICU is always used to service maskable interrupts in a μPD70208 system. Prior to accepting maskable interrupts, the ICU must first be initialized (figure 28). Following initialization, command words from the CPU can change the interrupt request priorities, mask/unmask interrupt requests, and select the polling mode. Figures 29 and 30 list the ICU initialization and command words.

Interrupt initialization words 1-4 (IIW1-IIW4) initialize the ICU, indicate whether external μPD71059s are connected as slaves, select the base interrupt vector, and select edge- or level-triggered inputs for INT1-INT7. Interrupt sources from the TCU are fixed as edge-triggering. INT0 is internally connected to TOUT0, and INT2 may be connected to TOUT1 by the IRSW field in the OPCN.

The interrupt mask word (IMKW) contains programmable mask bits for each of the eight interrupt inputs. The interrupt priority and finish word (IPFW) is used by the interrupt handler to terminate processing of an interrupt or change interrupt priorities. The interrupt mode word (IMDW) selects the polling register, interrupt request (IRQ) or interrupt in service (IIS) register, and the nesting mode.

The initialization words are written in consecutive order starting with IIW1. IIW2 sets the interrupt vector. IIW3 specifies which interrupts are connected to slaves. IIW3 is only required in extended systems. The ICU will only expect to receive IIW3 if SNGL = 0 (bit D_1 of IIW1). IIW4 is only written if II4 = 1 (bit D_0 of IIW1).

μPD71059 Cascade Connection

To increase the number of maskable interrupts, up to seven slave μPD71059 Interrupt Controllers can be cascaded. During cascade operation (figure 31), each slave μPD71059 INT output is routed to one of the μPD70208 INTP inputs. During the second interrupt acknowledge bus cycle, the ICU places the slave address on address lines A_{10}-A_8. Each slave compares this address with the slave address programmed using interrupt initialization word 3 (IIW3). If the same, the slave will place the interrupt vector on pins AD_7-AD_0 during the second interrupt acknowledge bus cycle.

Figure 28. Initialization Sequence

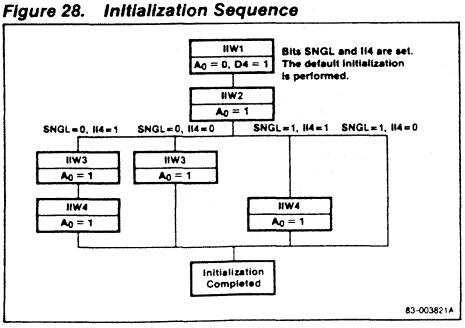


Figure 29. Interrupt Initialization Words 1-4

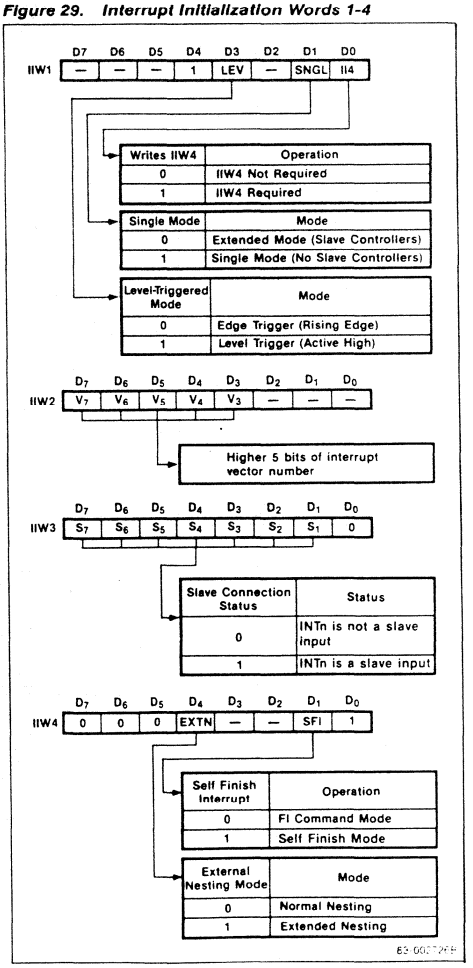


Figure 30. Command Words

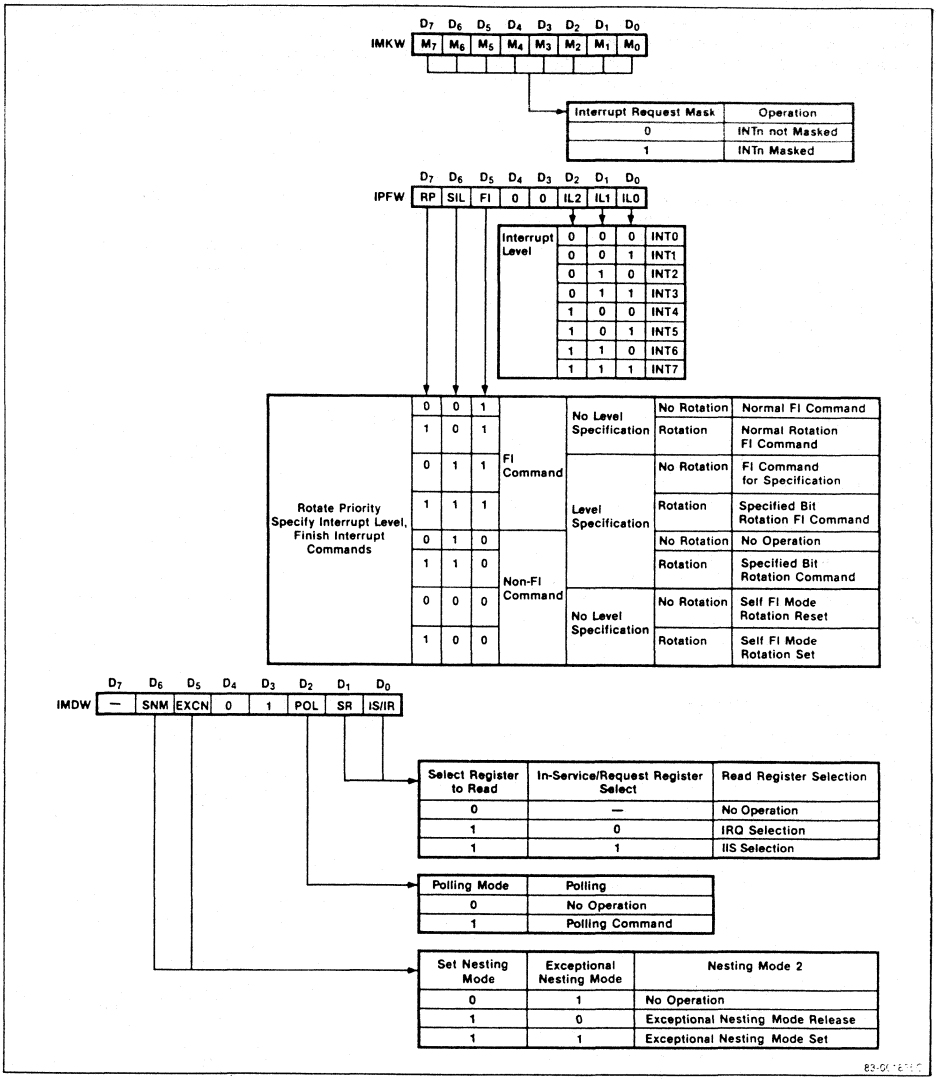
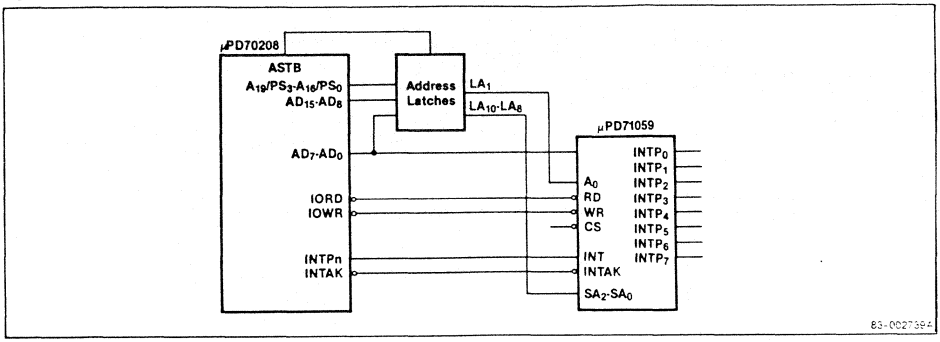


Figure 31. μPD71059 Cascade Connection



DMA Control Unit

The DMA Control Unit (DMAU) is a high-speed DMA controller compatible with the μPD71071 DMA Controller. The DMAU has four independent DMA channels and performs high-speed data transfers between memory and external peripheral devices at speeds as high as 2 megabytes/second in an 8-MHz system. Figure 32 is the block diagram for the DMAU.

The DMAU has the following features.

- Four independent DMA channels
- Cascade mode for slave μPD71071 DMA controllers
- 20-bit address registers
- 16-bit transfer count register
- Single, demand, and block transfer modes
- Bus release and bus hold modes
- Autoinitialization
- Address increment/decrement
- Fixed/rotating channel priorities
- TC output at transfer end
- Forced termination of service by $\overline{END}$ input

DMAU Basic Operation

The DMAU operates in either a slave or master mode. In the slave mode, the DMAU samples the four DMARQ input pins every clock. If one or more inputs are active, the corresponding DMA request bits are set and the DMAU sends a bus request to the BAU while continuing to sample the DMA request inputs. After the BAU returns the DMA bus acknowledge signal, the DMAU stops DMA request sampling, selects the DMA channel with the highest priority, and enters the bus master mode to perform the DMA transfer. While in the bus master mode, the DMAU controls the external bus and performs DMA transfers based on the preprogrammed channel information.

Terminal Count

The DMAU ends DMA service when the terminal count condition is generated or when the $\overline{END}$ input is asserted. A terminal count (TC) is produced when the contents of the current count register becomes zero. If autoinitialization is not enabled when DMA service terminates, the mask bit of the channel is set and the DMARQ input of that channel is masked. Otherwise, the current count and address registers are reloaded from the base registers and new DMA transfers are again enabled.

DMA Transfer Type

The type of transfer the DMAU performs depends on the following conditions.

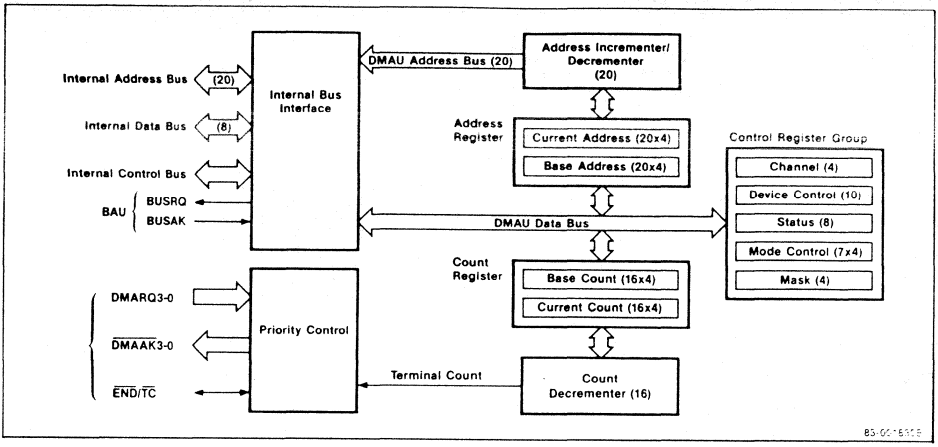
- Direction of the transfer (each channel)
- Transfer mode (each channel)
- Bus mode

Transfer Direction

All DMA transfers use memory as a reference point. Therefore, a DMA read operation transfers data from memory to an I/O port. A DMA write reads an I/O port and writes the data to memory. During memory-to-I/O transfer, the DMA mode (DMD) register is used to select the transfer directions for each channel and activate the appropriate control signals.

Operation	Transfer Direction	Activated Signals
DMA read	Memory → I/O	$\overline{IOWR}$, $\overline{MRD}$
DMA write	I/O → Memory	$\overline{IORD}$, $\overline{MWR}$
DMA verify		Addresses only, no transfer performed

Figure 32. DMAU Block Diagram

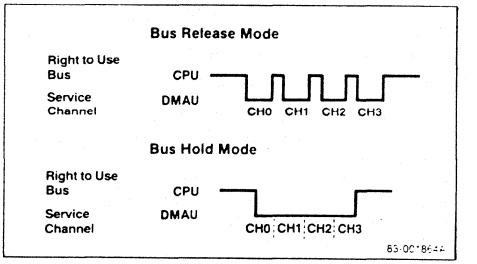


Bus Mode

The DMA device control (DDC) register selects operation in either the bus release or bus hold mode. The selected bus mode determines the DMAU conditions for return of the bus to the BAU. Figure 33 shows that in bus release mode, only one channel is serviced after the DMAU obtains the bus. When DMA service ends (termination conditions depend on the transfer mode), the DMAU returns the bus to the BAU regardless of the state of other DMA requests, and the DMAU reenters the slave mode. When the DMAU regains use of the bus, a new DMA operation can begin.

In bus hold mode, several channels can receive contiguous service without releasing the bus. If there is another valid DMA request when a channel's DMA service is finished, the new DMA service can begin immediately after the previous service without returning the bus to the BAU.

Figure 33. Bus Modes



Transfer Modes

The DMD register also selects either single, demand, or block transfer mode for each channel. The conditions for the termination of each transfer characterize each transfer mode. The following table shows the various transfer modes and termination conditions.

Transfer Mode	Termination Conditions
Single	After each byte/word transfer
Demand	$\overline{\text{END}}$ input Terminal count Inactive DMARQ DMARQ of a higher priority channel becomes active (bus hold mode)
Block	$\overline{\text{END}}$ input Terminal count

The operation of single, demand, and block mode transfers depends on whether the DMAU is in bus release or bus hold mode. Figure 34 shows the operation flow for the six possible transfer and bus mode operations in DMA transfer.

Single-Mode Transfer. In bus release mode, when a channel completes transfer of a single byte, the DMAU enters the slave mode regardless of the state of DMA request inputs. In this manner, other lower-priority bus masters will be able to access the bus.

In bus hold mode, when a channel completes transfer of a single byte, the DMAU terminates the channel's service even if the DMARQ request signal is asserted. The DMAU will then service any other requesting channel. If there are no requests from any other DMA channels, the DMAU releases the bus and enters the slave state.

Demand-Mode Transfer. In bus release mode, the currently active channel continues to transfer data as long as the DMA request of that channel is active, even though other DMA channels are issuing higher-priority requests. When the DMA request of the serviced channel becomes inactive, the DMAU releases the bus and enters the slave state.

In bus hold mode, when the active channel completes a single transfer, the DMAU checks the other DMA request lines without ending the current service. If there is a higher-priority DMA request, the DMAU stops the service of the current channel and starts servicing the highest-priority channel requesting service. If there is no higher request than the current one, the DMAU continues to service the currently active channel. Lower-priority DMA requests are honored without releasing the bus after the current channel service is complete.

Block-Mode Transfer. In bus release mode, the current channel continues DMA transfers until a terminal count or the external END input becomes active. During this time, the DMAU ignores all other DMA requests. After completion of the block transfer, the DMAU releases the bus and enters the slave state, even if DMA requests from other channels are active.

In bus hold mode, the current channel transfers data until an internal or external END signal becomes active. When the service is complete, the DMAU checks all DMA requests without releasing the bus. If there is an active request, the DMAU immediately begins servicing the request. The DMAU releases the bus after it honors all DMA requests or a higher-priority bus master requests the bus.

Byte Transfer

The DMD register can specify only byte DMA transfers for each channel. Depending on the mode selected, the address register can either increment or decrement whereas the count register is always decremented.

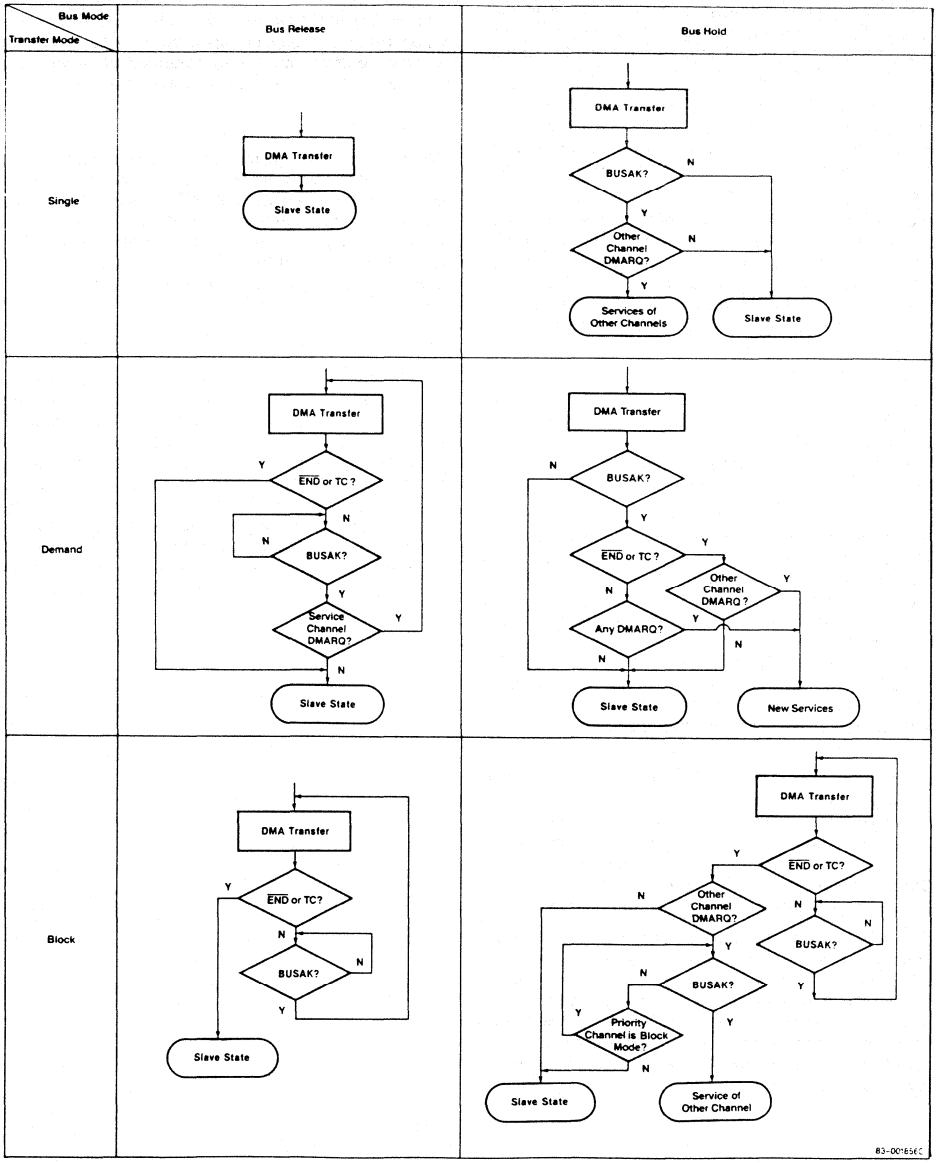
Autoinitialize

When the DMD register selects autoinitialize for a channel, the DMAU automatically reinitializes the address and count registers when $\overline{END}$ is asserted or the terminal count condition is reached. The contents of the base address and base count registers are transferred to the current address and current count registers. and the applicable bit of the mask register remains cleared.

Channel Priority

Each of the four DMAU channels is assigned a priority. When multiple DMA requests from several channels occur simultaneously, the channel with the highest priority will be serviced first. The DDC register selects one of two priority schemes: fixed or rotating (figure 35). In fixed priority, channel 0 is assigned the highest priority and channel 3, the lowest. In rotating priority, priority order is rotated after each service so that the channel last serviced receives the lowest priority. This method prevents the exclusive servicing of higher-priority channels and the lockout of lower-priority DMA channels.

Figure 34. Transfer Modes



Cascade Connection

Slave μPD71071 DMA Controllers can be cascaded to easily expand the system DMA channel capacity to 16 DMA channels. Figure 36 shows an example of cascade connection. During cascade operation, the DMAU acts as a mediator between the BAU and the slave μPD71071s. All other bus outputs are disabled while a slave DMA controller is active.

The DMAU always operates in the bus hold mode while a cascade channel is in service, even when the bus release mode is programmed. Other DMA requests are held pending while a slave μPD71071 channel is in service. When the cascaded μPD71071 ends service and moves into the slave state, the DMAU also moves to the slave state and releases the bus. At this time, all bits of the DMAU request register are cleared. The DMAU continues to operate normally with the other noncascaded channels.

Figure 35. Priority Order

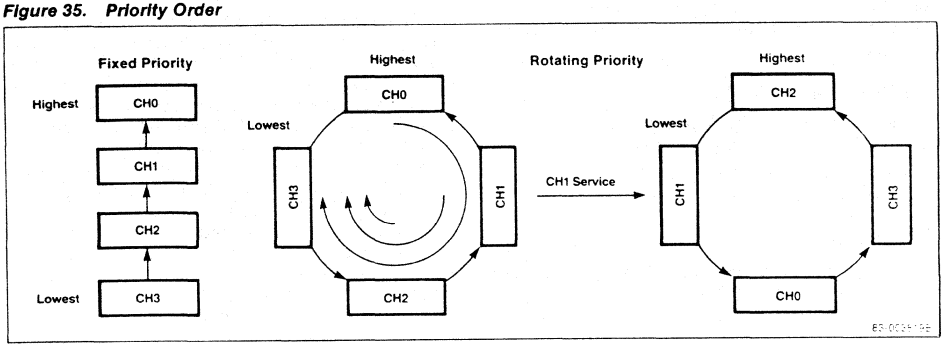
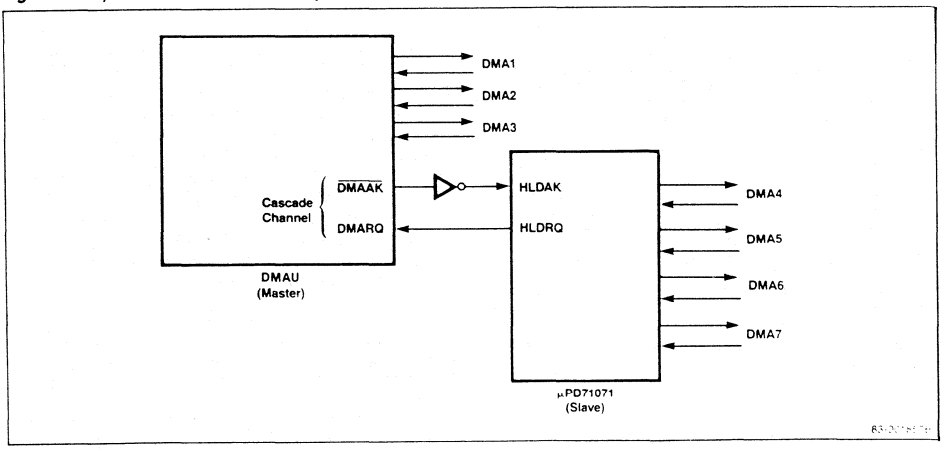


Figure 36. μPD71071 Cascade Example



Bus Waiting Operation

The DMAU will automatically perform a bus waiting operation (figure 37) whenever the RCU refresh request queue fills. When the DMA bus acknowledge goes inactive, the DMAU enters the bus waiting mode and inactivates the DMA bus request signal. Control of the bus is then transferred to the higher-priority RCU by the BAU.

Two clocks later, the DMAU reasserts its internal DMA bus request. The bus waiting mode is continued until the DMA bus acknowledge signal again becomes active and the interrupted DMA service is immediately restarted.

Programming the DMAU

To prepare a channel for DMA transfer, the following characteristics must be programmed.

- Starting address for the transfer
- Transfer count
- DMA operating mode
- Transfer size (byte/word)

The contents of the OPHA and DULA registers determine the base I/O port address of the DMAU. Addresses A_3-A_0 are used to select a particular register as follow:

A_3	A_2	A_1	A_0	Register	Operation
0	0	0	0	DICM	Write
0	0	0	1	DCH	Read/Write
0	0	1	0	DBC/DCC (low)	Read/Write
0	0	1	1	DBC/DCC (high)	Read/Write
0	1	0	0	DBA/DCA (low)	Read/Write
0	1	0	1	DBA/DCA (high)	Read/Write
0	1	1	0	DBA/DCA (upper)	Read/Write
0	1	1	1	Reserved	—
1	0	0	0	DDC (low)	Read/Write
1	0	0	1	DDC (high)	Read/Write
1	0	1	0	DMD	Read/Write
1	0	1	1	DST	Read
1	1	0	0	Reserved	—
1	1	0	1	Reserved	—
1	1	1	0	Reserved	—
1	1	1	1	DMK	Read/Write

Word I/O instructions can be used to read/write the register pairs listed below. All other registers are accessed via byte I/O instructions.

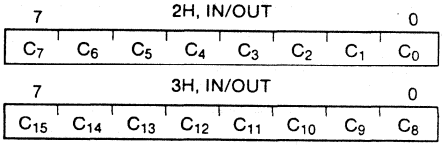
DBC/DCC
DBA/DCA (higher/lower only)
DDC

DMAU Registers

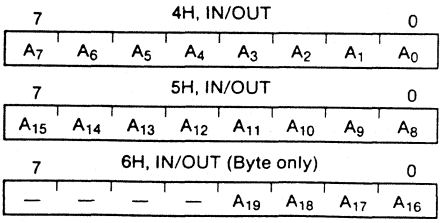
Initialize. The DMA initialize command (DICM) register (figure 38) is used to perform a software reset of the DMAU. The DICM is accessed using the byte OUT instruction.

Channel Register. Writes to the DMA channel (DCH) register (figure 39) select one of the four DMA channels for programming and also the base/current registers. Reads of the DCH register return the currently-selected channel and the register access mode.

Count Registers. When bit 2 of the DCH register is cleared, a write to the DMA count register updates both the DMA base count (DBC) and the DMA current count (DCC) registers with a new count. If bit 2 of the DCH register is set, a write to the DMA count register affects only the DBC register. The DBC register holds the initial count value until a new count is specified. If autoinitialization is enabled, this value is transferred to the DCC register when a terminal count or END condition occurs. For each DMA transfer, the current count register is decremented by one. The format of the DMA count register is shown below. The count value loaded into the DBC/DCC registers is one less than the desired transfer count.



Address Register. Use either byte or word I/O instructions with the lower two bytes (4H and 5H) of the DMA address register. However, byte I/O instructions must be used to access the high-order byte (6H) of this register. When bit 2 of the channel register is cleared, a write to the DMA address register updates both the DMA base address (DBA) and the DMA current address (DCA) registers with the new address. If bit 2 of the DCH register is set, a write to the DMA address register affects only the DBA register.



The DBA register holds the starting address value until a new address is specified. This value is transferred to the DCA register automatically if autoinitialization is selected. For each DMA transfer, the current address register is incremented/decremented by one.

Device Control Register. The DMA device control (DDC) register (figure 40) is used to to program the DMA transfer characteristics common to all DMA channels. It controls the bus mode, write timing, priority logic, and enable/disable of the DMAU.

Status Register. The DMA status (DST) register (figure 41) contains information about the current state of each DMA channel. Software can determine if a termination condition has been reached (TC_3-TC_0) or if a DMA service request is present (RQ_3-RQ_0). The byte IN instruction must be used to read this register.

Figure 37. Bus Waiting Operation

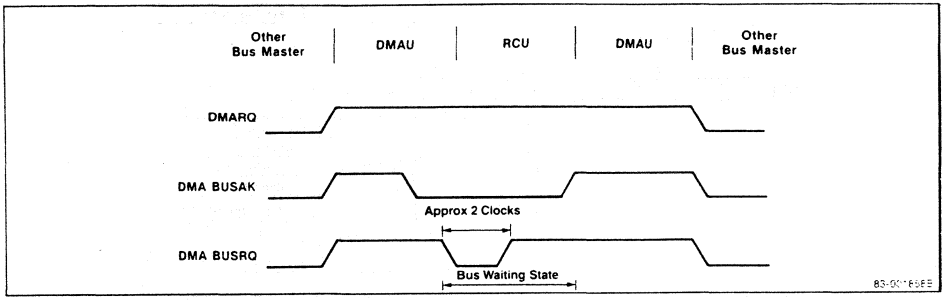
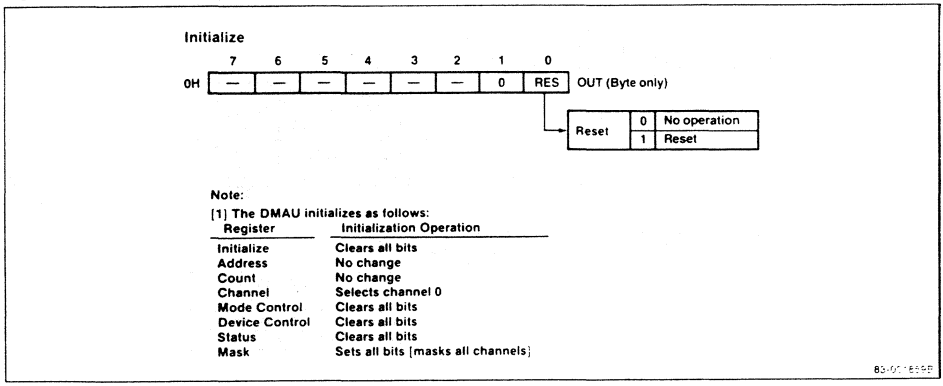


Figure 38. DMA Initialize Command Register



Note:
[1] The DMAU initializes as follows:

Register	Initialization Operation
Initialize	Clears all bits
Address	No change
Count	No change
Channel	Selects channel 0
Mode Control	Clears all bits
Device Control	Clears all bits
Status	Clears all bits
Mask	Sets all bits (masks all channels)

Figure 39. DMA Channel Register

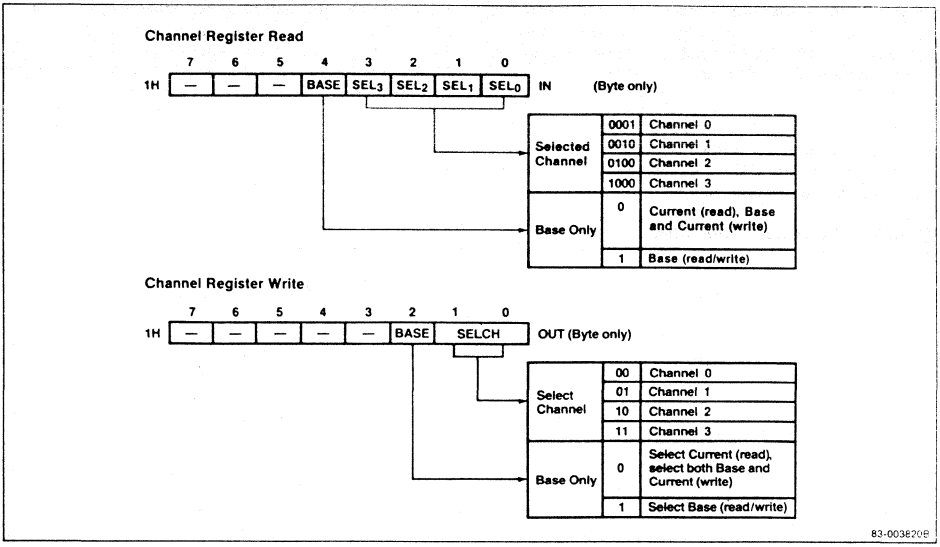
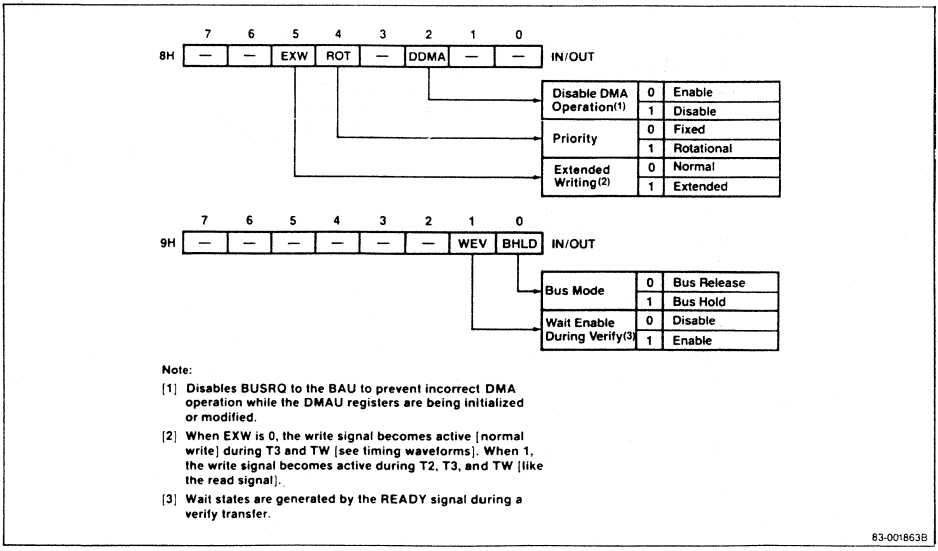


Figure 40. DMA Device Control Register



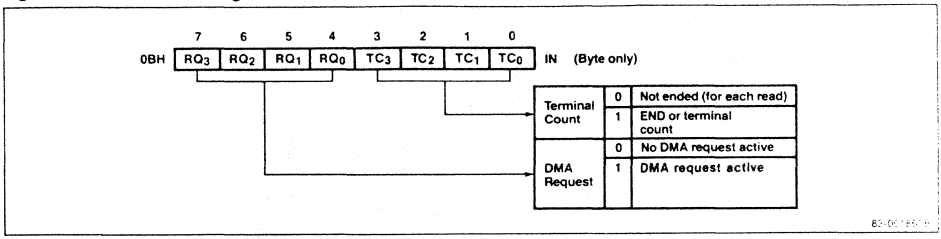
Note:

[1] Disables BUSRQ to the BAU to prevent incorrect DMA operation while the DMAU registers are being initialized or modified.

[2] When EXW is 0, the write signal becomes active [normal write] during T3 and TW [see timing waveforms]. When 1, the write signal becomes active during T2, T3, and TW [like the read signal].

[3] Wait states are generated by the READY signal during a verify transfer.

Figure 41. DMA Status Register



Mode Control Register. The DMA mode (DMD) register (figure 42) selects the operating mode for each DMA channel. The DCH register selects which DMD register will be accessed. A byte IN/OUT instruction must be used to access this register.

Mask Register Read/Write. The DMA mask (DMK) register (figure 43) allows software to individually enable and disable DMA channels. The DMK register can only be accessed via byte I/O instructions.

Reset

The falling edge of the $\overline{RESET}$ signal resets the μPD70208. The signal must be held low for at least four clock cycles to be recognized as valid.

CPU Reset State Register	Reset Value
PFP	0000H
PC	0000H
PS	FFFFH
SS	0000H
DS0	0000H
DS1	0000H
PSW	F002H
AW, BW, CW, DW, IX, IY, BP, SP	Undefined
Instruction queue	Cleared

When $\overline{RESET}$ returns to the high level, the CPU will start fetching instructions from physical address FFFF0H.

Internal Peripheral Devices

Internal peripheral devices initialized on reset are listed in the following table. I/O devices not listed are not initialized on reset and must be initialized by software.

	Register	Reset Value
System I/O area	OPCN	----0000
	OPSEL	----0000
	WCY1	11111111
	WCY2	----1111
	TCKS	---00000
	RFC	x--01000
SCU	SMD	01001011
	SCM	--0000-0
	SIMK	------11
	SST	10000100
	DCH	---00001
	DMD	000000-0
DMAU	DDC (low)	--00-0--
	DDC (high)	------00
	DST	xxxx0000
	DMK	----1111

Symbols: x = unaffected; 0 = cleared; 1 = set; (-) = unused

Output Pin Status

The following table lists output pin status during reset

Signal	Status
$\overline{INTAK}$, $\overline{BUFEN}$, $\overline{BUFR/W}$, $\overline{MRD}$, $\overline{MWR}$, $\overline{END/TC}$, $\overline{IOWR}$, $\overline{IORD}$, $\overline{REFRQ}$, BS_2-BS_0, $\overline{BUSLOCK}$, RESOUT, $\overline{DMAAK3}$-$\overline{DMAAK0}$	High level
QS_1-QS_0, ASTB, HLDAK	Low level
A_{19}-A_{16}/PS_3-PS_0, TOUT2	High or low level
A_{15}-A_8, AD_7-AD_0	High impedance
CLKOUT	Continues to supply clock

Figure 42. DMA Mode Register

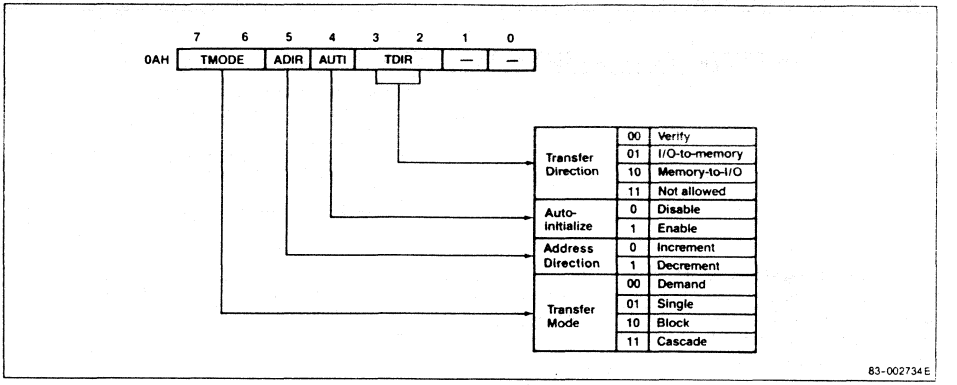
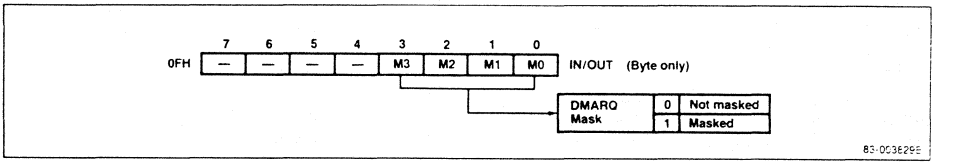


Figure 43. DMA Mask Register



Instruction Set

Symbols

Preceding the instruction set, several tables explain symbols, abbreviations, and codes.

Clocks

In the Clocks column of the instruction set, the numbers cover these operations: instruction decoding, effective address calculation, operand fetch, and instruction execution.

Clock timings assume the instruction has been pre-fetched and is present in the four-byte instruction queue. Otherwise, add four clocks for each byte not present.

For instructions that reference memory operands, the number on the left side of the slash (/) is for byte operands and the number on the right side is for word operands.

For conditional control transfer or branch instructions, the number on the left side of the slash is applicable if the transfer or branch takes place. The number on the right side is applicable if it does not take place.

If a range of numbers is given, the execution time depends on the operands involved.

Symbols

Symbol	Meaning
acc	Accumulator (AW or AL)
disp	Displacement (8 or 16 bits)
dmem	Direct memory address
dst	Destination operand or address
ext-disp8	16-bit displacement (sign-extension byte + 8-bit displacement)
far_label	Label within a different program segment
far_proc	Procedure within a different program segment
fp_op	Floating point instruction operation
imm	8- or 16-bit immediate operand
imm3/4	3/4-bit immediate bit offset
imm8	8-bit immediate operand
imm16	16-bit immediate operand
mem	Memory field (000 to 111): 8- or 16-bit memory location

Symbols

Symbol	Meaning
mem8	8-bit memory location
mem16	16-bit memory location
mem32	32-bit memory location
memptr16	Word containing the destination address within the current segment
memptr32	Double word containing a destination address in another segment
mod	Mode field (00 to 10)
near_label	Label within the current segment
near_proc	Procedure within the current segment
offset	Immediate offset data (16 bits)
pop_value	Number of bytes to discard from the stack
reg	Register field (000 to 111): 8- or 16-bit general-purpose register
reg8	8-bit general-purpose register
reg16	16-bit general-purpose register
regptr	16-bit register containing a destination address within the current segment
regptr16	Register containing a destination address within the current segment
seg	Immediate segment data (16 bits)
short_label	Label between −128 and −127 bytes from the end of the current instruction
sr	Segment register
src	Source operand or address
temp	Temporary register (8/16/32 bits)
tmpcy	Temporary carry flag (1 bit)
AC	Auxiliary carry flag
AH	Accumulator (high byte)
AL	Accumulator (low byte)
AND	Logical product
AW	Accumulator (16 bits)
BH	BW register (high byte)
BL	BW register (low byte)
BP	BP register
BRK	Break flag
BW	BW register (16 bits)
CH	CW register (high byte)
CL	CW register (low byte)
CW	CW register (16 bits)
CY	Carry flag
DH	DW register (high byte)
DIR	Direction flag
DL	DW register (low byte)

Symbols (cont)

Symbol	Meaning
DS0	Data segment 0 register (16 bits)
DS1	Data segment 1 register (16 bits)
DW	DW register (16 bits)
IE	Interrupt enable flag
IX	Index register (source) (16 bits)
IY	Index register (destination) (16 bits)
MD	Mode flag
OR	Logical sum
P	Parity flag
PC	Program counter (16 bits)
PS	Program segment register (16 bits)
PSW	Program status word (16 bits)
R	Register set
S	Sign extend operand field S = 0 No sign extension S = 1 Sign extend immediate byte operand
S	Sign flag
SP	Stack pointer (16 bits)
SS	Stack segment register (16 bits)
V	Overflow flag
W	Word/byte field (0 to 1)
X, XXX, YYY, ZZZ	Data to identify the instruction code of the external floating point arithmetic chip
XOR	Exclusive logical sum
XXH	Two-digit hexadecimal value
XXXXH	Four-digit hexadecimal value
Z	Zero flag
( )	Values in parentheses are memory contents
←	Transfer direction
+	Addition
−	Subtraction
x	Multiplication
÷	Division
%	Modulo

Flag Operations

Symbol	Meaning
(blank)	No change
0	Cleared to 0
1	Set to 1
x	Set or cleared according to result
u	Undefined
R	Restored to previous state

Memory Addressing Modes

mem	mod = 00	mod = 01	mod = 10
000	BW + IX	BW + IX + disp8	BW + IX + disp16
001	BW + IY	BW + IY + disp8	BW + IY + disp16
010	BP + IX	BP + IX + disp8	BP + IX + disp16
011	BP + IY	BP + IY + disp8	BP + IY + disp16
100	IX	IX + disp8	IX + disp16
101	IY	IY + disp8	IY + disp16
110	Direct	BP + disp8	BP + disp16
111	BW	BW + disp8	BW + disp16

Register Selection (mod = 11)

reg	W = 0	W = 1
000	AL	AW
001	CL	CW
010	DL	DW
011	BL	BW
100	AH	SP
101	CH	BP
110	DH	IX
111	BH	IY

Segment Register Selection

sr	Segment Register
00	DS1
01	PS
10	SS
11	DS0

Instruction Set

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Data Transfer Instructions																									
MOV	reg, reg	1	0	0	0	1	0	1	W	1	1		reg			reg		2	2						
	mem, reg	1	0	0	0	1	0	0	W	mod			reg			mem		7/11	2-4						
	reg, mem	1	0	0	0	1	0	1	W	mod			reg			mem		10/14	2-4						
	mem, imm	1	1	0	0	0	1	1	W	mod			reg			mem		9/13	3-6						
	reg, imm	1	0	1	1	W		reg										4	2-3						
	acc, dmem	1	0	1	0	0	0	0	W									10/14	3						
	dmem, acc	1	0	1	0	0	0	1	W									9/13	3						
	sr, reg16	1	0	0	0	1	1	1	0	1	1	0	sr			reg		2	2						
	sr, mem16	1	0	0	0	1	1	1	0	mod		0	sr			mem		14	2-4						
	reg16, sr	1	0	0	0	1	1	0	0	1	1	0	sr			reg		2	2						
	mem16, sr	1	0	0	0	1	1	0	0	mod		0	sr			mem		12	2-4						
	DS0, reg16, mem32	1	1	0	0	0	1	0	1	mod			reg			mem		25	2-4						
	DS1, reg16, mem32	1	1	0	0	0	1	0	0	mod			reg			mem		25	2-4						
	AH, PSW	1	0	0	1	1	1	1	1									2	1						
	PSW, AH	1	0	0	1	1	1	1	0									3	1	x	x		x	x	x
LDEA	reg16, mem16	1	0	0	0	1	1	0	1	mod			reg			mem		4	2-4						
TRANS	src_table	1	1	0	1	0	1	1	1									9	1						
XCH	reg, reg	1	0	0	0	0	1	1	W	1	1		reg			reg		3	2						
	mem, reg	1	0	0	0	0	1	1	W	mod			reg			mem		13/21	2-4						
	AW, reg16	1	0	0	1	0		reg										3	1						
Repeat Prefixes																									
REPC		0	1	1	0	0	1	0	1									2	1						
REPNC		0	1	1	0	0	1	0	0									2	1						
REP REPE REPZ		1	1	1	1	0	0	1	1									2	1						
REPNE REPNZ		1	1	1	1	0	0	1	0									2	1						
Block Transfer Instructions																									
MOVBK	dst, src	1	0	1	0	0	1	0	W									1 9 (9) + 8n (W = 0) 9 (17) + 16n (W = 1)							
CMPBK	dst, src	1	0	1	0	0	1	1	W									1 7 (13) + 14n (W = 0) 7 (21) + 22n (W = 1)		x	x	x	x	x	x
CMPM	dst	1	0	1	0	1	1	1	W									1 7 (7) + 10n (W = 0) 7 (11) + 14n (W = 1)		x	x	x	x	x	x
LDM	src	1	0	1	0	1	1	0	W									1 7 (7) + 9n (W = 0) 7 (11) + 13n (W = 1)							
STM	dst	1	0	1	0	1	0	1	W									1 5 (5) + 4n (W = 0) 5 (9) + 8n (W = 1)							

n = number of transfers
String instruction execution clocks for a single instruction execution are in parentheses

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
I/O Instructions																									
IN	acc, imm8	1	1	1	0	0	1	0	W									9/13	2						
	acc, DW	1	1	1	0	1	1	0	W									8/12	1						
OUT	imm8, acc	1	1	1	0	0	1	1	W									8/12	2						
	DW, acc	1	1	1	0	1	1	1	W									8/12	1						
INM	dst, DW	0	1	1	0	1	1	0	W									9 (10) + 8n (W = 0) 9 (18) + 16n (W = 1)	1						
OUTM	DW, src	0	1	1	0	1	1	1	W									9 (10) + 8n (W = 0) 9 (18) + 16n (W = 1)	1						
		n = number of transfers String instruction execution clocks for a single instruction execution are in parentheses.																							
BCD Instructions																									
ADJBA		0	0	1	1	0	1	1	1									7	1	x	x	u	u	u	u
ADJ4A		0	0	1	0	0	1	1	1									3	1	x	x	u	x	x	x
ADJBS		0	0	1	1	1	1	1	1									7	1	x	x	u	u	u	u
ADJ4S		0	0	1	0	1	1	1	1									3	1	x	x	u	x	x	x
ADD4S	dst, src	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	0	7 + 19n	2	u	x	u	u	u	x
SUB4S	dst, src	0	0	0	0	1	1	1	1	0	0	1	0	0	0	1	0	7 + 19n	2	u	x	u	u	u	x
CMP4S	dst, src	0	0	0	0	1	1	1	1	0	0	1	0	0	1	1	0	7 + 19n	2	u	x	u	u	u	x
ROL4	reg8	0 1	0 1	0 0	0 0	1 0	1	1 reg	1	0	0	1	0	1	0	0	0	13	3						
	mem8	0 mod	0	0 0	0 0	1 0	1	1 mem	1	0	0	1	0	1	0	0	0	25	3-5						
ROR4	reg8	0 1	0 1	0 0	0 0	1 0	1	1 reg	1	0	0	1	0	1	0	1	0	17	3						
	mem8	0 mod	0	0 0	0 0	1 0	1	1 mem	1	0	0	1	0	1	0	1	0	29	3-5						
		n = number of BCD digits divided by 2																							
Data Type Conversion Instructions																									
CVTBD		1	1	0	1	0	1	0	0	0	0	0	0	1	0	1	0	15	2	u	u	u	x	x	x
CVTDB		1	1	0	1	0	1	0	1	0	0	0	0	1	0	1	0	7	2	u	u	u	x	x	x
CVTBW		1	0	0	1	1	0	0	0									2	1						
CVTWL		1	0	0	1	1	0	0	1									4/5	1						
Arithmetic Instructions																									
ADD	reg, reg	0	0	0	0	0	0	1	W	1	1	reg		reg				2	2	x	x	x	x	x	x
	mem, reg	0	0	0	0	0	0	0	W	mod		reg		mem				13/21	2-4	x	x	x	x	x	x
	reg, mem	0	0	0	0	0	0	1	W	mod		reg		mem				10/14	2-4	x	x	x	x	x	x
	reg, imm	1	0	0	0	0	0	S	W	1	1	0	0	0	reg			4	3-4	x	x	x	x	x	x
	mem, imm	1	0	0	0	0	0	S	W	mod		0	0	0	mem			15/23	3-6	x	x	x	x	x	x
	acc, imm	0	0	0	0	0	1	0	W									4	2-3	x	x	x	x	x	x

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Arithmetic Instructions (cont)																									
ADDC	reg, reg	0	0	0	1	0	0	1	W	1	1		reg				reg	2	2	x	x	x	x	x	x
	mem, reg	0	0	0	1	0	0	0	W	mod			reg				mem	13/21	2-4	x	x	x	x	x	x
	reg, mem	0	0	0	1	0	0	1	W	mod			reg				mem	10/14	2-4	x	x	x	x	x	x
	reg, imm	1	0	0	0	0	0	S	W	1	1	0	1	0			reg	4	3-4	x	x	x	x	x	x
	mem, imm	1	0	0	0	0	0	S	W	mod			0	1	0		mem	15/23	3-6	x	x	x	x	x	x
	acc, imm	0	0	0	1	0	1	0	W									4	2-3	x	x	x	x	x	x
SUB	reg, reg	0	0	1	0	1	0	1	W	1	1		reg				reg	2	2	x	x	x	x	x	x
	mem, reg	0	0	1	0	1	0	0	W	mod			reg				mem	13/21	2-4	x	x	x	x	x	x
	reg, mem	0	0	1	0	1	0	1	W	mod			reg				mem	10/14	2-4	x	x	x	x	x	x
	reg, imm	1	0	0	0	0	0	S	W	1	1	1	0	1			reg	4	3-4	x	x	x	x	x	x
	mem, imm	1	0	0	0	0	0	S	W	mod			1	0	1		mem	15/23	3-6	x	x	x	x	x	x
	acc, imm	0	0	1	0	1	1	0	W									4	2-3	x	x	x	x	x	x
SUBC	reg, reg	0	0	0	1	1	0	1	W	1	1		reg				reg	2	2	x	x	x	x	x	x
	mem, reg	0	0	0	1	1	0	0	W	mod			reg				mem	13/21	2-4	x	x	x	x	x	x
	reg, mem	0	0	0	1	1	0	1	W	mod			reg				mem	10/14	2-4	x	x	x	x	x	x
	reg, imm	1	0	0	0	0	0	S	W	1	1	0	1	1			reg	4	3-4	x	x	x	x	x	x
	mem, imm	1	0	0	0	0	0	S	W	mod			0	1	1		mem	15/23	3-6	x	x	x	x	x	x
	acc, imm	0	0	0	1	1	1	0	W									4	2-3	x	x	x	x	x	x
INC	reg8	1	1	1	1	1	1	1	0	1	1	0	0	0			reg	2	2	x		x	x	x	x
	mem	1	1	1	1	1	1	1	W	mod			0	0	0		mem	13/21	2-4	x		x	x	x	x
	reg16	0	1	0	0	0		reg										2	1	x		x	x	x	x
DEC	reg8	1	1	1	1	1	1	1	0	1	1	0	0	1			reg	2	2	x		x	x	x	x
	mem	1	1	1	1	1	1	1	W	mod			0	0	1		mem	13/21	2-4	x		x	x	x	x
	reg16	0	1	0	0	1		reg										2	1	x		x	x	x	x
MULU	reg	1	1	1	1	0	1	1	W	1	1	1	0	0			reg	21-30	2	u	x	x	u	u	u
	mem	1	1	1	1	0	1	1	W	mod			1	0	0		mem	26/39	2-4	u	x	x	u	u	u
MUL	reg	1	1	1	1	0	1	1	W	1	1	1	0	1			reg	33-47	2	u	x	x	u	u	u
	mem	1	1	1	1	0	1	1	W	mod			1	0	1		mem	38-56	2-4	u	x	x	u	u	u
	reg16,reg16,imm8	0	1	1	0	1	0	1	1	1	1		reg				reg	28-34	3	u	x	x	u	u	u
	reg16,mem16,imm8	0	1	1	0	1	0	1	1	mod			reg				mem	37-43	3-5	u	x	x	u	u	u
	reg16,reg16,imm16	0	1	1	0	1	0	0	1	1	1		reg				reg	36-42	4	u	x	x	u	u	u
	reg16,mem16,imm16	0	1	1	0	1	0	0	1	mod			reg				mem	45-51	4-6	u	x	x	u	u	u
DIVU	reg	1	1	1	1	0	1	1	W	1	1	1	1	0			reg	19/25	2	u	u	u	u	u	u
	mem	1	1	1	1	0	1	1	W	mod			1	1	0		mem	24/34	2-4	u	u	u	u	u	u
DIV	reg	1	1	1	1	0	1	1	W	1	1	1	1	1			reg	29-43	2	u	u	u	u	u	u
	mem	1	1	1	1	0	1	1	W	mod			1	1	1		mem	34-52	2-4	u	u	u	u	u	u

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Comparison Instructions																									
CMP	reg, reg	0	0	1	1	1	0	1	W	1	1		reg				reg	2	2	x	x	x	x	x	x
	mem, reg	0	0	1	1	1	0	0	W	mod			reg				mem	10/14	2-4	x	x	x	x	x	x
	reg, mem	0	0	1	1	1	0	1	W	mod			reg				mem	10/14	2-4	x	x	x	x	x	x
	reg, imm	1	0	0	0	0	0	S	W	1	1	1	1	1			reg	4	3-4	x	x	x	x	x	x
	mem, imm	1	0	0	0	0	0	S	W	mod			1	1	1		mem	12/16	3-6	x	x	x	x	x	x
	acc, imm	0	0	1	1	1	1	0	W									4	2-3	x	x	x	x	x	x
Logical Instructions																									
NOT	reg	1	1	1	1	0	1	1	W	1	1	0	1	0			reg	2	2						
	mem	1	1	1	1	0	1	1	W	mod			0	1	0		mem	13/21	2-4						
NEG	reg	1	1	1	1	0	1	1	W	1	1	0	1	1			reg	2	2	x	x	x	x	x	x
	mem	1	1	1	1	0	1	1	W	mod			0	1	1		mem	13/21	2-4	x	x	x	x	x	x
TEST	reg, reg	1	0	0	0	0	1	0	W	1	1		reg				reg	2	2	u	0	0	x	x	x
	mem, reg	1	0	0	0	0	1	0	W	mod			reg				mem	9/13	2-4	u	0	0	x	x	x
	reg, imm	1	1	1	1	0	1	1	W	1	1	0	0	0			reg	4	3-4	u	0	0	x	x	x
	mem, imm	1	1	1	1	0	1	1	W	mod			0	0	0		mem	10/14	3-6	u	0	0	x	x	x
	acc, imm	1	0	1	0	1	0	0	W									4	2-3	u	0	0	x	x	x
AND	reg, reg	0	0	1	0	0	0	1	W	1	1		reg				reg	2	2	u	0	0	x	x	x
	mem, reg	0	0	1	0	0	0	0	W	mod			reg				mem	13/21	2-4	u	0	0	x	x	x
	reg, mem	0	0	1	0	0	0	1	W	mod			reg				mem	10/14	2-4	u	0	0	x	x	x
	reg, imm	1	0	0	0	0	0	0	W	1	1	1	0	0			reg	4	3-4	u	0	0	x	x	x
	mem, imm	1	0	0	0	0	0	0	W	mod			1	0	0		mem	15/23	3-6	u	0	0	x	x	x
	acc, imm	0	0	1	0	0	1	0	W									4	2-3	u	0	0	x	x	x
OR	reg, reg	0	0	0	0	1	0	1	W	1	1		reg				reg	2	2	u	0	0	x	x	x
	mem, reg	0	0	0	0	1	0	0	W	mod			reg				mem	13/21	2-4	u	0	0	x	x	x
	reg, mem	0	0	0	0	1	0	1	W	mod			reg				mem	10/14	2-4	u	0	0	x	x	x
	reg, imm	1	0	0	0	0	0	0	W	1	1	0	0	1			reg	4	3-4	u	0	0	x	x	x
	mem, imm	1	0	0	0	0	0	0	W	mod			0	0	1		mem	15/23	3-6	u	0	0	x	x	x
	acc, imm	0	0	1	0	0	1	0	W									4	2-3	u	0	0	x	x	x
XOR	reg, reg	0	0	1	1	0	0	1	W	1	1		reg				reg	2	2	u	0	0	x	x	x
	mem, reg	0	0	1	1	0	0	0	W	mod			reg				mem	13/21	2-4	u	0	0	x	x	x
	reg, mem	0	0	1	1	0	0	1	W	mod			reg				mem	10/14	2-4	u	0	0	x	x	x
	reg, imm	1	0	0	0	0	0	0	W	1	1	1	1	0			reg	4	3-4	u	0	0	x	x	x
	mem, imm	1	0	0	0	0	0	0	W	mod			1	1	0		mem	15/23	3-6	u	0	0	x	x	x
	acc, imm	0	0	1	0	0	1	0	W									4	2-3	u	0	0	x	x	x

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Bit Manipulation Instructions																									
INS	reg8, reg8	0	0	0	0	1	1	1	1	0	0	1	1	0	0	0	1	35-133	3						
		1	1		reg				reg																
	reg8, imm8	0	0	0	0	1	1	1	1	0	0	1	1	1	0	0	1	35-133	4						
		1	1	0	0	0			reg																
EXT	reg8, reg8	0	0	0	0	1	1	1	1	0	0	1	1	0	0	1	1	34-59	3						
		1	1		reg				reg																
	reg8, imm8	0	0	0	0	1	1	1	1	0	0	1	1	1	0	1	1	34-59	4						
		1	1	0	0	0			reg																
TEST1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	0	W	3	3	u	0	0	u	u	x
		1	1	0	0	0			reg																
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	0	W	7/11	3-5	u	0	0	u	u	x
		mod			0	0	0		mem																
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	0	W	4	4	u	0	0	u	u	x
		1	1	0	0	0			reg																
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	0	W	8/12	4-6	u	0	0	u	u	x
		mod			0	0	0		mem																
SET1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	0	W	4	3						
		1	1	0	0	0			reg																
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	0	W	10/18	3-5						
		mod			0	0	0		mem																
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	0	W	5	4						
		1	1	0	0	0			reg																
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	0	W	11/19	4-6						
		mod			0	0	0		mem																
	CY	1	1	1	1	1	0	0	1									2	1		1				
	DIR	1	1	1	1	1	1	0	1									2	1						
CLR1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	1	W	5	3						
		1	1	0	0	0			reg																
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	1	W	11/19	3-5						
		mod			0	0	0		mem																
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1	W	6	4						
		1	1	0	0	0			reg																
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1	W	12/20	4-6						
		mod			0	0	0		mem																
	CY	1	1	1	1	1	0	0	0									2	1		0				
	DIR	1	1	1	1	1	1	0	0									2	1						
NOT1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	1	W	4	3						
		1	1	0	0	0			reg																
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	1	W	10/18	3-5						
		mod			0	0	0		mem																
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	1	W	5	4						
		1	1	0	0	0			reg																
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	1	W	11/19	4-6						
		mod			0	0	0		mem																
	CY	1	1	1	1	0	1	0	1									2	1		x				

Instruction Set (cont)

Mnemonic	Operands	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Shift/Rotate Instructions																									
SHL	reg, 1	1	1	0	1	0	0	0	W	1	1	1	0	0		reg		2	2	u	x	x	x	x	x
	mem, 1	1	1	0	1	0	0	0	W	mod					1	0	0	mem	13/21	2-4	u	x	x	x	x	x
	reg, CL	1	1	0	1	0	0	1	W	1	1	1	0	0		reg		7 + n	2	u	x	u	x	x	x
	mem, CL	1	1	0	1	0	0	1	W	mod					1	0	0	mem	16/24 + n	2-4	u	x	u	x	x	x
	reg, imm8	1	1	0	0	0	0	0	W	1	1	1	0	0		reg		7 + n	3	u	x	u	x	x	x
	mem, imm8	1	1	0	0	0	0	0	W	mod					1	0	0	mem	16/24 + n	3-5	u	x	u	x	x	x
SHR	reg, 1	1	1	0	1	0	0	0	W	1	1	1	0	1		reg		2	2	u	x	x	x	x	x
	mem, 1	1	1	0	1	0	0	0	W	mod					1	0	1	mem	13/21	2-4	u	x	x	x	x	x
	reg, CL	1	1	0	1	0	0	1	W	1	1	1	0	1		reg		7 + n	2	u	x	u	x	x	x
	mem, CL	1	1	0	1	0	0	1	W	mod					1	0	1	mem	16/24 + n	2-4	u	x	u	x	x	x
	reg, imm8	1	1	0	0	0	0	0	W	1	1	1	0	1		reg		7 + n	3	u	x	u	x	x	x
	mem, imm8	1	1	0	0	0	0	0	W	mod					1	0	1	mem	16/24 + n	3-5	u	x	u	x	x	x
SHRA	reg, 1	1	1	0	1	0	0	0	W	1	1	1	1	1		reg		2	2	u	x	0	x	x	x
	mem, 1	1	1	0	1	0	0	0	W	mod					1	1	1	mem	13/21	2-4	u	x	0	x	x	x
	reg, CL	1	1	0	1	0	0	1	W	1	1	1	1	1		reg		7 + n	2	u	x	u	x	x	x
	mem, CL	1	1	0	1	0	0	1	W	mod					1	1	1	mem	16/24 + n	2-4	u	x	u	x	x	x
	reg, imm8	1	1	0	0	0	0	0	W	1	1	1	1	1		reg		7 + n	3	u	x	u	x	x	x
	mem, imm8	1	1	0	0	0	0	0	W	mod					1	1	1	mem	16/24 + n	3-5	u	x	u	x	x	x
ROL	reg, 1	1	1	0	1	0	0	0	W	1	1	0	0	0		reg		2	2		x	x			
	mem, 1	1	1	0	1	0	0	0	W	mod					0	0	0	mem	13/21	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	0	0		reg		7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod					0	0	0	mem	16/24 + n	2-4		x	u			
	reg, imm	1	1	0	0	0	0	0	W	1	1	0	0	0		reg		7 + n	3		x	u			
	mem, imm	1	1	0	0	0	0	0	W	mod					0	0	0	mem	16/24 + n	3-5		x	u			
ROR	reg, 1	1	1	0	1	0	0	0	W	1	1	0	0	1		reg		2	2		x	u			
	mem, 1	1	1	0	1	0	0	0	W	mod					0	0	1	mem	13/21	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	0	1		reg		7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod					0	0	1	mem	16/24 + n	2-4		x	u			
	reg, imm8	1	1	0	0	0	0	0	W	1	1	0	0	1		reg		7 + n	3		x	u			
	mem, imm8	1	1	0	0	0	0	0	W	mod					0	0	1	mem	16/24 + n	3-5		x	u			
ROLC	reg, 1	1	1	0	1	0	0	0	W	1	1	0	1	0		reg		2	2		x	x			
	mem, 1	1	1	0	1	0	0	0	W	mod					0	1	0	mem	13/21	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	1	0		reg		7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod					0	1	0	mem	16/24 + n	2-4		x	u			
	reg, imm8	1	1	0	0	0	0	0	W	1	1	0	1	0		reg		7 + n	3		x	u			
	mem, imm8	1	1	0	0	0	0	0	W	mod					0	1	0	mem	16/24 + n	3-5		x	u			

n = number of shifts

Instruction Set (cont)

Mnemonic	Operands	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Shift Rotate Instructions (cont)																									
RORC	reg, 1	1	1	0	1	0	0	0	W	1	1	0	1	1	reg			2	2		x	x			
	mem, 1	1	1	0	1	0	0	0	W	mod			0	1	1	mem		13/21	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	1	1	reg			7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod			0	1	1	mem		16/24 + n	2-4		x	u			
	reg, imm8	1	1	0	0	0	0	0	W	1	1	0	1	1	reg			7 + n	3		x	u			
	mem, imm8	1	1	0	0	0	0	0	W	mod			0	1	1	mem		16/24 + n	3-5		x	u			
										n = number of shifts															
Stack Manipulation Instructions																									
PUSH	mem16	1	1	1	1	1	1	1	1	mod			1	1	0	mem		23	2-4						
	reg16	0	1	0	1	0	reg											10	1						
	sr	0	0	0	sr		1	1	0									10	1						
	PSW	1	0	0	1	1	1	0	0									10	1						
	R	0	1	1	0	0	0	0	0									65	1						
	imm	0	1	1	0	1	0	S	0									9-10	2-3						
POP	mem16	1	0	0	0	1	1	1	1	mod			0	0	0	mem		25	2-4						
	reg16	0	1	0	1	1	reg											12	1						
	sr	0	0	0	sr		1	1	1									12	1						
	PSW	1	0	0	1	1	1	0	1									12	1	R	R	R	R	R	R
	R	0	1	1	0	0	0	0	1									75	1						
PREPARE	imm16, imm8	1	1	0	0	1	0	0	0	*imm8 = 0 : 16 imm8 > 1 : 21 + 16 (imm8 − 1)								*	4						
DISPOSE		1	1	0	0	1	0	0	1									10	1						
Control Transfer Instructions																									
CALL	near_proc	1	1	1	0	1	0	0	0									20	3						
	regptr	1	1	1	1	1	1	1	1	1	1	0	1	0	reg			18	1						
	memptr16	1	1	1	1	1	1	1	1	mod			0	1	0	mem		31	2-4						
	far_proc	1	0	0	1	1	0	1	0									29	5						
	memptr32	1	1	1	1	1	1	1	1	mod			0	1	1	mem		47	2-4						
RET		1	1	0	0	0	0	1	1									19	1						
	pop_value	1	1	0	0	0	0	1	0									24	3						
		1	1	0	0	1	0	1	1									29	1						
	pop_value	1	1	0	0	1	0	1	0									32	3						
BR	near_label	1	1	1	0	1	0	0	1									13	3						
	short_label	1	1	1	0	1	0	0	1									12	2						
	reg	1	1	1	1	1	1	1	1	1	1	1	0	0	reg			11	2						
	memptr16	1	1	1	1	1	1	1	1	mod			1	0	0	mem		23	2-4						
	far_label	1	1	1	0	1	0	1	0									15	5						
	memptr32	1	1	1	1	1	1	1	1	mod			1	0	1	mem		34	2-4						
BV	near_label	0	1	1	1	0	0	0	0									14/4	2						
BNV	near_label	0	1	1	1	0	0	0	1									14/4	2						

Instruction Set (cont)

Mnemonic	Operands	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Control Transfer Instructions (cont)																									
BC, BL	near_label	0	1	1	1	0	0	1	0									14/4	2						
BNC, BNL	near_label	0	1	1	1	0	0	1	1									14/4	2						
BE, BZ	near_label	0	1	1	1	0	1	0	0									14/4	2						
BNE, BNZ	near_label	0	1	1	1	0	1	0	1									14/4	2						
BNH	near_label	0	1	1	1	0	1	1	0									14/4	2						
BH	near_label	0	1	1	1	0	1	1	1									14/4	2						
BN	near_label	0	1	1	1	1	0	0	0									14/4	2						
BP	near_label	0	1	1	1	1	0	0	1									14/4	2						
BPE	near_label	0	1	1	1	1	0	1	0									14/4	2						
BPO	near_label	0	1	1	1	1	0	1	1									14/4	2						
BLT	near_label	0	1	1	1	1	1	0	0									14/4	2						
BGE	near_label	0	1	1	1	1	1	0	1									14/4	2						
BLE	near_label	0	1	1	1	1	1	1	0									14/4	2						
BGT	near_label	0	1	1	1	1	1	1	1									14/4	2						
DBNZNE	near_label	1	1	1	0	0	0	0	0									14/5	2						
DBNZE	near_label	1	1	1	0	0	0	0	1									14/5	2						
DBNZ	near_label	1	1	1	0	0	0	1	0									13/5	2						
BCWZ	near_label	1	1	1	0	0	0	1	1									13/5	2						
Interrupt Instructions																									
BRK	3	1	1	0	0	1	1	0	0									50	1						
	imm8	1	1	0	0	1	1	0	1									50	2						
BRKV	imm8	1	1	0	0	1	1	1	1									52/3	1						
RETI		1	1	0	0	1	1	1	0									39	1	R	R	R	R	R	R
CHKIND	reg16, mem32	0	1	1	0	0	0	1	0	mod			reg				mem	72-75/25	2-4						
BRKEM	imm8	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	50	3						
CPU Control Instructions																									
HALT		1	1	1	1	0	1	0	0									2	1						
BUSLOCK		1	1	1	1	0	0	0	0									2	1						
FPO1	fp_op	1	1	0	1	1	X	X	X	1	1	Y	Y	Y	Z	Z	Z	2	2						
	fp_op, mem	1	1	0	1	1	X	X	X	mod		Y	Y	Y		mem		14	2-4						
FPO2	fp_op	0	1	1	0	0	1	1	X	1	1	Y	Y	Y	Z	Z	Z	2	2						
	fp_op, mem	0	1	1	0	0	1	1	X	mod		Y	Y	Y		mem		14	2-4						
POLL		1	0	0	1	1	0	1	1	n = number of times POLL pin is sampled.								2 + 5n	1						
NOP		1	0	0	1	0	0	0	0									3	1						
DI		1	1	1	1	1	0	1	0									2	1						
EI		1	1	1	1	1	0	1	1									2	1						
DS0:, DS1:, PS:, and SS: (segment override prefixes)		0	0	1	seg		1	1	0									2	1						
8080 Instruction Set Enhancements																									
RETEM		1	1	1	0		1	1	0	1	1	1	1	1	1	1	0	1	39	2	R	R	R	R	R	R
CALLN	imm8	1	1	1	0		1	1	0	1	1	1	1	0	1	1	0	1	58	3						

Description

The μPD70216 (V50™) is a high-performance, low-power 16-bit microprocessor integrating a number of commonly-used peripherals to dramatically reduce the size of microprocessor systems. The CMOS construction makes the μPD70216 ideal for the design of portable computers, instrumentation, and process control equipment.

The μPD70216 contains a powerful instruction set that is compatible with the μPD70108/μPD70116 (V20™/V30™) and μPD8086/μPD8088 instruction sets. Instruction set support includes a wide range of arithmetic, logical, and control operations as well as bit manipulation, BCD arithmetic, and high-speed block transfer instructions. The μPD70216 can also execute the entire μPD8080AF instruction set using the 8080 emulation mode. Also available is the μPD70208 (V40™), identical to the μPD70216 but with an 8-bit external data bus.

Features

- ☐ V20/V30 instruction set compatible
- ☐ Minimum instruction execution time: 250 ns (at 8 MHz)
- ☐ Direct addressing of 1M bytes of memory
- ☐ Powerful set of addressing modes
- ☐ 14 16-bit registers
- ☐ On-chip peripherals including
  - — Clock generator
  - — Bus interface
  - — Bus arbitration
  - — Programmable wait state generator
  - — DRAM refresh control
  - — Three 16-bit timer/counters
  - — Asynchronous serial I/O control
  - — Eight-input interrupt control
  - — Four-channel DMA control
- ☐ Hardware effective address calculation logic
- ☐ Maskable and nonmaskable interrupts
- ☐ μPD72191 Floating Point Processor interface
- ☐ IEEE 796 compatible bus interface
- ☐ Low-power standby mode
- ☐ Low-power CMOS technology

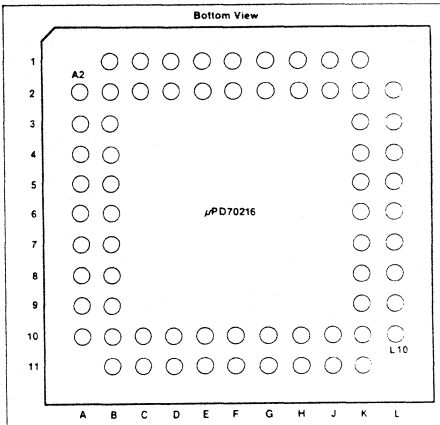
V20, V30, V40, and V50 are trademarks of NEC Corporation.

Ordering Information

Part Number	Package	Maximum Frequency
μPD70216R-8	68-pin PGA	8 MHz
μPD70216L-8	68-pin PLCC	8 MHz
μPD70216G-8	80-pin plastic miniflat	8 MHz

Pin Configurations

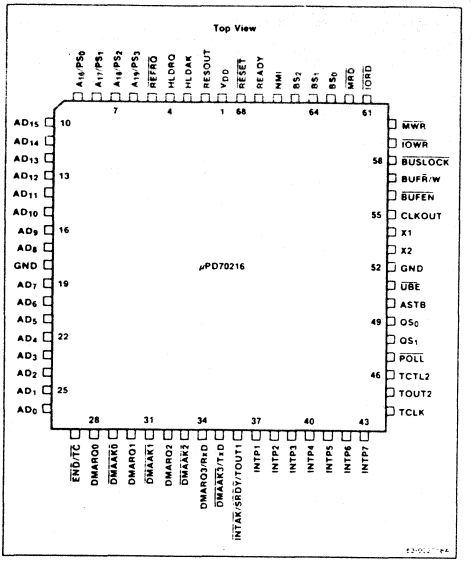
68-Pin PGA



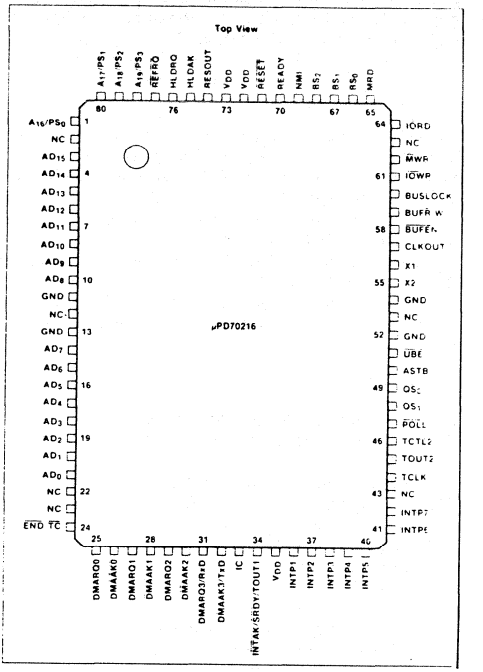
Pin	Symbol	Pin	Symbol	Pin	Symbol	Pin	Symbol
A2	INTP7	B9	DMARQ1	F10	AD_7	K4	NMI
A3	INTP5	B10	DMARQ0	F11	GND	K5	$\overline{RESET}$
A4	INTP3	B11	AD_0	G1	X1	K6	RESOUT
A5	INTP1	C1	TCTL2	G2	CLKOUT	K7	HLDRQ
A6	$\overline{DMAAK3}$/TxD	C2	$\overline{POLL}$	G10	AD_8	K8	A_{19}/PS_3
A7	$\overline{DMAAK2}$	C10	AD_1	G11	AD_9	K9	A_{17}/PS_1
A8	$\overline{DMAAK1}$	C11	AD_2	H1	$\overline{BUFEN}$	K10	AD_{14}
A9	$\overline{DMAAK0}$	D1	QS_1	H2	BUFR/$\overline{W}$	K11	AD_{15}
A10	$\overline{END}/\overline{TC}$	D2	QS_0	H10	AD_{10}	L2	$\overline{IORD}$
B1	TCLK	D10	AD_3	H11	AD_{11}	L3	BS_0
B2	TOUT2	D11	AD_4	J1	$\overline{BUSLOCK}$	L4	BS_2
B3	INTP6	E1	ASTB	J2	$\overline{IOWR}$	L5	READY
B4	INTP4	E2	$\overline{UBE}$	J10	AD_{12}	L6	V_{DD}
B5	INTP2	E10	AD_5	J11	AD_{13}	L7	HLDAK
B6	$\overline{INTAK}$/$\overline{SRDY}$/TOUT1	E11	AD_6	K1	$\overline{MWR}$	L8	$\overline{REFRQ}$
B7	DMARQ3/RxD	F1	GND	K2	$\overline{MRD}$	L9	A_{18}/PS_2
B8	DMARQ2	F2	X2	K3	BS_1	L10	A_{16}/PS_0

Pin Configurations (cont)

68-Pin PLCC



80-Pin Plastic Miniflat



Pin Identification

Symbol	Function
A_{19}-A_{16}/PS_3-PS_0	Multiplexed address/processor status outputs
AD_{15}-AD_0	Multiplexed address/data bus
ASTB	Address strobe output
$\overline{BUFEN}$	Data bus transceiver enable output
BUF$\overline{R}$/W	Data bus transceiver direction output
$\overline{BUSLOCK}$	Buslock output
BS_2-BS_0	Bus status outputs
CLKOUT	System clock output
$\overline{DMAAK0}$	DMA channel 0 acknowledge output
$\overline{DMAAK1}$	DMA channel 1 acknowledge output
$\overline{DMAAK2}$	DMA channel 2 acknowledge output
$\overline{DMAAK3}$/TxD	DMA channel 3 acknowledge output/Serial transmit data output
DMARQ0	DMA channel 0 request input
DMARQ1	DMA channel 1 request input
DMARQ2	DMA channel 2 request input
DMARQ3/RxD	DMA channel 3 request input/Serial receive data input
$\overline{END}$/$\overline{TC}$	End input/Terminal count output
GND	Ground
HLDAK	Hold acknowledge output
HLDRQ	Hold request input
IC	Internal connection; leave unconnected
$\overline{INTAK}$/TOUT1/$\overline{SRDY}$	Interrupt acknowledge output/Timer/counter 1 output/Serial ready output
INTP1-INTP7	Interrupt request inputs
$\overline{IORD}$	I/O read strobe output
$\overline{IOWR}$	I/O write strobe output
$\overline{MRD}$	Memory read strobe output
$\overline{MWR}$	Memory write strobe output
NC	No connection
NMI	Nonmaskable interrupt input
$\overline{POLL}$	Poll input
QS_1-QS_0	CPU queue status outputs
READY	Ready input
$\overline{REFRQ}$	Refresh request output
$\overline{RESET}$	Reset input
RESOUT	Synchronized reset output

Symbol	Function
TCLK	Timer/counter external clock input
TCTL2	Timer/counter 2 control input
TOUT2	Timer/counter 2 output
$\overline{UBE}$	Upper byte enable output
V_{DD}	+5 V power supply input
X1, X2	Crystal/external clock inputs

Pin Functions

A_{19}-A_{16}/PS_3-PS_0 [Address/Status Bus]

These three-state output pins contain the upper 4 bits of the 20-bit address during T1 and processor status information during T2, T3, Tw, and T4. During T1 of a memory read or write cycle, these pins contain the upper 4 bits of the 20-bit address. These pins are forced low during T1 of an I/O bus cycle.

Processor status is output during T2, T3, Tw, and T4 of both memory and I/O bus cycles. PS_3 is zero during any CPU native mode bus cycle. During any DMA, refresh, or 8080 emulation mode bus cycle, PS_3 outputs a high level. PS_2 outputs the contents of the interrupt enable (IE) flag in the CPU PSW register. PS_1 and PS_0 indicate the segment register used to form the physical address of a CPU bus cycle as follows:

PS_1	PS_0	Segment
0	0	Data segment 1 (DS1)
0	1	Stack segment (SS)
1	0	Program segment (PS)
1	1	Data segment 0 (DS0)

These pins are in the high-impedance state during hold acknowledge.

AD_{15}-AD_0 [Address/Data Bus]

These three-state pins form the active-high, time-multiplexed address/data bus. During T1 of a bus cycle, AD_{15}-AD_0 output the lower 16 bits of the 20-bit memory or I/O address. During the T2, T3, Tw, and T4 states, AD_{15}-AD_0 form the 16-bit bidirectional data bus.

The memory and I/O address spaces are organized into a pair of byte-wide banks. The even bank is accessed whenever $AD_0 = 0$ during T1 of a bus cycle. Access to the odd bank is controlled by the $\overline{UBE}$ pin.

The AD_{15}-AD_0 pins enter the high-impedance state during hold acknowledge or internal interrupt acknowledge bus cycles or while $\overline{RESET}$ is asserted. Pins AD_{10}-AD_8 contain the slave address of an external interrupt controller during the second interrupt acknowledge bus cycle.

ASTB [Address Strobe]

This active-high output is used to latch the address from the multiplexed address bus in an external address latch during T1 of a bus cycle. ASTB is held at a low level during hold acknowledge.

$\overline{\text{BUFEN}}$ [Buffer Enable]

$\overline{\text{BUFEN}}$ is an active-low output for enabling an external data bus transceiver during a bus cycle. $\overline{\text{BUFEN}}$ is asserted during T2 through T4 of a read cycle, T2 through T3 of a slave interrupt acknowledge cycle, and T1 through T4 of a write cycle. $\overline{\text{BUFEN}}$ is not asserted when the bus cycle corresponds to an internal peripheral, DMA, refresh, or internal interrupt acknowledge cycle. $\overline{\text{BUFEN}}$ enters the high-impedance state during hold acknowledge.

BUF$\overline{\text{R}}$/W [Buffer Read/Write]

BUF$\overline{\text{R}}$/W is a three-state, active-low output used to control the direction of an external data bus transceiver. A high level indicates the μPD70216 will perform a write cycle and a low level indicates a read cycle. BUF$\overline{\text{R}}$/W enters the high-impedance state during hold acknowledge.

$\overline{\text{BUSLOCK}}$

This active-low output provides a means for the CPU to indicate to an external bus arbiter that the bus cycles of the next instruction are to be kept contiguous. $\overline{\text{BUSLOCK}}$ is asserted for the duration of the instruction following the $\overline{\text{BUSLOCK}}$ prefix. $\overline{\text{BUSLOCK}}$ is also asserted during interrupt acknowledge cycles and enters the high-impedance state during hold acknowledge. While $\overline{\text{BUSLOCK}}$ is asserted, DMAU, RCU, and external bus requests are disabled.

BS_2-BS_0 [Bus Status]

Outputs BS_2-BS_0 indicate the type of bus cycle being performed as follows.

BS_2	BS_1	BS_0	Bus Cycle
0	0	0	Interrupt acknowledge
0	0	1	I/O read
0	1	0	I/O write
0	1	1	Halt
1	0	0	Instruction fetch
1	0	1	Memory read (1)
1	1	0	Memory write (2)
1	1	1	Passive state

Note:

(1) Memory read bus cycles include CPU, DMA read, DMA verify and refresh bus cycles.

(2) Memory write bus cycles include CPU and DMA write bus cycles

BS_2-BS_0 are three-state outputs and are high impedance during hold acknowledge.

CLKOUT

The CLKOUT output is used to generate all internal timing for the μPD70216. CLKOUT has a 50-percent duty cycle at half the frequency of the input clock source.

$\overline{\text{DMAAK0}}$-$\overline{\text{DMAAK2}}$ [DMA Acknowledge]

This set of outputs contains the DMA acknowledge signals for channels 0-2 from the internal DMA controller and indicate that the peripheral can perform the requested transfer.

$\overline{\text{DMAAK3}}$/TxD [DMA Acknowledge 3]/[Serial Transmit Data]

Two output signals multiplexed on this pin are selected by the PF field of the on-chip peripheral connection register.

- $\overline{\text{DMAAK3}}$ is an active-low output and enables an external DMA peripheral to perform the requested DMA transfer for channel 3.
- TxD is the serial output from the serial control unit.

DMARQ0-DMARQ2 [DMA Request]

These synchronized inputs are used by external peripherals to request DMA service for channels 0-2 from the internal DMA controller.

DMARQ3/RxD [DMA Request 3]/[Serial Receive Data]

Two input signals multiplexed on this pin are selected by the PF field of the on-chip peripheral connection register.

- DMARQ3 is used by an external peripheral to request a DMA transfer cycle for channel 3.
- RxD is the serial input to the serial control unit.

$\overline{END}/\overline{TC}$ [End/Terminal Count]

This active-low bidirectional pin controls the termination of a DMA service. Assertion of $\overline{END}$ by external hardware during DMA service causes the service to terminate. When a DMA channel reaches its terminal count, the DMAU asserts $\overline{TC}$, indicating the programmed operation has completed.

$\overline{END}/\overline{TC}$ is an open-drain I/O pin, and requires an external 2.2-kΩ pull-up resistor.

HLDAK [Hold Acknowledge]

When an external bus requester has become the highest priority requester, the internal bus arbiter will assert the HLDAK output indicating the address, data, and control buses have entered a high-impedance state and are available for use by the external bus master.

Should the internal DMAU or RCU (demand mode) request the bus, the bus arbiter will drive HLDAK low. When this occurs, the external bus master should complete the current bus cycle and negate the HLDRQ signal. This allows the bus arbiter to reassign the bus to the higher priority requester.

HLDRQ [Hold Request]

This active-high signal is asserted by an external bus master requesting to use the local address, data, and control buses. The HLDRQ input is used by the internal bus arbiter, which gives control of the buses to the highest priority bus requester in the following order.

Bus Master	Priority
RCU	Highest (demand mode)
DMAU	•
HLDRQ	•
CPU	•
RCU	Lowest (normal operation)

$\overline{INTAK}/TOUT1/\overline{SRDY}$ [Interrupt Acknowledge]/[Timer 1 Output]/[Serial Ready]

Three output signals multiplexed on this pin are selected by the PF field of the on-chip peripheral connection register.

- $\overline{INTAK}$ is an interrupt acknowledge signal used to cascade external slave μPD71059 Interrupt Controllers. $\overline{INTAK}$ is asserted during T2, T3, and Tw states of an interrupt acknowledge cycle.
- TOUT1 is the output of timer/counter 1.
- $\overline{SRDY}$ is an active-low output and indicates that the serial control unit is ready to receive the next character.

INTP1-INTP7 [Peripheral Interrupts]

INTP1-INTP7 accept either rising-edge or high-level triggered asynchronous interrupt requests from external peripherals. These INTP1-INTP7 inputs are internally synchronized and prioritized by the interrupt control unit, which requests the CPU to perform an interrupt acknowledge bus cycle. External interrupt controllers such as the μPD71059 can be cascaded to increase the number of vectored interrupts.

These interrupt inputs cause the CPU to exit both the standby and 8080 emulation modes.

INTP1-INTP7 contain internal pull-up resistors and may be left unconnected.

$\overline{IORD}$ [I/O Read]

This three-state pin outputs an active-low I/O read strobe during T2, T3, and Tw of an I/O read bus cycle. Both CPU I/O read and DMA write bus cycles assert $\overline{IORD}$. $\overline{IORD}$ is not asserted when the bus cycle corresponds to an internal peripheral. It enters the high-impedance state during hold acknowledge.

$\overline{IOWR}$ [I/O Write]

This three-state pin outputs an active-low I/O write strobe during T2, T3, and Tw of a CPU I/O write or an extended DMA read cycle and during T3 and Tw of a DMA read bus cycle. $\overline{IOWR}$ is not asserted when the bus cycle corresponds to an internal peripheral. It enters the high-impedance state during hold acknowledge.

$\overline{MRD}$ [Memory Read Strobe]

This three-state pin outputs an active-low memory read strobe during T2, T3, and Tw of a memory read bus cycle. CPU memory read, DMA read, and refresh bus cycles all assert $\overline{MRD}$. $\overline{MRD}$ enters the high-impedance state during hold acknowledge.

$\overline{MWR}$ [Memory Write Strobe]

This three-state pin outputs an active-low memory write strobe during T2, T3, and Tw of a CPU memory write or DMA extended write bus cycle and during T3 and Tw of a DMA normal write bus cycle. $\overline{MWR}$ enters the high-impedance state during hold acknowledge.

NMI [Nonmaskable Interrupt]

The NMI pin is a rising-edge-triggered interrupt input that cannot be masked by software. NMI is sampled by CPU logic each clock cycle and when found valid for five or more CLKOUT cycles, the NMI interrupt is accepted. The CPU will process the NMI interrupt immediately after the current instruction finishes execution by fetching the segment and offset of the NMI handler from interrupt vector 2. The NMI interrupt causes the CPU to exit both the standby and 8080 emulation modes. The NMI input takes precedence over the maskable interrupt inputs.

$\overline{POLL}$ [Poll]

The active-low $\overline{POLL}$ input is used to synchronize the operation of external devices with the CPU. During execution of the POLL instruction, the CPU checks the $\overline{POLL}$ input state every five clocks until $\overline{POLL}$ is once again asserted.

QS_1-QS_0 [Queue Status]

The QS_1 and QS_0 outputs maintain instruction synchronization between the μPD70216 CPU and external devices such as the μPD72191 Floating Point Processor. These outputs are interpreted as follows.

QS_1	QS_0	Instruction Queue Status
0	0	No operation
0	1	First byte of instruction fetched
1	0	Flush queue contents
1	1	Subsequent byte of instruction fetched

Queue status is valid for one clock cycle after the CPU has accessed the instruction queue.

READY [Ready]

This active-high input synchronizes external memory and peripheral devices with the μPD70216. Slow memory and I/O devices can lengthen a bus cycle by negating the READY input and forcing the BIU to insert Tw states. READY must be negated prior to the rising edge of CLKOUT during the T2 state to guarantee recognition. When READY is once again asserted and recognized by the BIU, the BIU will proceed to the T4 state.

The READY input operates in parallel with the internal μPD70216 wait control unit and can be used to insert more than three wait states into a bus cycle.

$\overline{REFRQ}$ [Refresh Request]

$\overline{REFRQ}$ is an active-low output indicating the current bus cycle is a memory refresh operation. $\overline{REFRQ}$ is used to disable memory address decode logic and refresh dynamic memories. The 8-bit refresh row address is placed on A_8-A_1 during a refresh bus cycle.

$\overline{RESET}$ [Reset]

The $\overline{RESET}$ input is used to force the μPD70216 to a known state by resetting the CPU and on-chip peripherals. $\overline{RESET}$ must be asserted for a minimum of four clocks to guarantee recognition. After $\overline{RESET}$ has been released, the CPU will start program execution from address FFFF0H.

$\overline{RESET}$ will release the CPU from the low-power standby mode and force it to the native mode.

RESOUT [Reset Output]

This active-high output is available to perform a system-wide reset function. Reset is internally synchronized with CLKOUT and output on the RESOUT pin.

TCLK

TCLK is an external clock source for the timer control unit. The three timer/counters can be programmed to operate with either the TCLK input or a prescaled CLKOUT input.

TCTL2

TCTL2 is the control input for timer/counter 2.

TOUT2

TOUT2 is the output of timer/counter 2.

$\overline{UBE}$ (Upper Byte Enable)

$\overline{UBE}$ is an active-low output, asserted when the upper byte of the 16-bit data bus contains valid data. $\overline{UBE}$ is used along with A_0 by the memory decoding logic to select the even/odd banks as follows.

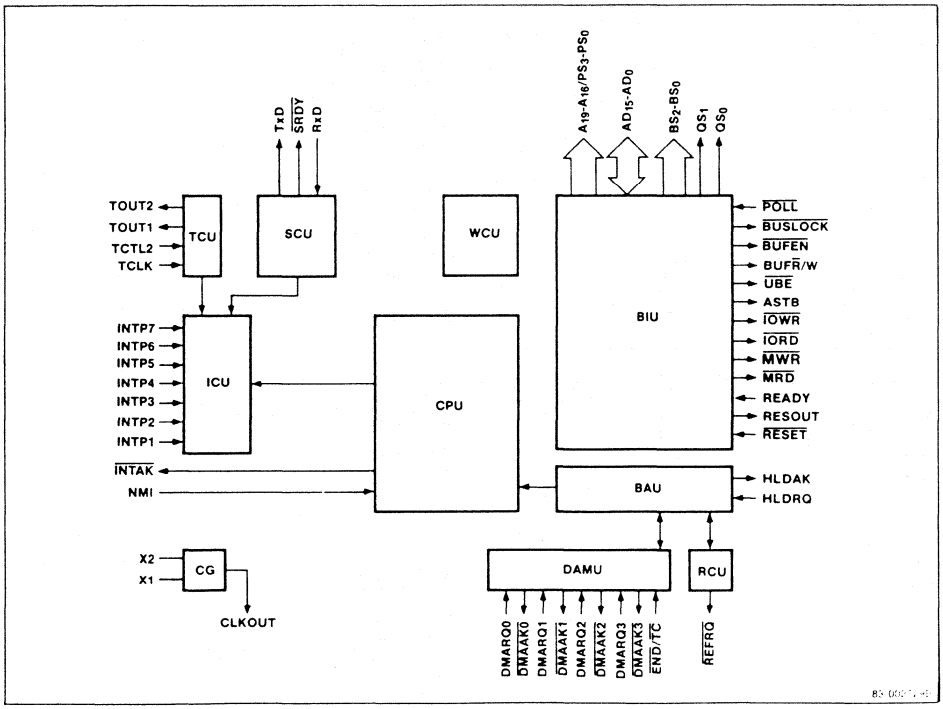
Operation	$\overline{UBE}$	A_0	Bus Cycles
Word, even address	0	0	1
Word, odd address	0 1	1 (1st bus cycle) 0 (2nd bus cycle)	2
Byte, even address	1	0	1
Byte, odd address	0	1	1

$\overline{UBE}$ is a three-state output and enters the high-impedance state during hold acknowledge.

X1, X2 (Clock Inputs)

These pins accept either a parallel resonant, fundamental mode crystal or an external oscillator input with a frequency twice the desired operating frequency.

Block Diagram



Absolute Maximum Ratings

$T_A = +25°C$

Power supply voltage, V_{DD}	−0.5 to +7.0 V
Input voltage, V_I	−0.5 to V_{DD} + 0.3 V
CLK input voltage, V_K	−0.5 to V_{DD} + 1.0 V
Output voltage, V_O	−0.5 to V_{DD} + 0.3 V
Operating temperature, T_{OPT}	−10 to +70°C
Storage temperature, T_{STG}	−65 to +150°C

Comment: Exposing the device to stresses above those listed in the Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

$T_A = +25°C$, $V_{DD} = 0$ V

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Input capacitance	C_I		15	pF	f_C = 1 MHz; unmeasured pins are returned to 0 V.
Output capacitance	C_O		15	pF	

DC Characteristics

$T_A = -10$ to +70°C, $V_{DD} = +5$ V ±10%

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Input voltage, high	V_{IH}	2.2	V_{DD} + 0.3	V	
Input voltage, low	V_{IL}	−0.5	0.8	V	
X1, X2 input voltage, high	V_{KH}	3.9	V_{DD} + 1.0	V	
X1, X2 input voltage, low	V_{KL}	−0.5	0.6	V	
Output voltage, high	V_{OH}	0.7 V_{DD}		V	$I_{OH} = -400\ \mu A$
Output voltage, low	V_{OL}		0.4	V	$I_{OL} = 2.5$ mA
Input leakage current, high	I_{LIH}		10	μA	$V_I = V_{DD}$
Input leakage current, low	I_{LIPL}		−300	μA	$V_I = 0$ V, INTP input pins
	I_{LIL}		−10	μA	$V_I = 0$ V, other input pins
Output leakage current, high	I_{LOH}		10	μA	$V_O = V_{DD}$
Output leakage current, low	I_{LOL}		−10	μA	$V_O = 0$ V
Supply current	I_{DD}		90	mA	Normal mode
			20	mA	Standby mode

AC Characteristics

$T_A = -10$ to +70°C, $V_{DD} = +5$ V ± 10%, C_L = 100 pF

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
External clock input cycle time	t_{CYX}	62	250	ns	
External clock pulse width, high	t_{XXH}	20		ns	V_{KH} = 3.0 V
External clock pulse width, low	t_{XXL}	20		ns	V_{KL} = 1.5 V
External clock rise time	t_{XR}		10	ns	1.5 → 3.0 V
External clock fall time	t_{XF}		10	ns	3.0 → 1.5 V
CLKOUT cycle time	t_{CYK}	124	500	ns	
CLKOUT pulse width, high	t_{KKH}	0.5 t_{CYK} − 7		ns	V_{KH} = 3.0 V
CLKOUT pulse width, low	t_{KKL}	0.5 t_{CYK} − 7		ns	V_{KL} = 1.5 V
CLKOUT rise time	t_{KR}		7	ns	1.5 → 3.0 V
CLKOUT fall time	t_{KF}		7	ns	3.0 → 1.5 V
CLKOUT delay time from external clock	t_{DXK}		55	ns	
Input rise time (except external clock)	t_{IR}		20	ns	0.8 → 2.2 V
Input fall time (except external clock)	t_{IF}		12	ns	2.2 → 0.8 V
Output rise time (except CLKOUT)	t_{OR}		20	ns	0.8 → 2.2 V
Output fall time (except CLKOUT)	t_{OF}		12	ns	2.2 → 0.8 V
$\overline{\text{RESET}}$ setup time to CLKOUT↓	t_{SRESK}	25		ns	
$\overline{\text{RESET}}$ hold time after CLKOUT↓	t_{HKRES}	35		ns	
RESOUT delay time from CLKOUT↓	t_{DKRES}	5	60	ns	
READY inactive setup time to CLKOUT↑	t_{SRYLK}	15		ns	
READY inactive hold time after CLKOUT↑	t_{HKRYL}	25		ns	
READY active setup time to CLKOUT↑	t_{SRYHK}	15		ns	
READY active hold time after CLKOUT↑	t_{HKRYH}	25		ns	
NMI, $\overline{\text{POLL}}$ setup time to CLKOUT↑	t_{SIK}	15		ns	

AC Characteristics (cont)

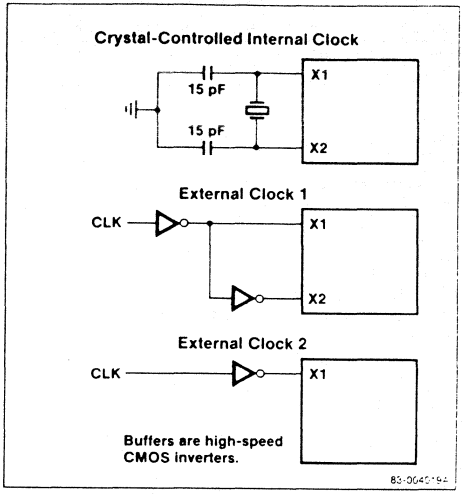
Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Data setup time to CLKOUT↓	t_{SDK}	20		ns	
Data hold time after CLKOUT↓	t_{HKD}	15		ns	
Address delay time from CLKOUT↓	t_{DKA}	10	60	ns	
Address hold time after CLKOUT↓	t_{HKA}	10		ns	
PS delay time from CLKOUT↓	t_{DKP}	10	60	ns	
PS float delay time from CLKOUT↑	t_{FKP}	10	60	ns	
Address setup time to ASTB↓	t_{SAST}	$t_{KKL} - 30$		ns	
Address float delay time from CLKOUT↓	t_{FKA}	t_{HKA}	60	ns	
ASTB↑ delay time from CLKOUT↓	t_{DKSTH}		50	ns	
ASTB↓ delay time from CLKOUT↑	t_{DKSTL}		55	ns	
ASTB pulse width, high	t_{STST}	$t_{KKL} - 10$		ns	
Address hold time after ASTB↓	t_{HSTA}	$t_{KKH} - 10$		ns	
Control delay time from CLKOUT	t_{DKCT}	15	60	ns	
$\overline{RD}$↓ delay time from address float	t_{DAFRL}	0		ns	
$\overline{RD}$↓ delay time from CLKOUT↓	t_{DKRL}	10	70	ns	
$\overline{RD}$↑ delay time from CLKOUT↓	t_{DKRH}	15	60	ns	
Address delay time from $\overline{RD}$↑	t_{DRHA}	$t_{CYK} - 40$		ns	
$\overline{RD}$ pulse width, low	t_{RR}	$2t_{CYK} - 50$		ns	
BUFR/W delay from BUFEN↑	t_{DBECT}	$t_{KKL} - 20$		ns	Read cycle
	t_{DWCT}	$t_{KKL} - 20$		ns	Write cycle
Data output delay time from CLKOUT↓	t_{DKD}	10	60	ns	
Data float delay time from CLKOUT↓	t_{FKD}	10	60	ns	
$\overline{WR}$ pulse width, low	t_{WW}	$2t_{CYK} - 40$		ns	
BS↓ delay time from CLKOUT↑	t_{DKBL}	10	60	ns	
BS↑ delay time from CLKOUT↓	t_{DKBH}	10	65	ns	

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
HLDRQ setup time to CLKOUT↑	t_{SHQK}	20		ns	
HLDAK delay time from CLKOUT↓	t_{DKHA}	10	100	ns	
Address drive delay time from CLKOUT↓	t_{DKA2}	t_{CYK}		ns	
$\overline{DMAAK}$ delay time from CLKOUT↑	t_{DKHDA}	10	70	ns	
$\overline{DMAAK}$ delay time from CLKOUT↓	t_{DKLDA}	10	115	ns	Cascade mode
$\overline{WR}$ pulse width, low (DMA cycle)	t_{WW1}	$2t_{CYK} - 40$		ns	DMA extended write cycle
$\overline{WR}$ pulse width, low (DMA cycle)	t_{WW2}	$t_{CYK} - 40$		ns	DMA normal write cycle
$\overline{TC}$ output delay time from CLKOUT↑	t_{DKTCL}		60	ns	
$\overline{TC}$ off delay time from CLKOUT↑	t_{DKTCF}		60	ns	
$\overline{TC}$ pulse width, low	t_{TCTCL}	$t_{CYK} - 15$		ns	
$\overline{TC}$ pullup delay time from CLKOUT↑	t_{DKTCH}		$t_{KKH} + t_{CYK} - 10$	ns	
$\overline{END}$ setup time to CLKOUT↑	t_{SEDK}	35		ns	
$\overline{END}$ pulse width, low	t_{EDEDL}	100		ns	
DMARQ setup time to CLKOUT↑	t_{SDQK}	35		ns	
INTPn pulse width, low	t_{IPIPL}	100		ns	
RxD setup time to SCU internal clock↓	t_{SRX}	1		μs	
RxD hold time after SCU internal clock↓	t_{HRX}	1		μs	
$\overline{SRDY}$ delay time from CLKOUT↓	t_{DKSR}		150	ns	
TxD delay time from TOUT1↓	t_{DTX}		500	ns	
TCTL2 setup time from CLKOUT↓	t_{SGK}	50		ns	
TCTL setup time to TCLK↑	t_{SGTK}	50		ns	
TCTL2 hold time after CLKOUT↓	t_{HKG}	100		ns	
TCTL2 hold time after TCLK↑	t_{HTKG}	50		ns	
TCTL2 pulse width, high	t_{GGH}	50		ns	

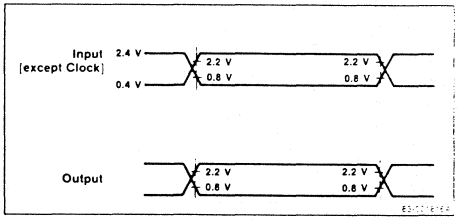
AC Characteristics (cont)

Parameter	Symbol	Limits Min	Max	Unit	Test Conditions
TCTL2 pulse width, low	t_{GGL}	50		ns	
TOUT output delay time from CLKOUT↓	t_{DKTO}		200	ns	
TOUT output delay time from TCLK↓	t_{DTKTO}		150	ns	
TOUT output delay time from TCTL2↓	t_{DGTO}		120	ns	
TCLK rise time	t_{TKR}		25	ns	
TCLK fall time	t_{TKF}		25	ns	
TCLK pulse width, high	t_{TKTKH}	50		ns	
TCLK pulse width, low	t_{TKTKL}	50		ns	
TCLK cycle time	t_{CYTK}	124	Dc	ns	
RD↓, WR↓ delay from DMAAK↓	t_{DDARW}	t_{KKH} − 30		ns	
DMAAK↑ delay from RD↑	t_{DRHDAH}	t_{KKL} − 30		ns	
RD↑ delay from WR↑	t_{DWHRH}	5		ns	

μPD70216 Clock Input Configurations

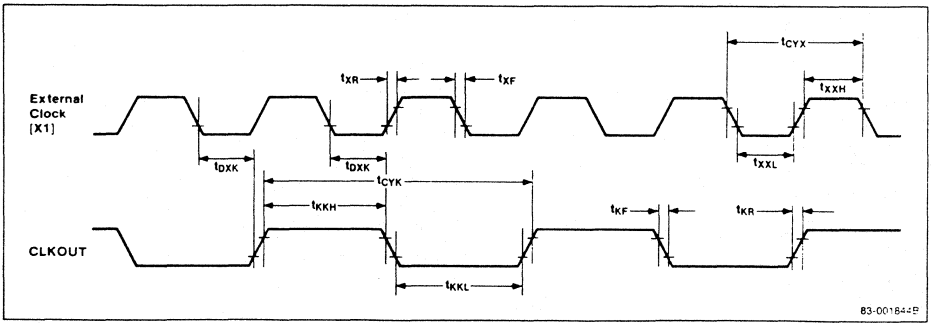


Timing Measurement Points



Timing Waveforms

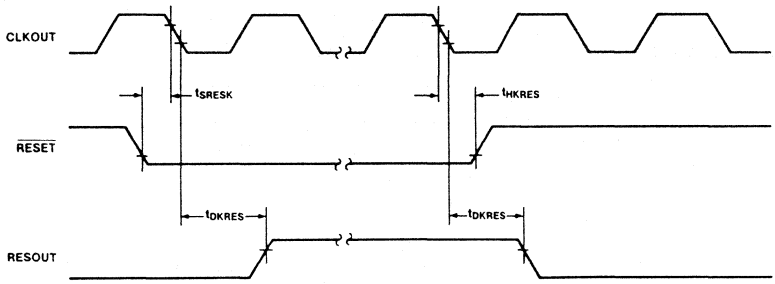
Clock Timing



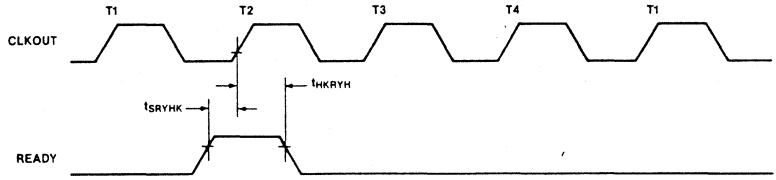
Timing Waveforms (cont)

Reset and Ready Timing

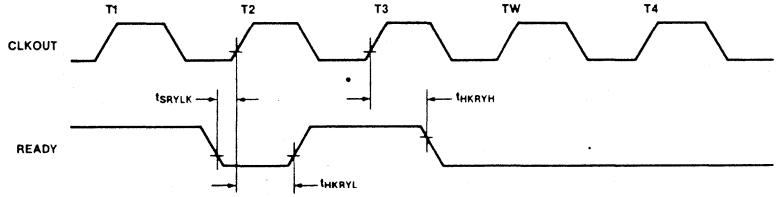
Reset Timing



Ready Timing, No Wait States

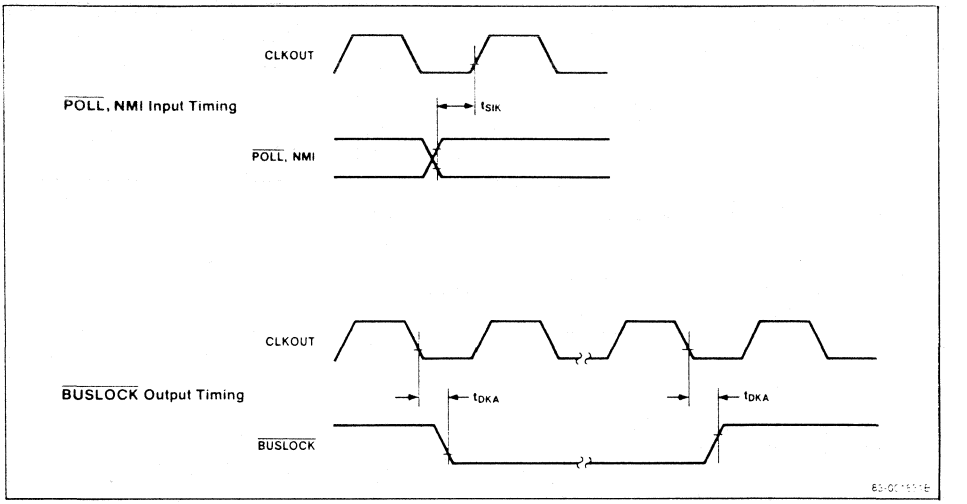


Ready Timng, Wait States



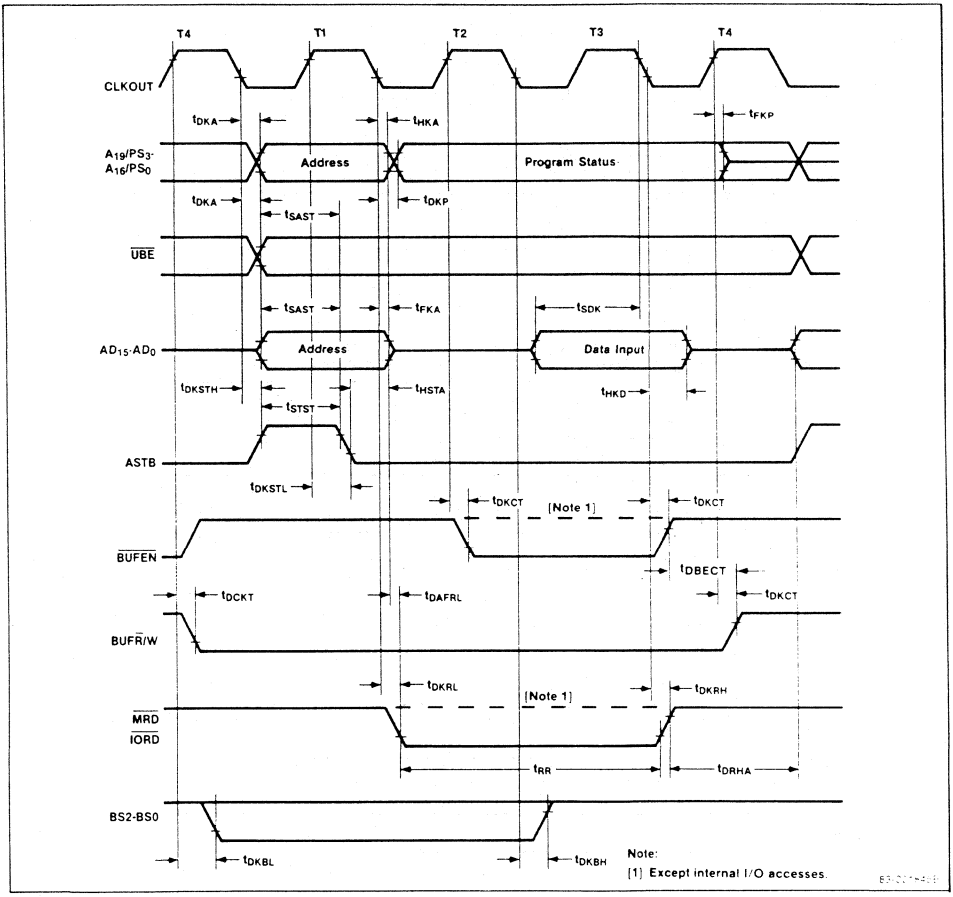
Timing Waveforms (cont)

Poll, NMI, and Buslock Timing



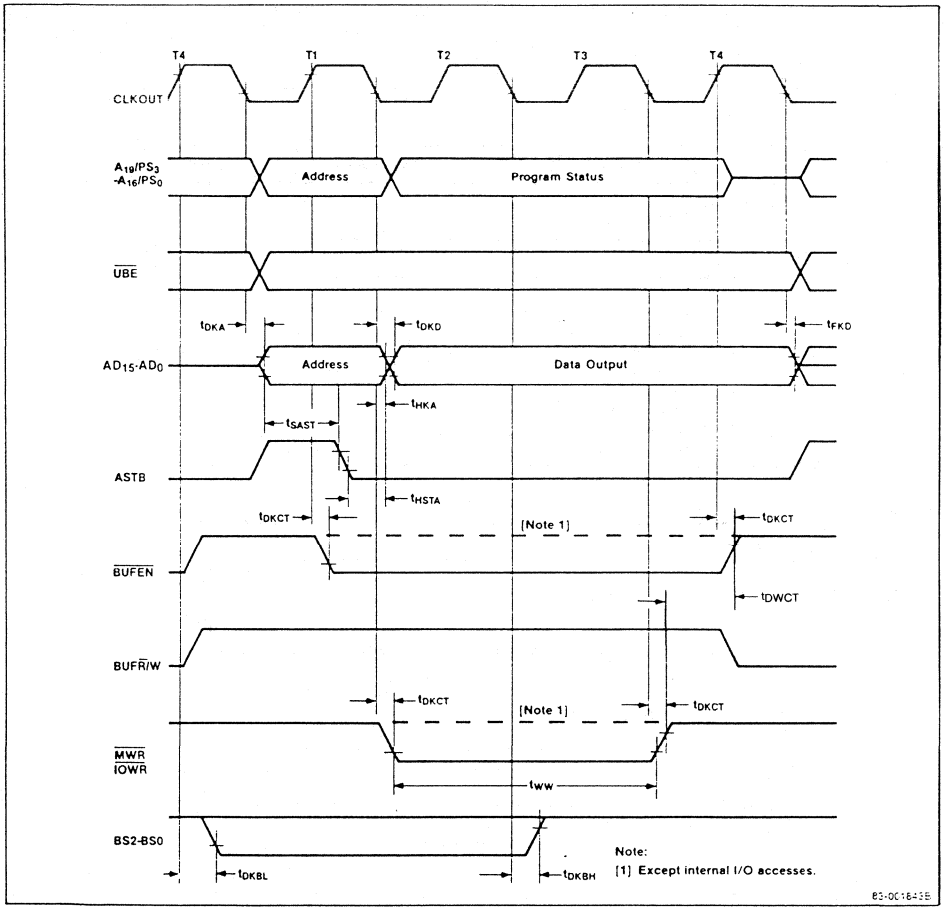
Timing Waveforms (cont)

Read Timing



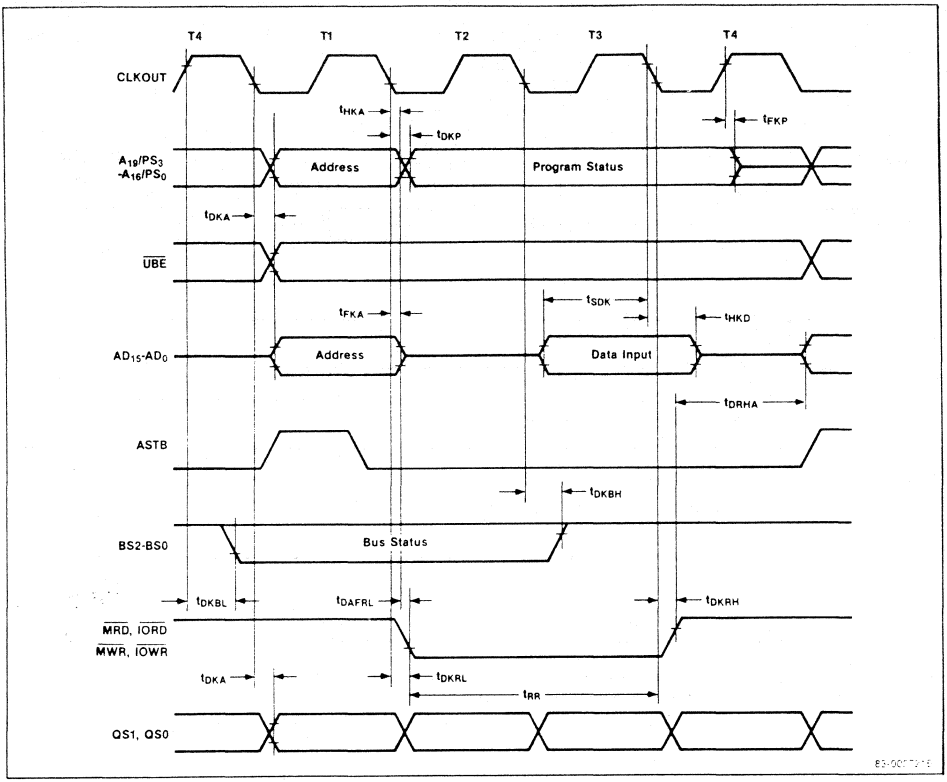
Timing Waveforms (cont)

Write Timing



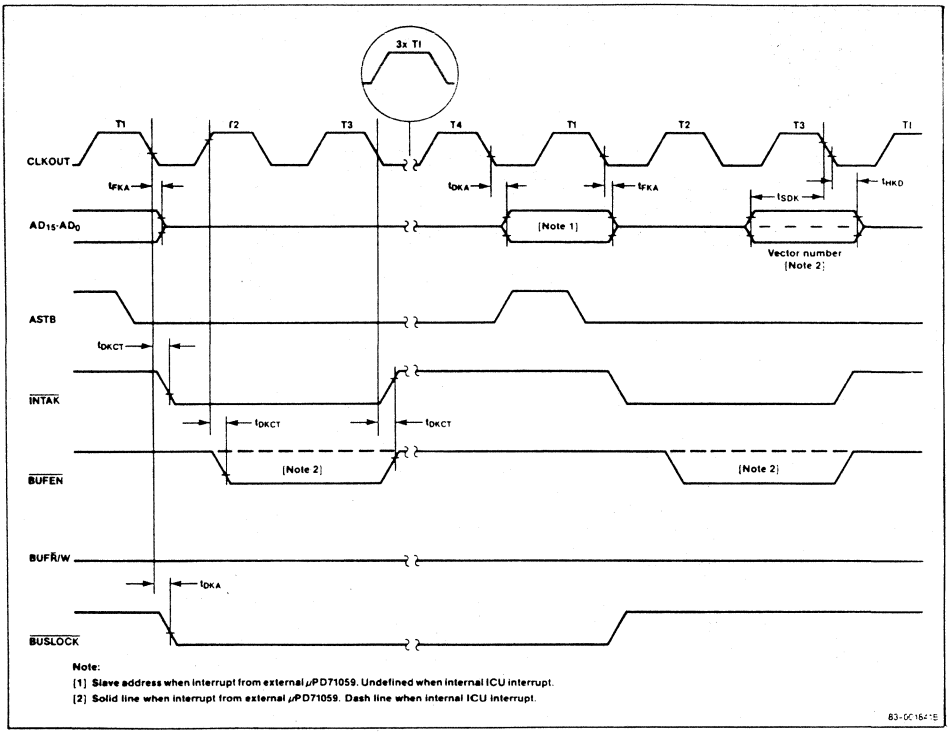
Timing Waveforms (cont)

Status Timing



Timing Waveforms (cont)

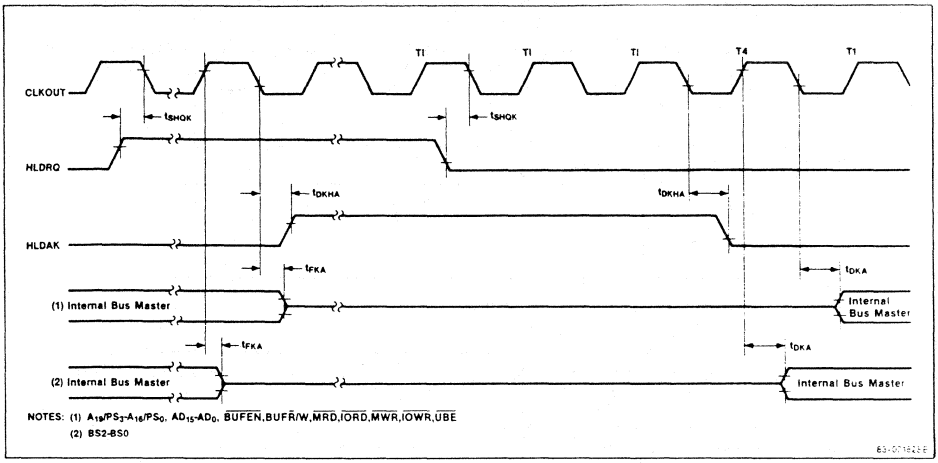
Interrupt Acknowledge Timing



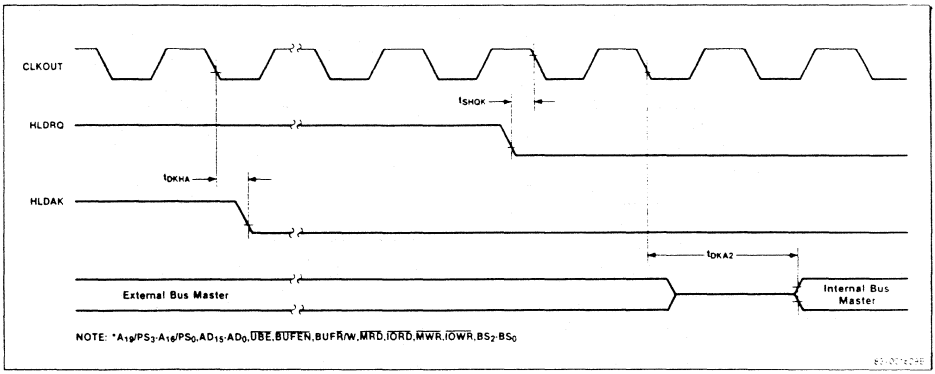
Note:
[1] Slave address when interrupt from external μPD71059. Undefined when internal ICU interrupt.
[2] Solid line when interrupt from external μPD71059. Dash line when internal ICU interrupt.

Timing Waveforms (cont)

HLDRQ/HLDAK Timing, Normal Operation

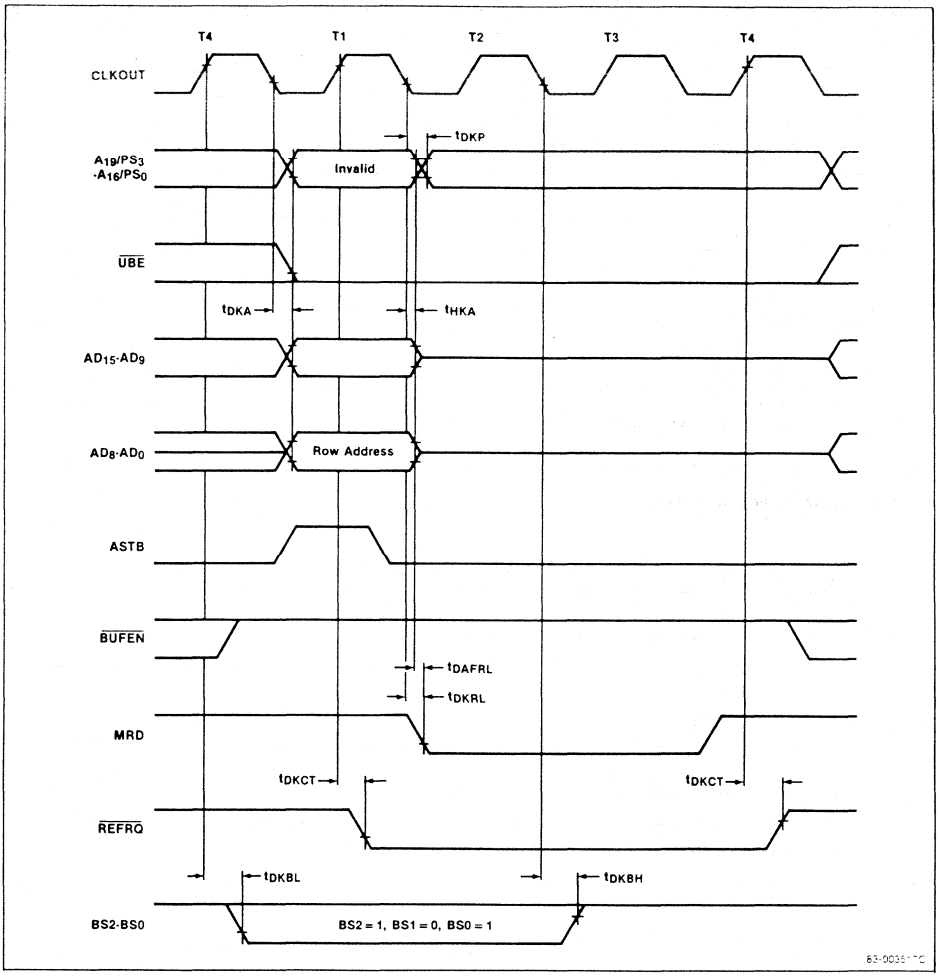


HLDRQ/HLDAK Timing, Bus Wait



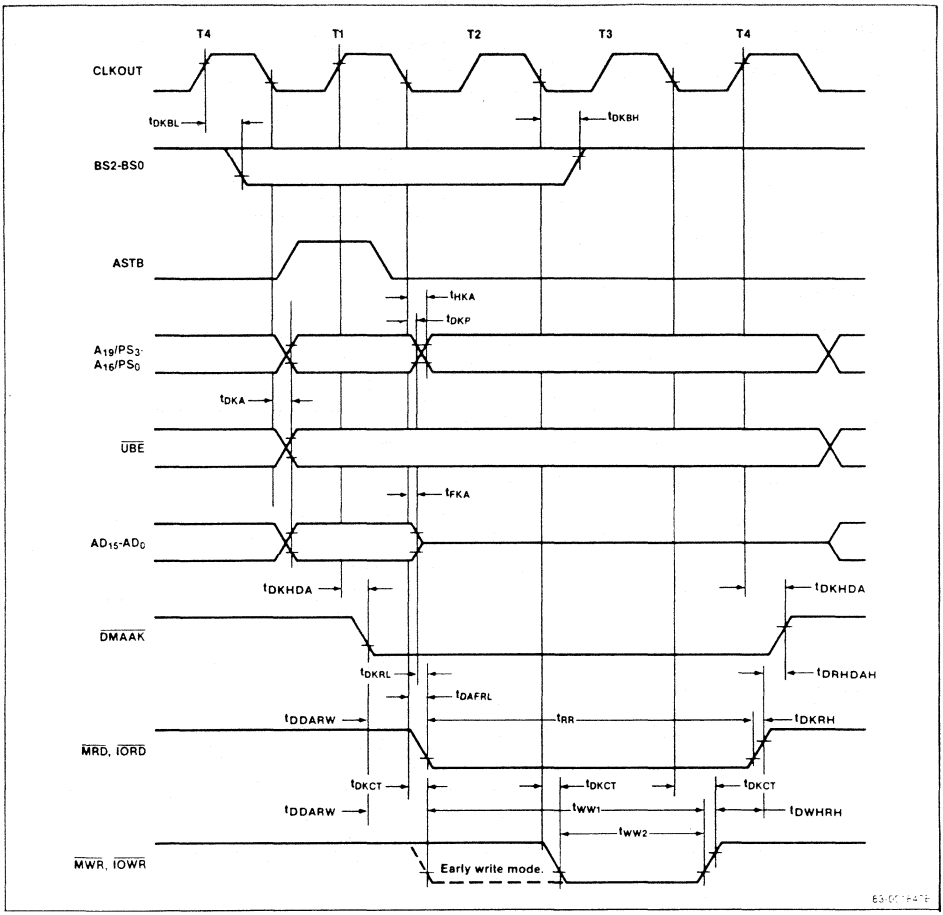
Timing Waveforms (cont)

Refresh Timing



Timing Waveforms (cont)

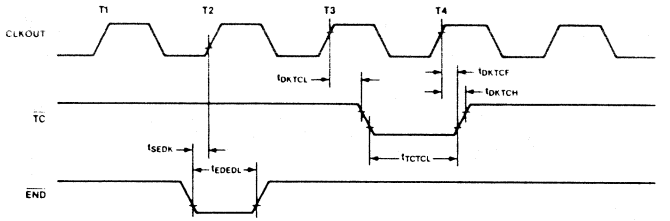
DMAU, DMA Transfer Timing



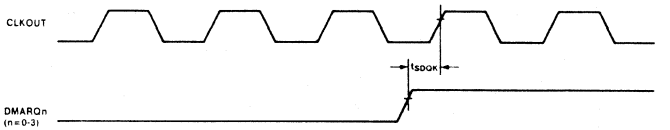
Timing Waveforms (cont)

DMA Timing

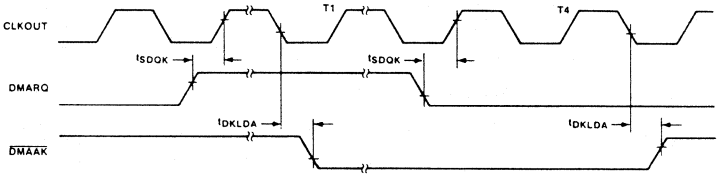
$\overline{END}/\overline{TC}$ Timing



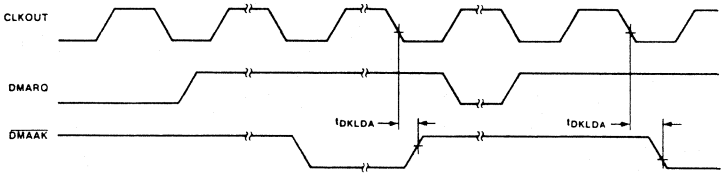
DMA Request Timing



Cascade Mode, Normal Operation

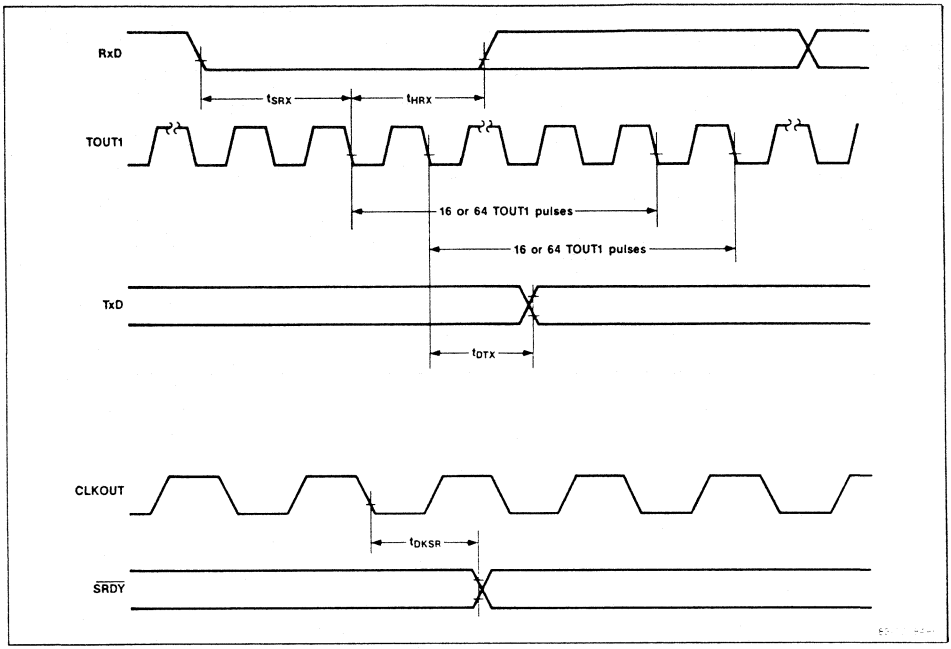


Cascade Mode, Refresh Cycle Insertion

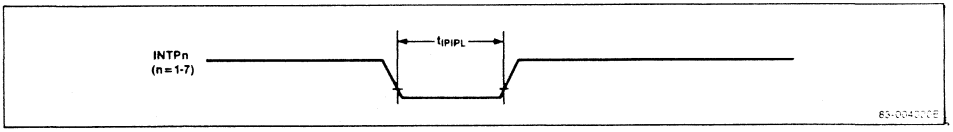


Timing Waveforms (cont)

SCU Timing

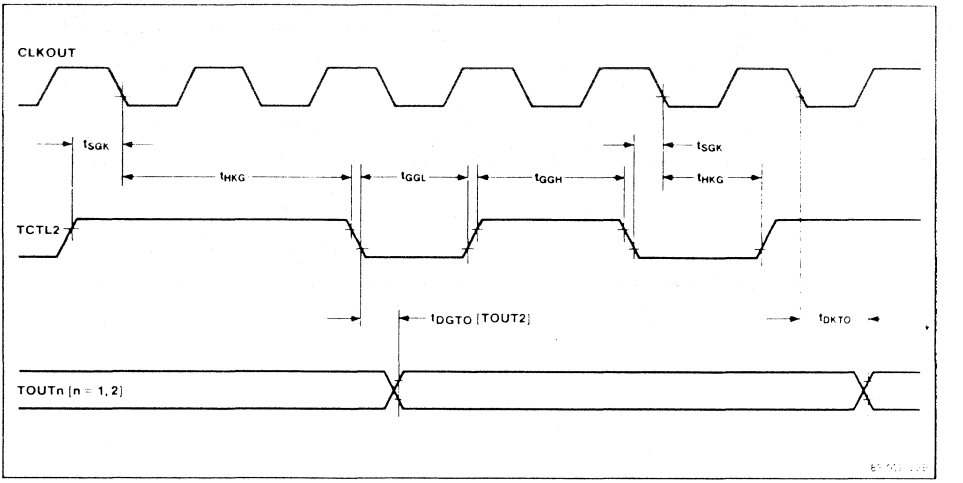


ICU Timing

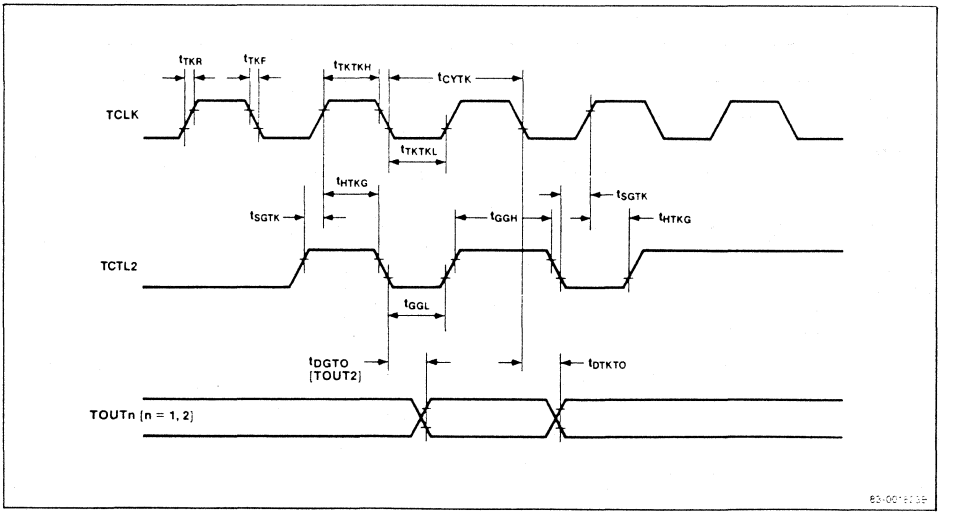


Timing Waveforms (cont)

TCU Timing, Internal Clock Source



TCU Timing, TCLK Source



Functional Description

Refer to the μPD70216 block diagram for an overview of the ten major functional blocks listed below.

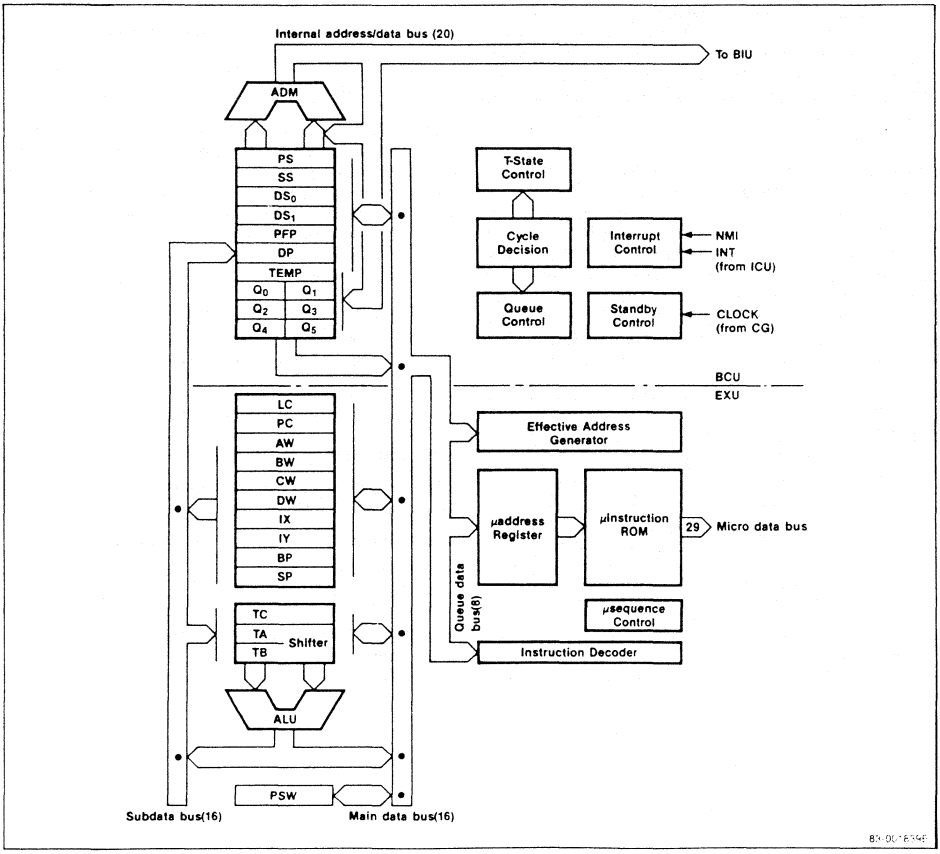
- Central processing unit (CPU)
- Clock generator (CG)
- Bus interface unit (BIU)
- Bus arbitration unit (BAU)
- Refresh control unit (RCU)
- Wait control unit (WCU)
- Timer/counter unit (TCU)
- Serial control unit (SCU)
- Interrupt control unit (ICU)
- DMA control unit (DMAU)

Central Processing Unit

The μPD70216 CPU functions similarly to the CPU of the μPD70116 CMOS microprocessor. However, because the μPD70216 has internal peripheral devices, its bus architecture has been modified to permit sharing the bus with internal peripherals. The μPD70216 CPU is object code compatible with both the μPD70108/μPD70116 and the μPD8086/μPD8088 microprocessors.

Figure 1 is the μPD70216 CPU block diagram. A listing of the μPD70216 instruction set is at the end of this data sheet.

Figure 1. μPD70216 CPU Block Diagram



Register Configuration

Program Counter [PC]. The program counter is a 16-bit binary counter that contains the program segment offset of the next instruction to be executed. The PC is incremented each time the microprogram fetches an instruction from the instruction queue. The contents of the PC are replaced whenever a branch, call, return, or break instruction is executed and during interrupt processing. At this time, the contents of the PC are the same as the prefetch pointer (PFP).

Prefetch Pointer [PFP]. The prefetch pointer is a 16-bit binary counter that contains the program segment offset of the next instruction to be fetched for the instruction queue. Because instruction queue prefetch is independent of instruction execution, the contents of the PFP and PC are not always identical. The PFP is updated each time the bus interface unit (BIU) fetches an instruction for the instruction queue. The contents of the PFP are replaced whenever a branch, call, return or break instruction is executed and during interrupt processing. At this time, the contents of the PFP and PC are the same.

Segment Registers [PS, SS, DS_0, DS_1]. The μPD70216 memory address space is divided into 64K-byte logical segments. A memory address is determined by the sum of a 20-bit base address (obtained from a segment register) and a 16-bit offset known as the effective address (EA). I/O address space is not segmented and no segment register is used. The four segment registers are program segment (PS), stack segment (SS), data segment 0 (DS_0), and data segment 1 (DS_1). The following table lists their offsets and overrides.

Default Segment Register	Offset	Override
PS	PFP register	Invalid
SS	SP register	Invalid
SS	Effective address (BP-based)	PS, DS_0, DS_1
DS_0	Effective address (non BP-based)	PS, SS, DS_1
DS_0	IX register (1)	PS, SS, DS_1
DS_1	IY register (2)	Invalid

Note:

(1) Includes source block transfer, output, BCD string, and bit field extraction.

(2) Includes destination block transfer, input, BCD string, and bit field insertion.

General-Purpose Registers. The μPD70216 CPU contains four 16-bit general-purpose registers (AW, BW, CW, DW), each of which can be used as a pair of 8-bit registers by dividing into upper and lower bytes (AH, AL, BH, BL, CH, CL, DH, DL). General purpose registers may also be specified implicitly in an instruction. The implicit assignments are:

- AW Word multiplication/division, word I/O, data conversion
- AL Byte multiplication/division, byte I/O, BCD rotation, data conversion, translation
- AH Byte multiplication/division
- BW Translation
- CW Loop control, repeat prefix
- CL Shift/rotate bit counts, BCD operations
- DW Word multiplication/division, indirect I/O addressing

Pointer [SP, BP] and Index Registers [IX, IY]. These registers serve as base pointers or index registers when accessing memory using one of the base, indexed, or base indexed addressing modes. Pointer and index registers can also be used as operands for word data transfer, arithmetic, and logical instructions. These registers are implicitly selected by certain instructions as follows.

- SP Stack operations, interrupts
- IX Source block transfer, BCD string operations, bit field extraction
- IY Destination block transfer, BCD string operations, bit field insertion

Program Status Word [PSW]

The program status word consists of six status flags and four control flags.

Status Flags

- V (Overflow)
- S (Sign)
- Z (Zero)
- AC (Auxiliary Carry)
- P (Parity)
- CY (Carry)

Control Flags

- MD (Mode)
- DIR (Direction)
- IE (Interrupt Enable)
- BRK (Break)

When pushed onto the stack, the word image of the PSW is as follows:

15							8
MD	1	1	1	V	DIR	IE	BRK

7							0
S	Z	0	AC	0	P	1	CY

The status flags are set and cleared automatically depending upon the result of the previous instruction execution. Instructions are provided to set, clear, and complement certain status and control flags. Other flags can be manipulated by using the POP PSW instruction.

Between execution of the BRKEM and RETEM instructions, the native mode RETI and POP PSW instructions can modify the MD bit. Care must be exercised by emulation mode programs to prevent inadvertent alteration of this bit.

CPU Architectural Features

The major architectural features of the μPD70216 CPU are:

- Dual data buses
- Effective address generator
- Loop counter
- PC and PFP

Dual Data Buses. To increase performance, dual data buses (figure 2) have been employed in the CPU to fetch operands in parallel and avoid the bottleneck of a single bus. For two-operand instructions and effective address calculations, the dual data bus approach is 30 percent faster than single-bus systems.

Effective Address Generator. Effective address (EA) calculation requires only two clocks regardless of the addressing mode complexity due to the hardware effective address generator (figure 3). When compared with microprogrammed methods, the hardware approach saves between 3 and 10 clock cycles during effective address calculation.

Figure 2. Dual Data Buses

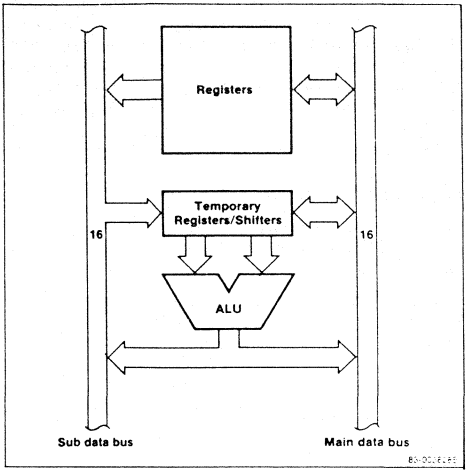
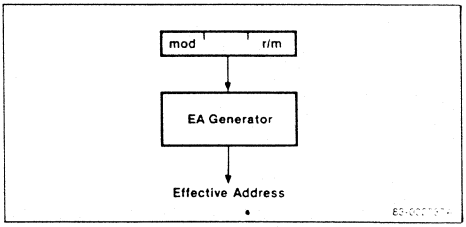


Figure 3. Effective Address Generator



Loop Counter and Shifters. A dedicated loop counter is used to count the iterations of block transfer and multiple shift instructions. This logic offers a significant performance advantage over architectures that control block transfers and multiple shifts using microprogramming. Dedicated shift registers also speed up the execution of the multiply and divide instructions. Compared with microprogrammed methods, multiply and divide instructions execute approximately four times faster.

Program Counter and Prefetch Pointer. The functions of instruction execution and queue prefetch are decoupled in the μPD70216. By avoiding a single-instruction pointer and providing separate PC and PFP registers, the execution time of control transfers and the interrupt response latency can be minimized. Several clocks are saved by avoiding the need to readjust an instruction pointer to account for prefetching before computing the new destination address.

Enhanced Instruction Set

In addition to the μPD8086/88 instruction set, the μPD70216 has added the following enhanced instructions.

Instruction	Function
PUSH imm	Push immediate data onto stack
PUSH R	Push all general registers onto stack
POP R	Pop all general registers from stack
MUL imm	Multiply register/memory by immediate data
SHL imm8 SHR imm8 SHRA imm8 ROL imm8 ROR imm8 ROLC imm8 RORC imm8	Shift/rotate by immediate count
CHKIND	Check array index
INM	Input multiple
OUTM	Output multiple
PREPARE	Prepare new stack frame
DISPOSE	Dispose current stack frame

Unique Instruction Set

In addition to the μPD70216 enhanced instruction set, the following unique instructions are supported.

Instruction	Function
INS	Insert bit field
EXT	Extract bit field
ADD4S	BCD string addition
SUB4S	BCD string subtraction
CMP4S	BCD string comparison
ROL4	Rotate BCD digit left
ROR4	Rotate BCD digit right
TEST1	Test bit
SET1	Set bit
CLR1	Clear bit
NOT1	Complement bit
REPC	Repeat while carry set
REPNC	Repeat while carry cleared
FPO2	Floating point operation 2

Bit Fields. Bit fields are data structures that range in length from 1 to 16 bits. Two separate operations on bit fields, insertion and extraction, with no restrictions on the position of the bit field in memory are supported. Separate segment, byte offset, and bit offset registers are used for bit field insertion and extraction. Because of their power and flexibility, these instructions are highly effective for graphics, high-level languages, and data packing/unpacking applications.

Insert bit field (INS) copies the bit field of specified length (0 = 1 bit, 15 = 16 bits) from the AW register to the bit field addressed by DS1:IY:reg8 (figure 4). The bit field length can be located in any byte register or supplied as an immediate value. The value in reg8 is a bit field offset. A content of 0 selects bit 0 and 15 selects bit 15 of the word DS0:IX points to. Following execution, the IY and bit offset register are updated to point to the start of the next bit field.

Bit field extraction (EXT) copies the bit field of specified length (0 = 1 bit, 15 = 16 bits) from the bit field addressed by DS0:IX:reg8 to the AW register (figure 5). If the bit field is less than 16 bits, it is right justified with a zero fill. The bit field length can be located in any byte register or supplied as immediate data. The value in reg8 is a bit field offset. A content of 0 selects bit 0 and 15 selects bit 15 of the word DS0:IX points to. Following execution, the IX and bit offset register are updated to point to the start of the next bit field.

Packed BCD Strings. These instructions are provided to efficiently manipulate packed BCD data as strings (length from 1 to 254 digits) or as a byte data type with a single instruction.

BCD string arithmetic is supported by the ADD4S, SUB4S, and CMP4S instructions. These instructions allow the source string (addressed by DS0:IX) and the destination string (addressed by DS1:IY) to be manipulated with a single instruction. When the number of BCD digits is even, the Z and CY flags are set according to the result of the operation. If the number of digits is odd, the Z flag will not be correctly set unless the upper 4 bits of the result are zero. The CY flag will not be correctly set unless there is a carry out of the upper 4 bits of the result.

The two BCD rotate instructions (ROR4, ROL4) perform rotation of a single BCD digit in the lower half of the AL register through the register or memory operand.

Bit Manipulation. Four bit manipulation instructions have been added to the μPD70216 instruction set. The ability to test, set, clear, or complement a single bit in a register or memory operand increases code readability as well as performance over the logical operations traditionally used to manipulate bit data.

Figure 4. Bit Field Insertion

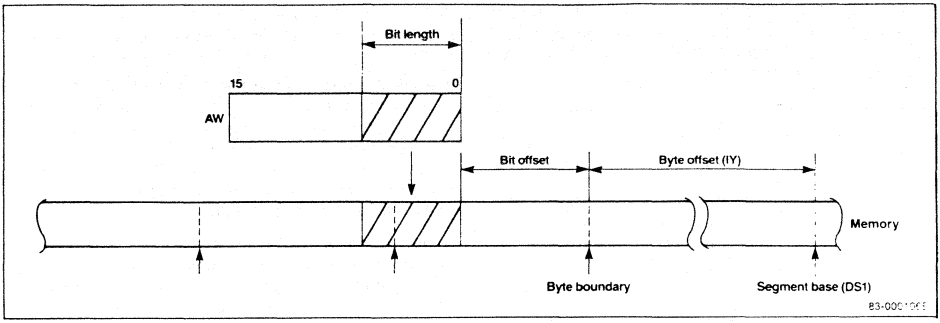
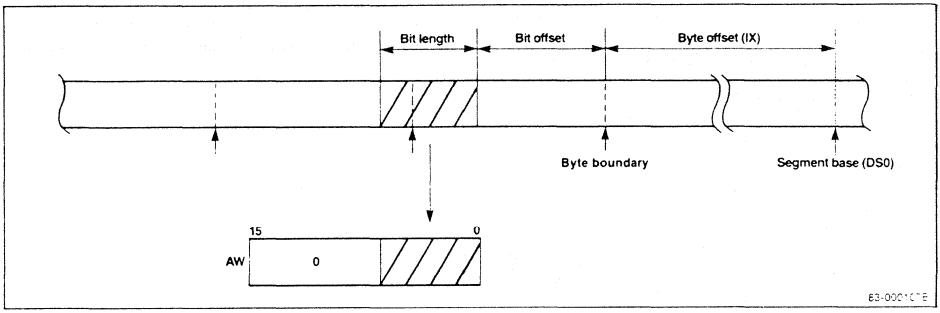


Figure 5. Bit Field Extraction.



Repeat Prefixes. Two repeat prefixes (REPC, REPNC) allow conditional block transfer instructions to use the state of the CY flag as a terminating condition. The use of these prefixes allows inequalities to be used when working on ordered data, increasing the performance of searching and sorting algorithms.

Floating Point Operation Instructions. Two floating point operation (FPO) instruction types are recognized by the μPD70216 CPU. These instructions are detected by the CPU, which performs any auxiliary processing such as effective address calculation and the initial bus cycle if specified by the instruction. It is the responsibility of the external coprocessor to latch the address information and data (if a read cycle) from the bus and complete the execution of the instruction.

8080 Emulation Mode. The μPD70216 CPU can operate in either of two modes; see figure 6. Native mode allows the execution of the μPD8086/88, enhanced and unique instructions. The other operating mode is 8080 emulation mode, which allows the entire μPD8080AF instruction set to be executed. A mode (MD) flag is provided to distinguish between the two operating modes. Native mode is active when MD is 1 and 8080 emulation mode is active when MD is 0.

Two instructions are provided to switch from native to 8080 emulation mode and return back. Break for emulation (BRKEM) operates similarly to a BRK instruction, except that after the PSW has been pushed on the native mode stack, the MD flag is cleared.

During 8080 emulation mode, the registers and flags of the 8080 are mapped onto the native mode registers and flags as shown below. Note that PS, SS, DS_0, DS_1, IX, IY, AH and the upper half of the PSW registers are inaccessible to 8080 programs.

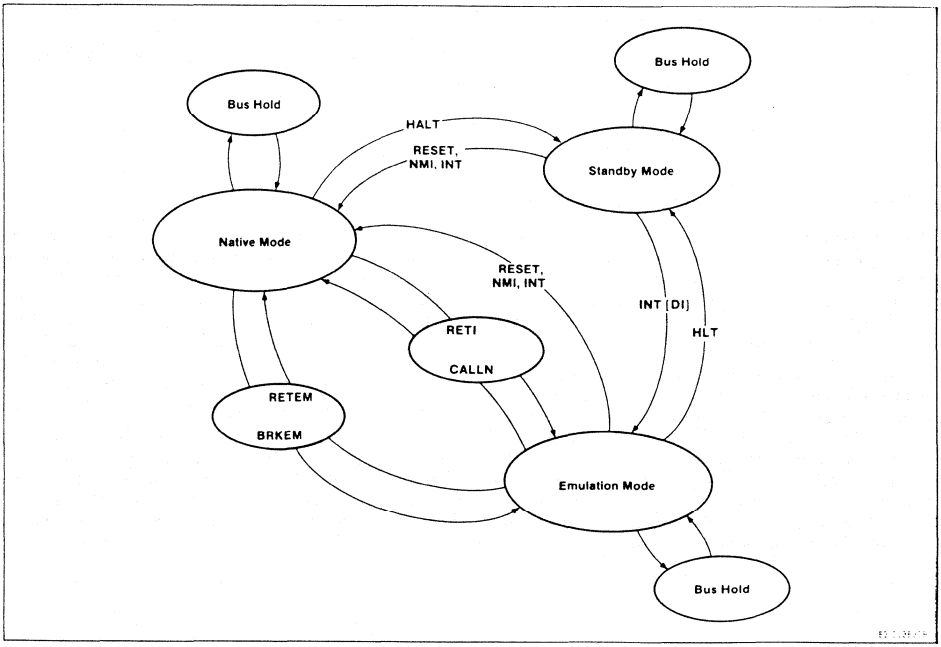
	μPD8080AF	μPD70216
Registers	A	AL
	B	CH
	C	CL
	D	DH
	E	DL
	H	BH
	L	BL
	SP	BP
	PC	PC
Flags	C	CY
	Z	Z
	S	S
	P	P
	AC	AC

During 8080 emulation mode, the BP register functions as the 8080 stack pointer. The use of separate stack pointers prevents inadvertent damage to the native stack pointer by emulation mode programs.

The 8080 emulation mode PC is combined with the PS register to form the 20-bit physical address. All emulation mode data references use DS0 as the segment register. For compatibility with older 8080 software these registers must be equal. By using different segment register contents, separate 64K-byte code and data spaces are possible.

Either an NMI or maskable interrupt will cause the 8080 emulation mode to be suspended. The CPU pushes the PS, PC, and PSW registers on the native mode stack, sets the MD bit (indicating native mode), and enters the specified interrupt handler. When the return from interrupt (RETI) instruction is executed, the PS, PC, and PSW (containing MD=0) are popped from the native stack and execution in 8080 emulation mode continues. Reset will also force a return to native mode.

Figure 6. μPD70216 Modes.



The 8080 emulation mode programs also have the capability to invoke native mode interrupt handlers by means of the call native (CALLN) instruction. This instruction operates the same as the BRK instruction except that the saved PSW indicates 8080 emulation mode.

To exit 8080 emulation mode, the return from emulation (RETEM) instruction pops the PS, PC, and PSW from the native mode stack and execution continues with the instruction following the BRKEM instruction. Nesting of 8080 emulation modes is prohibited.

Interrupt Operation

The μPD70216 supports a number of external interrupts and software exceptions. External interrupts are events asynchronous to program execution. On the other hand, exceptions always occur as a result of program execution.

The two types of external interrupts are:

- Nonmaskable interrupt (NMI)
- Maskable interrupt (INT)

The six software exceptions are:

- Divide error (DIV, DIVU instructions)
- Array bound error (CHKIND instruction)
- Break on overflow (BRKV instruction)
- Break (BRK, BRK3 instructions)
- Single step (BRK bit in PSW set)
- Mode switch (BRKEM, CALLN instructions)

Interrupt vectors are determined automatically for exceptions and the NMI interrupt or supplied by hardware for maskable interrupts. The 256 interrupt vectors are stored in a table (figure 7) located at address 00000H. Vectors 0 to 5 are predetermined and vectors 6 to 31 are reserved. Interrupt vectors 32 to 255 are available for use by application software.

Each vector is made up of two words. The word located at the lower address contains the new PC for the interrupt handler. The word at the next-higher address is the new PS value for the interrupt handler. These must be initialized by software at the start of a program.

Standby Mode

The μPD70216 CPU has a low-power standby mode, which can dramatically reduce power consumption during idle periods. Standby mode is entered by simply executing a native or 8080 emulation HALT instruction; no external hardware is required. All other peripherals such as the timer/counter unit, refresh control unit, and DMA control unit continue to operate as programmed.

During standby mode, the clock is distributed only to the circuits required to release the standby mode. When a RESET, NMI, or INT event is detected, the standby mode is released. Both NMI and unmasked interrupts are processed before control returns to the instruction following the HALT. In the case of the INT input being masked, execution will begin with the instruction immediately following the HALT instruction without an intervening interrupt acknowledge bus cycle. When maskable interrupts are again enabled, the interrupt will be serviced.

Output signal states in the standby mode are listed below.

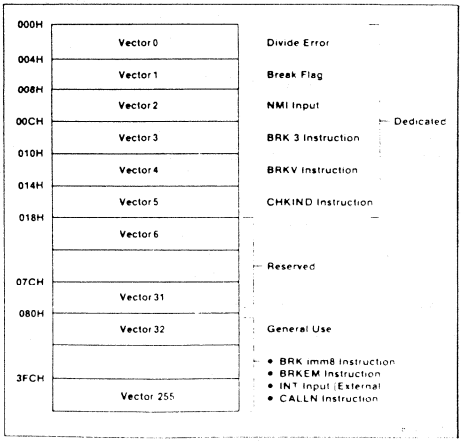
Output Signal	Status in Standby Mode
$\overline{INTAK}$, $\overline{BUFEN}$, $\overline{MRD}$, $\overline{MWR}$, $\overline{IOWR}$, $\overline{IORD}$ $\overline{UBE}$	High level
BS_2-BS_0 (Note 2)	Sends halt status (011), then remains high (111)
QS_1-QS_0, ASTB	Low level
$\overline{BUSLOCK}$	High level (low level if the $\overline{HALT}$ instruction follows the $\overline{BUSLOCK}$ prefix)
$\overline{BUFR}$/W, A_{19}-A_{16}/PS_3-PS_0, AD_{15}-AD_0	High or low level

Note:

(1) Output pin states during refresh and DMA bus cycles will be as defined for those operations.

(2) Halt status is presented prior to entering the passive state.

Figure 7. Interrupt Vector Table



Clock Generator

The clock generator (CG) generates a clock signal half the frequency of a parallel-resonant, fundamental mode crystal connected to pins X1 and X2. Figure 8 shows the recommended circuit configuration. Capacitors C1 and C2 are required for frequency stability. Their values can be calculated from the load capacitance (CL) specified by the crystal manufacturer.

$$C1 = C2 = 2\ (CL - CS)$$

CS is any stray capacitance in parallel with the crystal, such as the μPD70216 input capacitance.

External clock sources (figure 9) are also accommodated by applying the external clock to the X1 pin and its complement to the X2 pin. The CG distributes the clock to the CLKOUT pin and to each functional block of the μPD70216. The generated clock signal has a 50-percent duty cycle.

Bus Interface Unit

The bus interface unit (BIU) controls the external address, data, and control buses for the three internal bus masters: CPU, DMA control unit (DMAU), and refresh control unit (RCU). The BIU is also responsible for synchronization of the $\overline{\text{RESET}}$ and READY inputs with the clock. The synchronized reset signal is used internally by the μPD70216 and provided externally at the RESOUT pin as a system-wide reset. The synchronized READY signal is combined with the output of the wait control unit (WCU) and is distributed internally to the CPU, DMAU, and RCU. Figure 10 shows the synchronization of $\overline{\text{RESET}}$ and READY.

Figure 8. Crystal Configuration

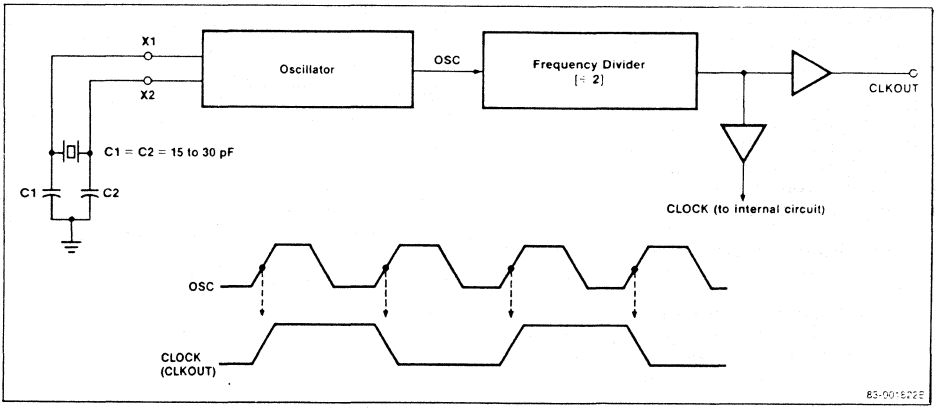
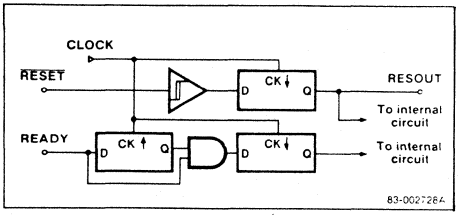


Figure 10. $\overline{\text{RESET}}$/READY Synchronization



Bus Arbitration Unit

The bus arbitration unit (BAU) arbitrates the local bus between the internal CPU, DMAU, and RCU bus requesters and an external bus master. The BAU bus priorities from the highest priority requester to the lowest are:

RCU (Demand mode)
DMAU
HLDRQ
CPU
RCU (Normal mode)

Note that RCU requests the bus at either the highest or lowest priority depending on the status of the refresh request queue. Bus masters other than the CPU are prohibited from using the bus when the CPU is executing an instruction containing a $\overline{\text{BUSLOCK}}$ prefix. Therefore, caution should be exercised when using the $\overline{\text{BUSLOCK}}$ prefix with instructions having a long execution time.

If a bus master with higher priority than the current bus master requests the bus, the BAU inactivates the current bus master's acknowledge signal. When the BAU sees the bus request from the current master go inactive, the BAU gives control of the bus to the higher priority bus master. The BAU performs bus switching between internal bus masters without the introduction of idle bus cycles, enhancing system throughput.

System I/O Area

The I/O address space from addresses FF00H to FFFFH is reserved for use as the system I/O area. Located in this area are the 12 μPD70216 registers that determine the I/O addressing, enable/disable peripherals, and control pin multiplexing.

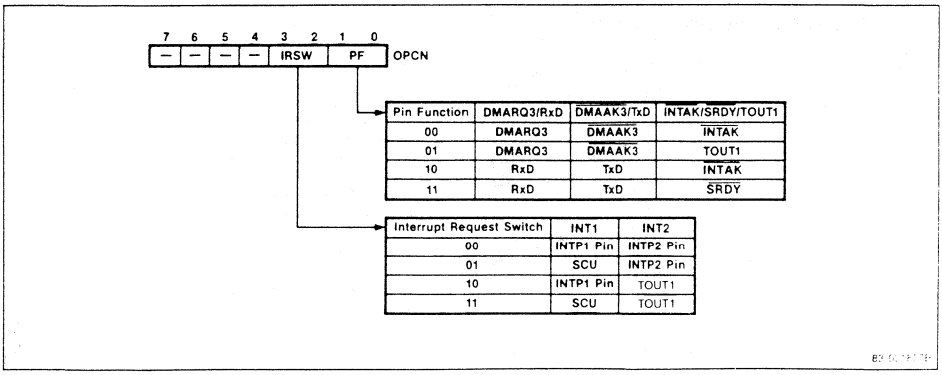
I/O Address	Register	Operation
FFFFH	Reserved	—
FFFEH	OPCN	Read/Write
FFFDH	OPSEL	Read/Write
FFFCH	OPHA	Read/Write
FFFBH	DULA	Read/Write
FFFAH	IULA	Read/Write
FFF9H	TULAL	Read/Write
FFF8H	SULA	Read/Write
FFF7H	Reserved	—
FFF6H	WCY2	Read/Write
FFF5H	WCY1	Read/Write
FFF4H	WMB	Read/Write
FFF3H	Reserved	—
FFF2H	RFC	Read/Write
FFF1H	Reserved	—
FFF0H	TCKS	Read/Write

On-Chip Peripheral Connection Register

The on-chip peripheral connection (OPCN) register controls multiplexing of the μPD70216 multiplexed pins. Figure 11 shows the format of the OPCN register. The interrupt request switch (IRSW) field controls multiplexing of ICU interrupt inputs INT1 and INT2. The output of an internal peripheral or an external interrupt source can be selected as the INT1 and INT2 inputs to the ICU.

The pin function (PF) field in the OPCN selects one of four possible states for the DMARQ3/RxD, $\overline{\text{DMAAK3}}$/TxD, and $\overline{\text{INTAK}}$/$\overline{\text{SRDY}}$/TOUT1 pins. Bit 0 of the

Figure 11. OPCN Register Format

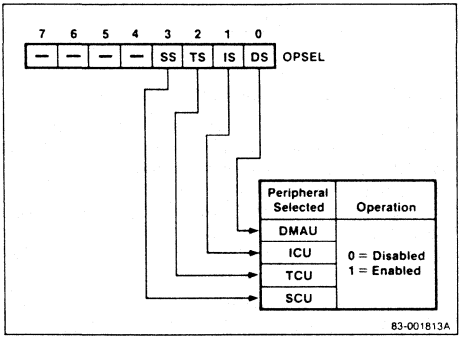


OPCN controls the function of the INTAK/SRDY/TOUT1 pin. If cleared, INTAK will appear on this output pin. If bit 0 is set, either TOUT1 or SRDY will appear at the output depending on the state of bit 1. If bit 1 is cleared, DMA channel 3 I/O signals will appear on the DMARQ3/RxD and DMAAK3/TxD pins. If the SCU is to be used, bit 1 of the PF field must be set.

On-Chip Peripheral Selection Register

The on-chip peripheral selection (OPSEL) register is used to enable or disable the μPD70216 internal peripherals. Figure 12 shows the format of the OPSEL register. Any of the four (DMAU, TCU, ICU, SCU) peripherals can be independently enabled or disabled by setting or clearing the appropriate OPSEL bit.

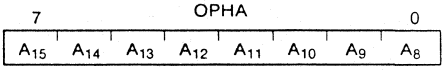
Figure 12. OPSEL Register Format



Internal Peripheral Relocation Registers

The five internal peripheral relocation registers (figure 13) are used to fix the I/O addresses of the DMAU, ICU, TCU, and SCU. The on-chip peripheral high-address (OPHA) register is common to all four internal peripherals and fixes the high-order byte of the 16-bit I/O address. The individual DMAU low-address (DULA) register, ICU low-address (IULA) register, TCU low-address (TULA) register, and the SCU low-address (SULA) register select the low-order byte of the I/O addresses for the DMAU, ICU, TCU, and SCU peripherals.

The contents of the OPHA register are:



The formats for the individual internal peripheral registers appear below. Since address checking is not performed, do not overlap two peripheral I/O address spaces.

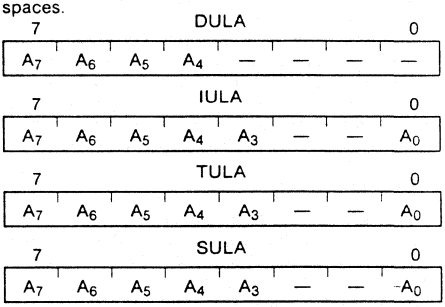


Figure 13. μPD70216 Peripheral Relocation

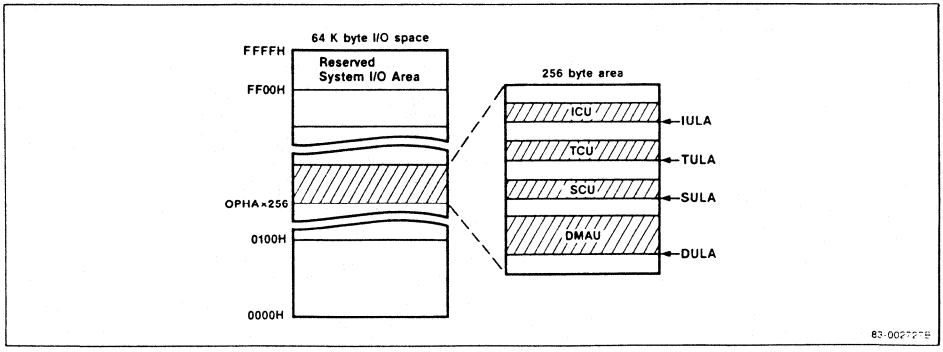
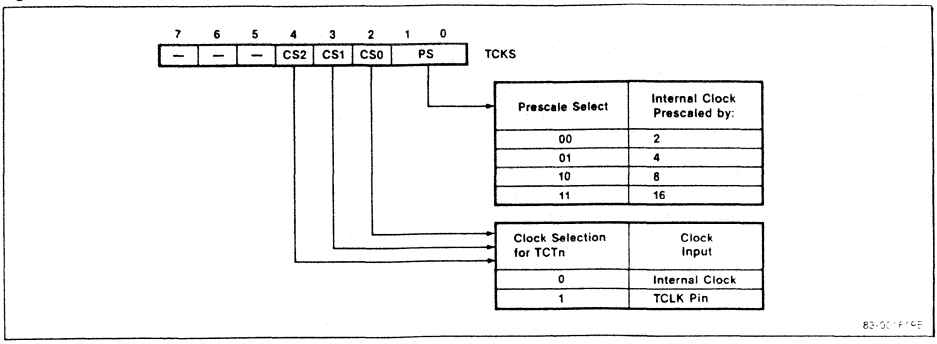


Figure 14. Timer Clock Selection Register



Timer Clock Selection Register

The timer clock selection (TCKS) register selects the clock source for each of the timer/counters as well as the divisor for the internal clock prescaler. Figure 14 shows the format of the TCKS register. The clock source for each timer/counter is independently selected from either the prescaled CLKOUT signal or from an external clock source (TCLK). The internal clock is derived from the CLKOUT signal and can be divided by 2, 4, 8, or 16 before being presented to the clock select logic.

Refresh Control Unit

The refresh control unit (RCU) refreshes external dynamic RAM devices by outputting an 8-bit row address on address lines A_8-A_1 and performing a word-aligned memory read bus cycle. Both $\overline{UBE}$ and A_0 are asserted to allow the refresh of both the even and odd memory banks. External logic can distinguish a refresh bus cycle by monitoring the refresh request ($\overline{REFRQ}$) pin. Following each refresh bus cycle, the refresh row counter is incremented. The refresh control (RFC) register in the system I/O area contains two fields. The refresh enable field enables or disables the refreshing function. The refresh timer (RTM) field selects a refresh interval to match the dynamic memory refresh requirements. Figure 15 shows the format for the RFC register.

To minimize the impact of refresh on the system bus bandwidth, the μPD70216 utilizes a refresh request queue to store refresh requests and perform refresh bus cycles in otherwise idle bus cycles.

The RCU normally requests the bus as the lowest-priority bus requester (normal mode). However, if seven refresh requests are allowed to accumulate in the RCU refresh request queue, the RCU will change to the highest-priority bus requester (demand mode). The RCU will then perform back-to-back refresh cycles until three requests remain in the queue. This guarantees the integrity of the DRAM system while maximizing performance.

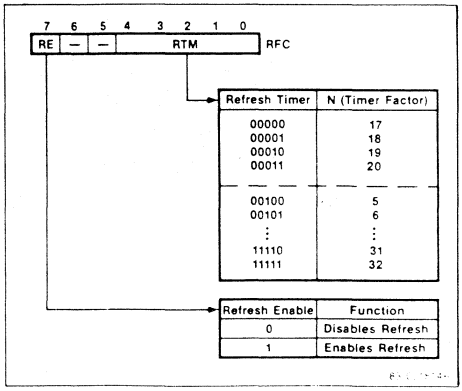
The refresh count interval can be calculated as follows.

Refresh interval = 8 x N x t_{CYK}

where N is the timer factor selected by the RTM field.

When the μPD70216 is reset, the RE field in the RFC register is unaffected and the RTM field is set to 01000 (N = 9). No refresh bus cycles occur while $\overline{RESET}$ is asserted.

Figure 15. Refresh Control Register



Wait Control Unit

The wait control unit (WCU) inserts from zero to three wait states into a bus cycle in order to compensate for the varying access times of memory and I/O devices. The number of wait states for CPU, DMAU, and RCU bus cycles is separately programmable. In addition, the memory address space is divided into three independent partitions to accommodate a wide range of system designs. $\overline{\text{RESET}}$ initializes the WCU to insert three wait states in all bus cycles. This allows operation with slow memory and peripheral devices before the initialization of the WCU registers.

The three system I/O area registers that control the WCU are wait cycle 1 (WCY1), wait cycle 2 (WCY2), and wait state memory boundary (WMB). The WCU always inserts wait states corresponding to the wait count programmed in WCY1 or WCY2 registers into a bus cycle, regardless of the state of the external READY input. After the programmed number of wait states occurs, the WCU will insert Tw states as long as the READY pin remains inactive. When READY is again asserted, the bus cycle continues with T4 as the next cycle. The μPD70216 internal peripherals never require wait states; four clock cycles will terminate an internal peripheral bus cycle.

CPU Wait States

The WMB register divides the 1M-byte memory address space into three independent partitions: lower, middle, and upper. Figure 16 shows the WMB register format.

Initialization software can then set the number of wait states for each memory partition and the I/O partition via the WCY1 register (figure 17).

DMA and Refresh Wait States

The WCY2 register (figure 18) specifies the number of wait states to be automatically inserted in DMA and refresh bus cycles.

Figure 16. Wait State Memory Boundary Register

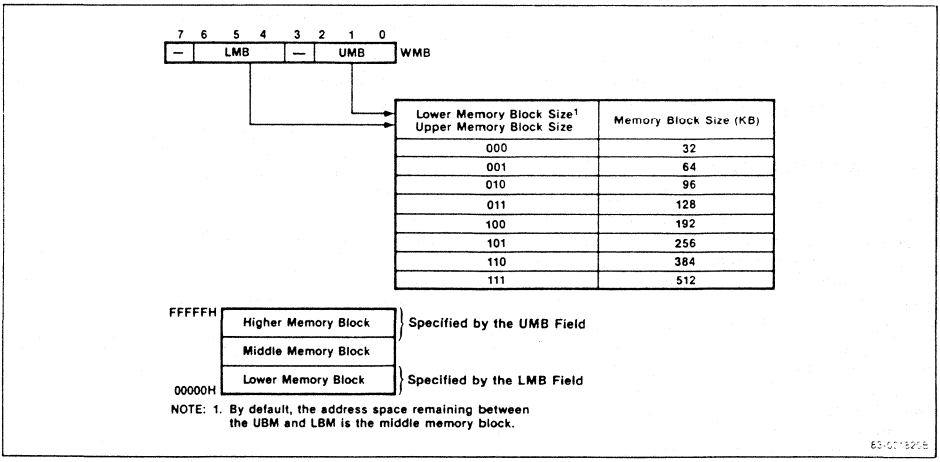


Figure 17. Wait Cycle 1 Register

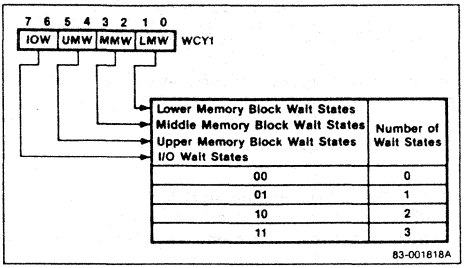
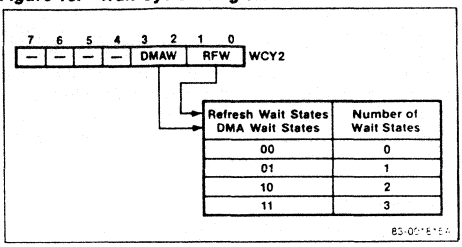


Figure 18. Wait Cycle 2 Register



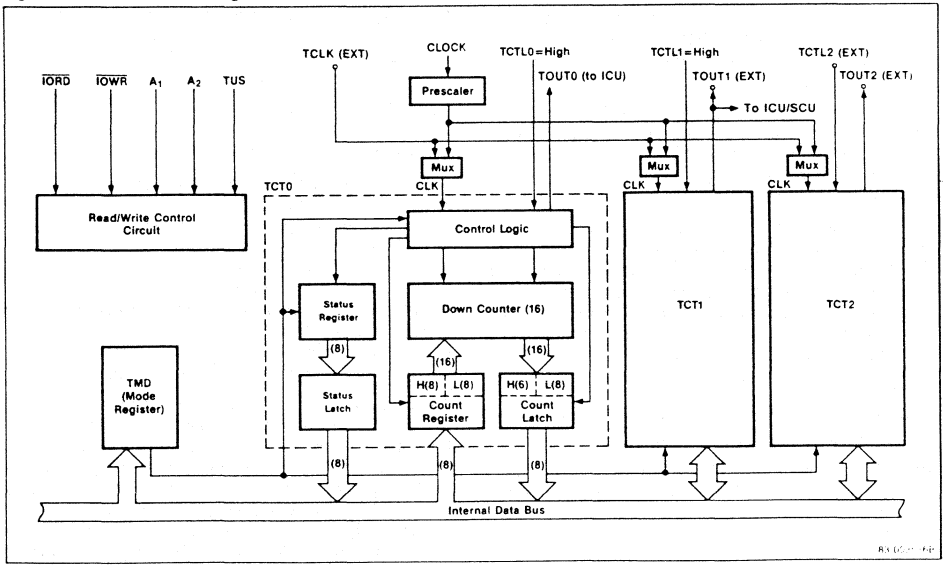
Timer/Counter Unit

The timer/counter unit (TCU) provides a set of three independent 16-bit timer/counters. The output signal of timer/counter 0 is hardwired internally as an interrupt source. The output of timer/counter 1 is available internally as an interrupt source, used as a baud rate generator, or used as an external output. The timer/counter 2 output is available as an external output. Due to mode restrictions, the TCU is a subset of the μPD71054 Programmable Timer/Counter. Figure 19 shows the internal block diagram of the TCU.

The TCU has the following features:

- Three 16-bit timer/counters
- Six programmable count modes
- Binary/BCD counting
- Multiple latch command
- Choice of two clock sources

Figure 19. TCU Block Diagram



Because $\overline{\text{RESET}}$ leaves the TCU in an uninitialized state, each timer/counter must be initialized by specifying an operating mode and a count. Once programmed, a timer/counter will continue to operate in that mode until another mode is selected. When the count has been written to the counter and transferred to the down counter, a new count operation starts. Both the current count and the counter status can be read while count operations are in progress.

TCU Commands

The TCU is programmed by issuing I/O instructions to the I/O port addresses programmed in the OPHA and TULA registers. The individual TCU registers are selected by address bits A_2 and A_1 as follows.

A_2	A_1	Register	Operation
0	0	TCT0 TST0	Read/Write Read
0	1	TCT1 TST1	Read/Write Read
1	0	TCT2 TST2	Read/Write Read
1	1	TMD	Write

The timer mode (TMD) register selects the operating mode for each timer/counter and issues the latch command for one or more timer/counters. Figure 20 shows the format for the TMD register.

Writes to the timer/counter 2-0 (TCT2-TCT0) registers stores the new count in the appropriate timer/counter. The count latch command is used before reading count data in order to latch the current count and prevent inaccuracies.

The timer status 2-0 (TST2-TST0) registers contain status information for the specified counter (figure 21). The latch command is used to latch the appropriate counter status before reading status information. If both status and counter data are latched for a counter, the first read operation returns the status data and subsequent read operations obtain the count data.

Count Modes

There are six programmable timer/counter modes. The timing waveforms for these modes are in figure 22.

Mode 0 [Interrupt on End of Count]. In this mode, TOUT changes from the low to high level when the specified count is reached. This mode is available on all timer/counters.

Mode 1 [Retriggerable One-shot]. In mode 1, a low-level one-shot pulse, triggered by TCTL2 is output from the TOUT2 pin. This mode is available only on timer/counter 2.

Mode 2 [Rate Generator]. In mode 2, TOUT cyclically goes low for one clock period when the counter reaches the 0001H count. A counter in this mode operates as a frequency divider. All timer/counters can operate using mode 2.

Mode 3 [Square Wave Generator]. Mode 3 is a frequency divider similar to mode 2, but the output has a symmetrical duty cycle. This mode is available on all three timer/counters. For counts of N = 2, use mode 2.

Mode 4 [Software Triggered Strobe]. In mode 4, when the specified count is reached, TOUT goes low for the duration of one clock pulse. Mode 4 is available on all timer/counters.

Mode 5 [Hardware Triggered Strobe]. Mode 5 is similar to mode 4 except that operation is triggered by the TCTL2 input and can be retriggered. This mode is available only on timer/counter 2.

Serial Control Unit

The serial control unit (SCU) is a single asynchronous serial channel that performs serial communication between the μPD70216 and an external serial device. The SCU is similar to the μPD71051 Serial Control Unit except for the lack of synchronous communication protocols. Figure 23 is the block diagram of the SCU.

The SCU has the following features.

- Full-duplex asynchronous serial controller
- Clock rate divisor (x16, x64)
- Baud rates to 38.4 kb/s supported
- 7-, 8-bit character lengths
- 1-, 2-bit stop bit lengths
- Break transmission and detection
- Full-duplex, double-buffered transmitter/receiver
- Even, odd, or no parity
- Parity, overrun, and framing error detection
- Receiver full and transmitter empty interrupts

The SCU contains four separately addressable registers for reading/writing data, reading status, and controlling operation of the SCU. The serial receive buffer (SRB) and the serial transmit buffer (STB) store the incoming and outgoing character data. The serial status (SST) register allows software to determine the current state of both the transmitter and receiver. The serial command (SCM) and serial mode (SMD) registers determine the operating mode of the SCU while the serial interrupt mask (SIMK) register allows software control of the SCU receive and transmit interrupts.

Figure 20. Timer Mode Register

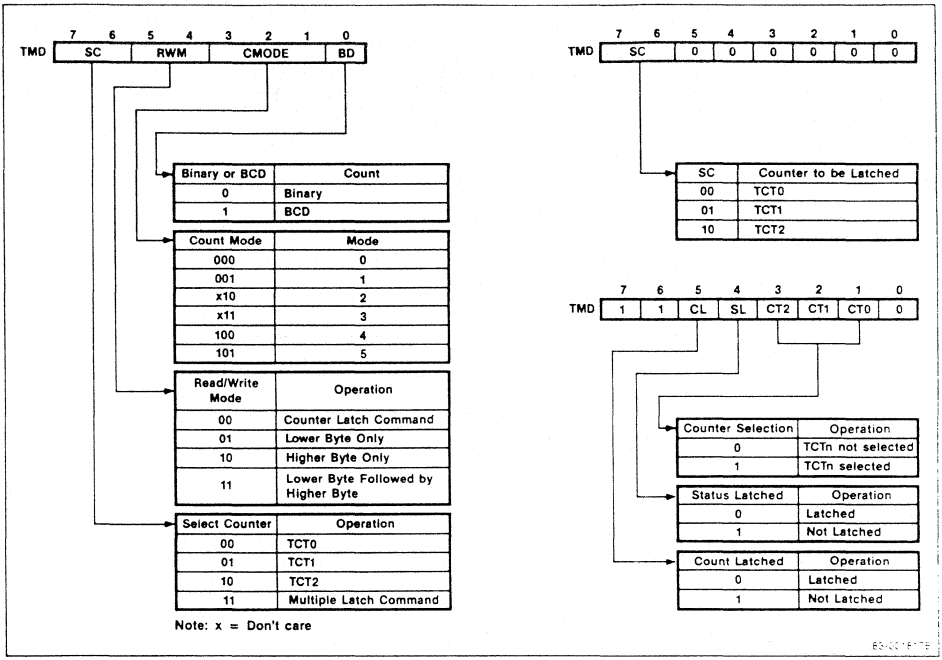


Figure 21. TCU Status Register

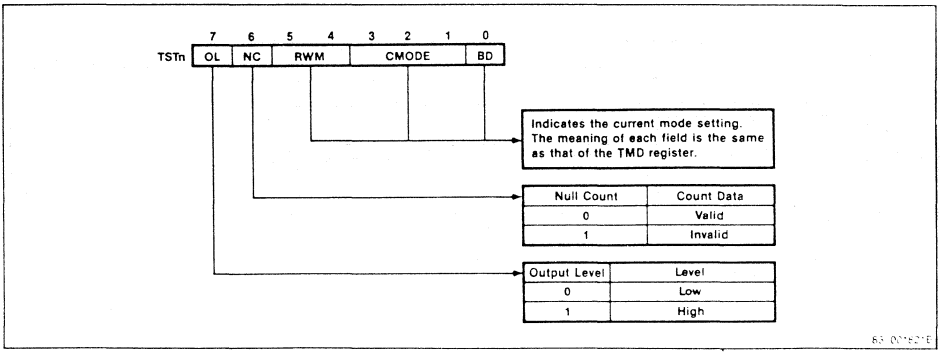


Figure 22. TCU Waveforms (Sheet 1 of 3)

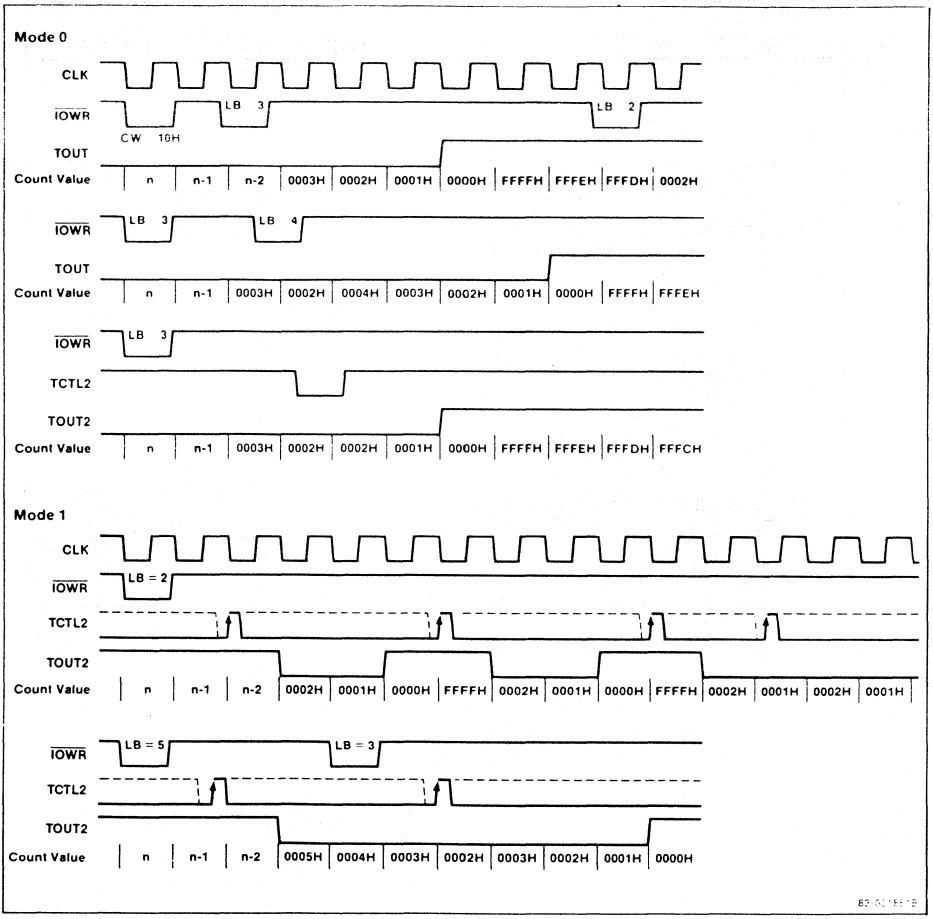


Figure 22. TCU Waveforms (Sheet 2 of 3)

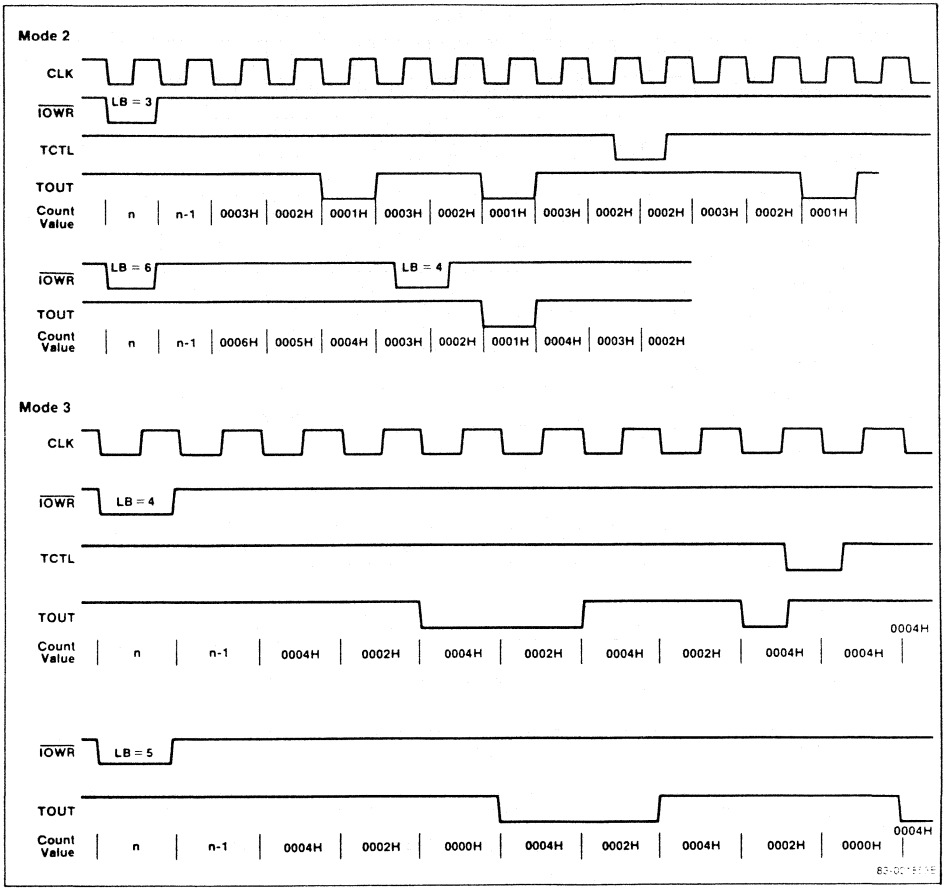


Figure 22. TCU Waveforms (Sheet 3 of 3)

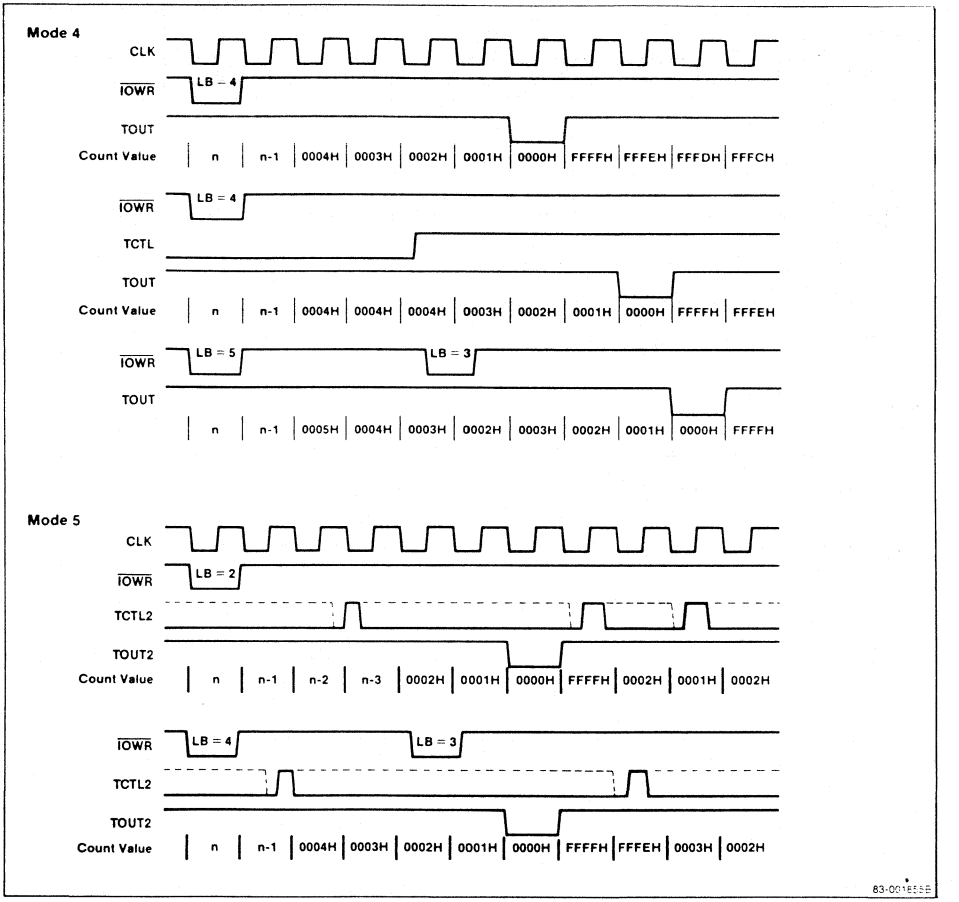
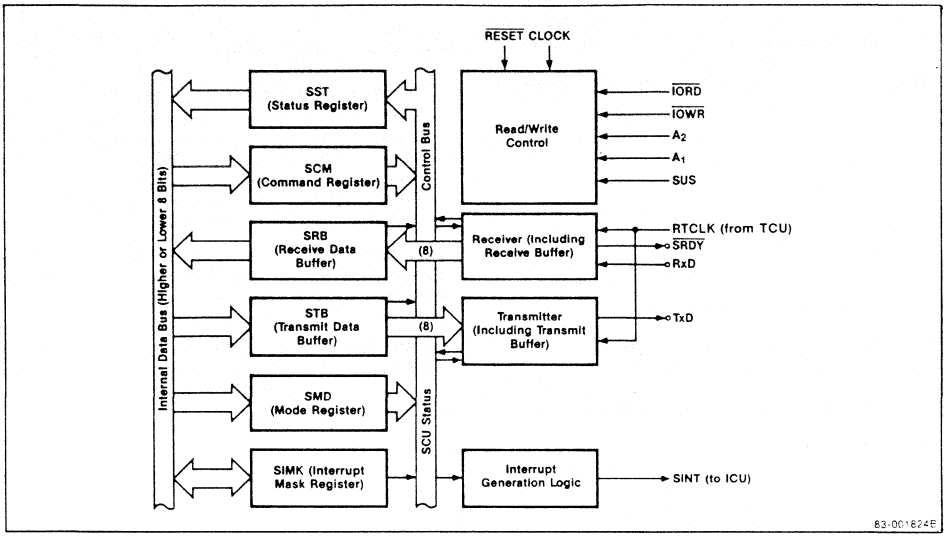


Figure 23. SCU Block Diagram



Receiver Operation

While the RxD pin is high, the SCU is in an idle state. A transition on RxD from high to low indicates the start of a new serial data reception. When a complete character has been received, it is transferred to the SRB; the receive buffer ready (RBRDY) bit in the SST register is set and (if unmasked) an interrupt is generated. The SST also latches any parity, overrun, or framing errors at this time.

The receiver detects a break condition when a null character with zero parity is received. The BRK bit is set for as long as the subsequent receive data is low and resets when RxD returns to a high level. The MRDY bit (SCM) and RBRDY (SST) are gated to form the output $\overline{\text{SRDY}}$. $\overline{\text{SRDY}}$ prevents overruns from occurring when the program is unable to process the input data. Software can control MRDY to prevent data from being sent from the remote transmitter while RBRDY can prevent the immediate overrun of a received character.

Transmitter Operation

TxD is kept high while the STB register is empty. When the transmitter is enabled and a character is written to the STB register, the data is converted to serial format and output on the TxD pin. The start bit indicates the start of the transmission and is followed by the character stream (LSB to MSB) and an optional parity bit. One or two stop bits are then appended, depending on the programmed mode. When the character has been transferred from the STB, the TRBDY bit in the SST is set and if unmasked, a transmit buffer empty interrupt is generated.

Serial data can be transmitted and received by polling the SST register and checking the TBRDY or RBRDY flags. Data can also be transmitted and received by SCU-generated interrupts to the interrupt control unit. The SCU generates an interrupt in either of these conditions:

(1) The receiver is enabled, the SRB is full, and receive interrupts are unmasked.

(2) The transmitter is enabled, the STB is empty, and transmit interrupts are unmasked.

SCU Registers and Commands

I/O instructions to the I/O addresses selected by the OPHA and SULA registers are used to read/write the SCU registers. Address bits A_1 and A_2 and the read/write lines select one of the six internal registers as follows:

A_2	A_1	Register	Operation
0	0	SRB STB	Read Write
0	1	SST SCM	Read Write
1	0	SMD	Write
1	1	SIMK	Read/write

The SRB and STB are 8-bit registers. When the character length is 7 bits, the lower 7 bits of the SRB register are valid and bit 7 is cleared to 0. If programmed for 7-bit characters, bit 7 of the STB is ignored.

The SST register (figure 24) contains the status of the transmit and receive data buffers and the error flags. Error flags are persistent. Once an error flag is set, it remains set until a clear error flags command is issued.

Figure 25 shows the SCM and SMD registers. The SCM register stores the command word that controls transmission, reception, error flag reset, break transmission, and the state of the $\overline{SRDY}$ pin. The SMD register stores the mode word that determines serial characteristics such as baud rate divisor, parity, character length, and stop bit length.

Initialization software should first program the SMD register followed by the SCM register. Unlike the μPD71051, the SMD register can be modified at any time without resetting the SCU.

The SIMK register (figure 26) controls the occurrence of RBRDY and TBRDY interrupts. When an interrupt is masked, it is prevented from propagating to the interrupt control unit.

Figure 24. SST Register

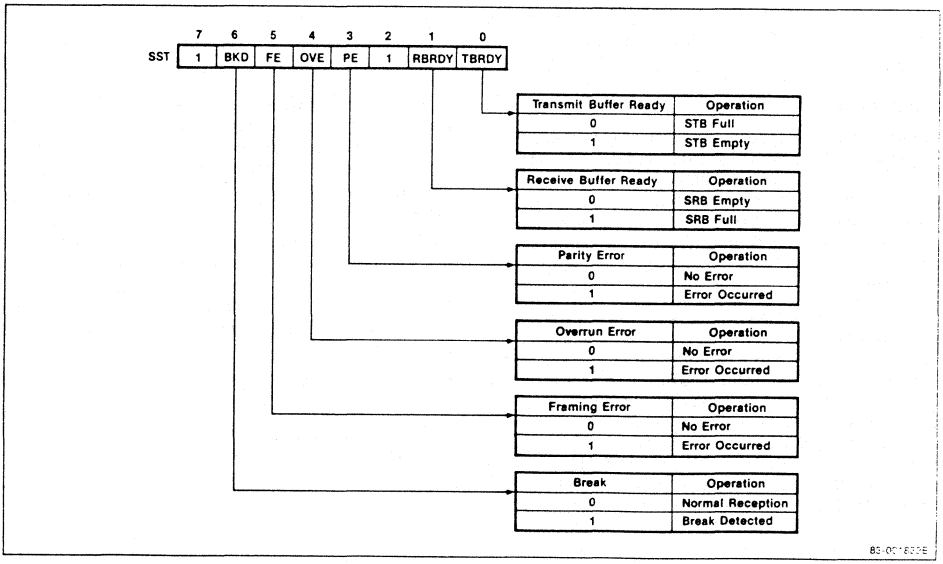


Figure 25. SCM and SMD Registers

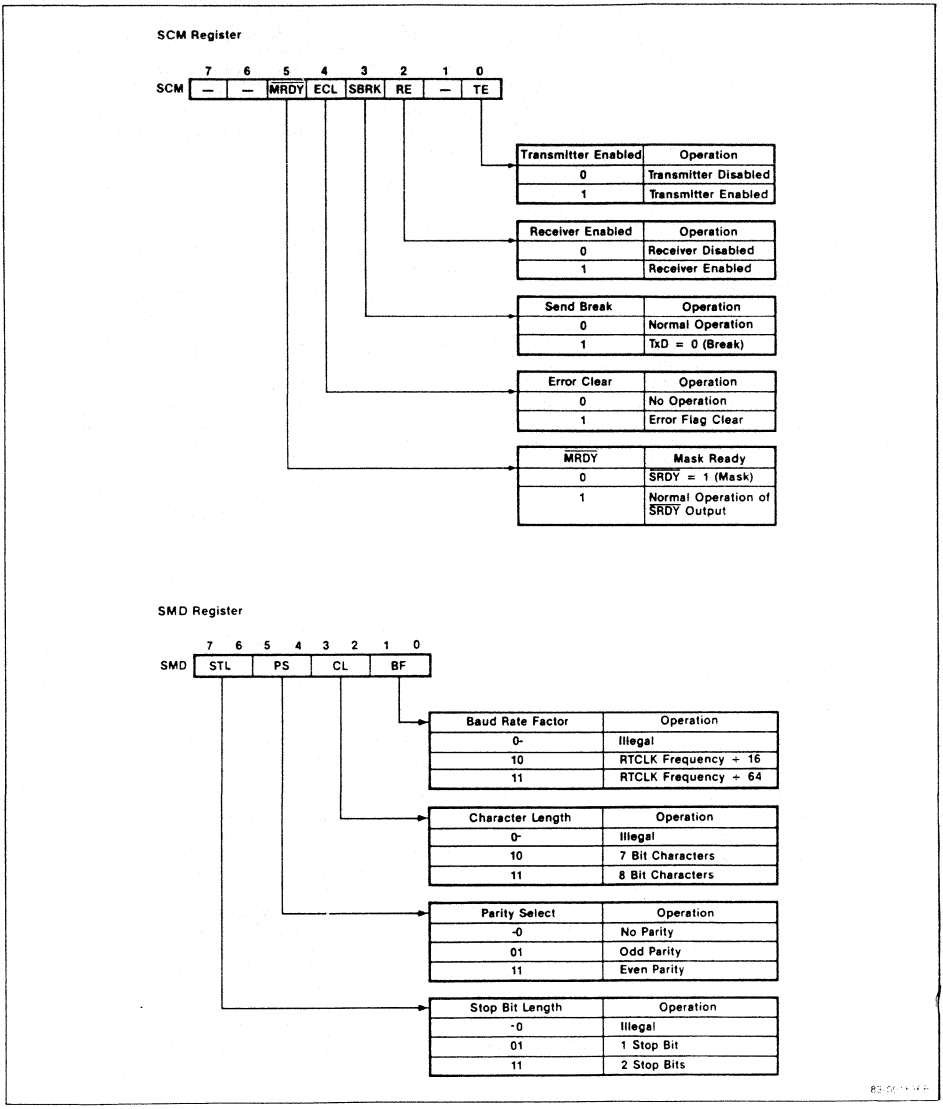
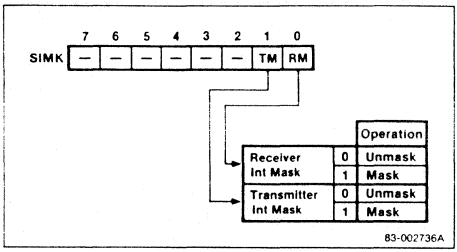


Figure 26. SIMK Register



Interrupt Control Unit

The interrupt control unit (ICU) is a programmable interrupt controller equivalent to the μPD71059. The ICU arbitrates up to eight interrupt inputs, generates a CPU interrupt request, and outputs the interrupt vector number on the internal data bus during an interrupt acknowledge cycle. Cascading up to seven external slave μPD71059s permits the μPD70216 to support up to 56 interrupt sources. Figure 27 is the block diagram for the ICU.

The ICU has the following features.

- Eight interrupt request inputs
- Cascadable with μPD71059 Interrupt Controllers
- Programmable edge- or level-triggered interrupts (TCU, edge-triggered interrupts only)
- Individually maskable interrupt requests
- Programmable interrupt request priority
- Polling mode

ICU Registers

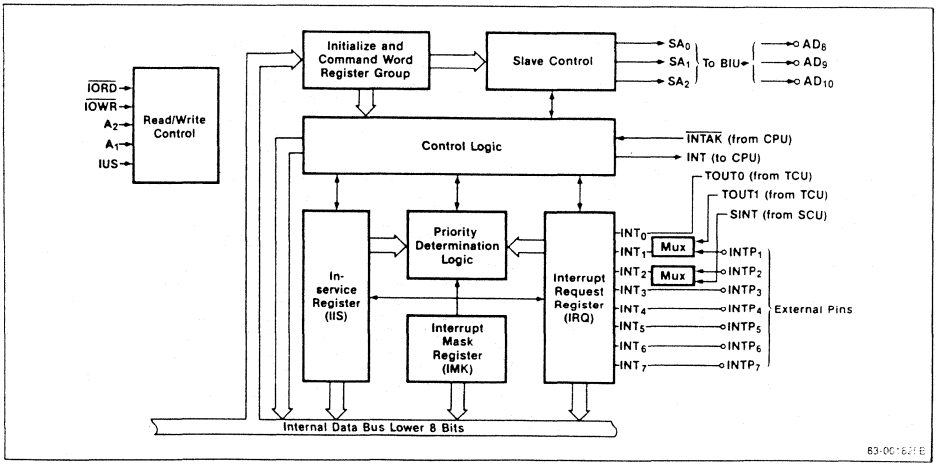
Use I/O instructions to the I/O addresses selected by the OPHA and IULA registers to read from and write to the ICU registers. Address bit A_1 and the command word selects an ICU internal register.

	A_1	Other Condition	Operation
Read	0	IMD selects IRQ	CPU ← IRQ data
	0	IMD selects IIS	CPU ← IIS data
	0	Polling phase	CPU ← Polling data
	1	—	CPU ← IMKW
Write	0	D4 = 1	CPU → IIW1
	0	D4 = 0 and D3 = 0	CPU → IPFW
	0	D4 = 0 and D3 = 1	CPU → IMDW
	1	During initialization	CPU → IIW2
	1		CPU → IIW3
	1		CPU → IIW4
	1	After initialization	CPU → IMKW

Note:

(1) In polling phase, polling data has priority over the contents of the IRQ or IIS register when read.

Figure 27. ICU Block Diagram



Initializing the ICU

The ICU is always used to service maskable interrupts in a μPD70216 system. Prior to accepting maskable interrupts, the ICU must first be initialized (figure 28). Following initialization, command words from the CPU can change the interrupt request priorities, mask/unmask interrupt requests, and select the polling mode. Figures 29 and 30 list the ICU initialization and command words.

Interrupt initialization words 1-4 (IIW1-IIW4) initialize the ICU, indicate whether external μPD71059s are connected as slaves, select the base interrupt vector, and select edge- or level-triggered inputs for INT1-INT7. Interrupt sources from the TCU are fixed as edge-triggering. INT0 is internally connected to TOUT0, and INT2 may be connected to TOUT1 by the IRSW field in the OPCN.

The interrupt mask word (IMKW) contains programmable mask bits for each of the eight interrupt inputs. The interrupt priority and finish word (IPFW) is used by the interrupt handler to terminate processing of an interrupt or change interrupt priorities. The interrupt mode word (IMDW) selects the polling register, interrupt request (IRQ) or interrupt in service (IIS) register, and the nesting mode.

The initialization words are written in consecutive order starting with IIW1. IIW2 sets the interrupt vector. IIW3 specifies which interrupts are connected to slaves. IIW3 is only required in extended systems. The ICU will only expect to receive IIW3 if SNGL = 0 (bit D_1 of IIW1). IIW4 is only written if II4 = 1 (bit D_0 of IIW1).

μPD71059 Cascade Connection

To increase the number of maskable interrupts, up to seven slave μPD71059 Interrupt Controllers can be cascaded. During cascade operation (figure 31), each slave μPD71059 INT output is routed to one of the μPD70216 INTP inputs. During the second interrupt acknowledge bus cycle, the ICU places the slave address on address lines AD_{10}-AD_8. Each slave compares this address with the slave address programmed using interrupt initialization word 3 (IIW3). If the same, the slave will place the interrupt vector on pins AD_7-AD_0 during the second interrupt acknowledge bus cycle.

Figure 28. Initialization Sequence

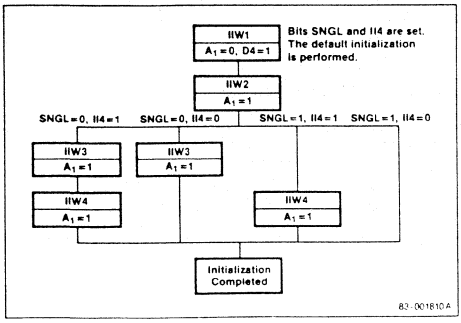


Figure 29. Interrupt Initialization Words 1-4

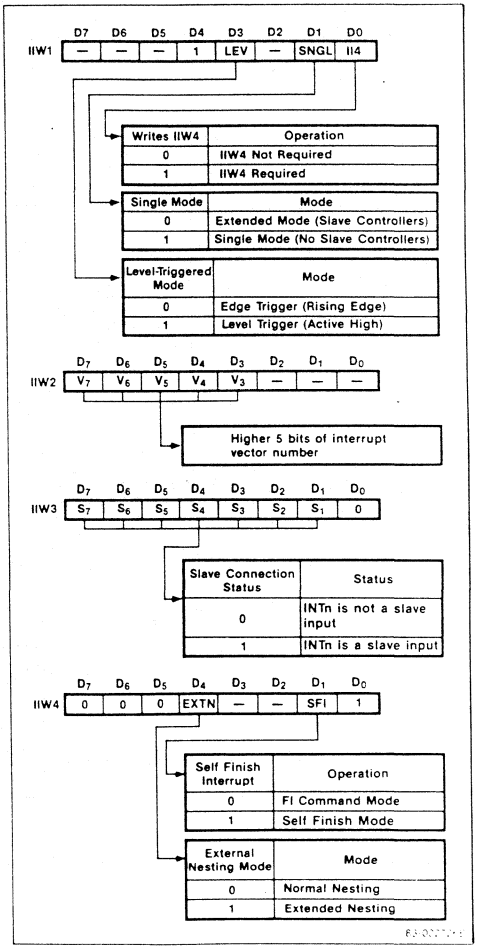


Figure 30. Command Words

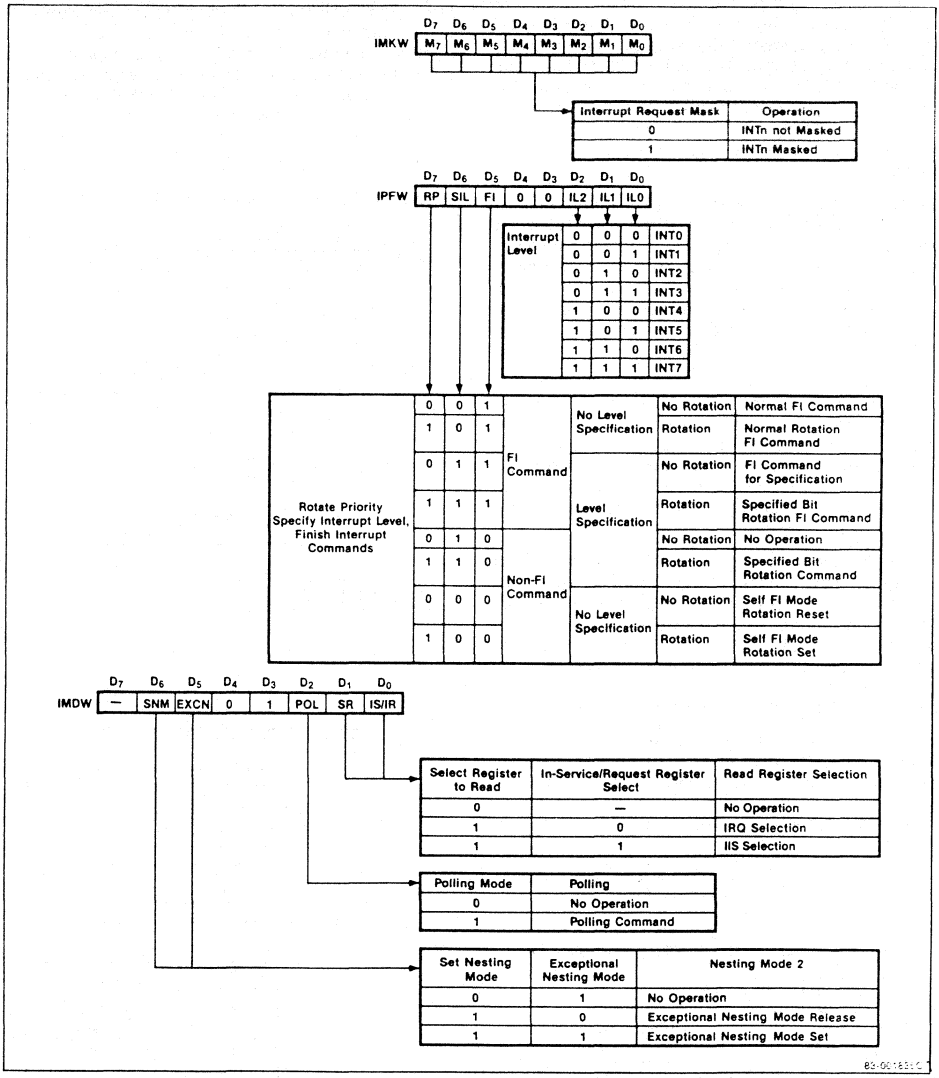
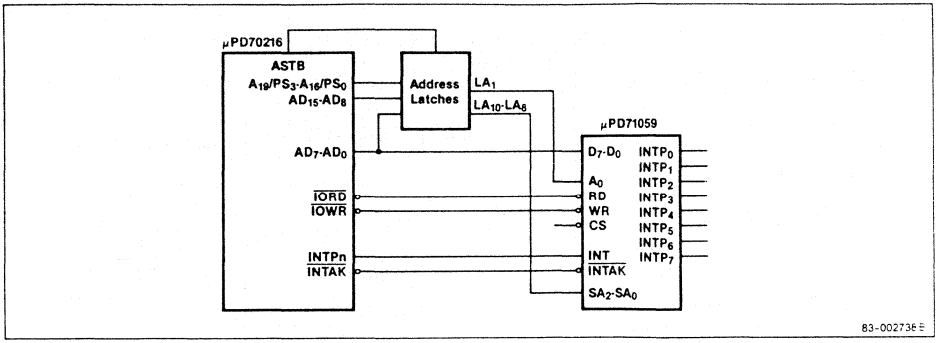


Figure 31. μPD71059 Cascade Connection



DMA Control Unit

The DMA Control Unit (DMAU) is a high-speed DMA controller compatible with the μPD71071 DMA Controller. The DMAU has four independent DMA channels and performs high-speed data transfers between memory and external peripheral devices at speeds as high as 4 megabytes/second in an 8-MHz system. Figure 32 is the block diagram for the DMAU.

The DMAU has the following features.

- Four independent DMA channels
- Cascade mode for slave μPD71071 DMA controllers
- 20-bit address registers
- 16-bit transfer count register
- Single, demand, and block transfer modes
- Bus release and bus hold modes
- Autoinitialization
- Address increment/decrement
- Fixed/rotating channel priorities
- TC output at transfer end
- Forced termination of service by $\overline{END}$ input

DMAU Basic Operation

The DMAU operates in either a slave or master mode. In the slave mode, the DMAU samples the four DMARQ input pins every clock. If one or more inputs are active, the corresponding DMA request bits are set and the DMAU sends a bus request to the BAU while continuing to sample the DMA request inputs. After the BAU returns the DMA bus acknowledge signal, the DMAU stops DMA request sampling, selects the DMA channel with the highest priority, and enters the bus master mode to perform the DMA transfer. While in the bus master mode, the DMAU controls the external bus and performs DMA transfers based on the preprogrammed channel information.

Terminal Count

The DMAU ends DMA service when the terminal count condition is generated or when the $\overline{END}$ input is asserted. A terminal count (TC) is produced when the contents of the current count register becomes zero. If autoinitialization is not enabled when DMA service terminates, the mask bit of the channel is set and the DMARQ input of that channel is masked. Otherwise, the current count and address registers are reloaded from the base registers and new DMA transfers are again enabled.

DMA Transfer Type

The type of transfer the DMAU performs depends on the following conditions.

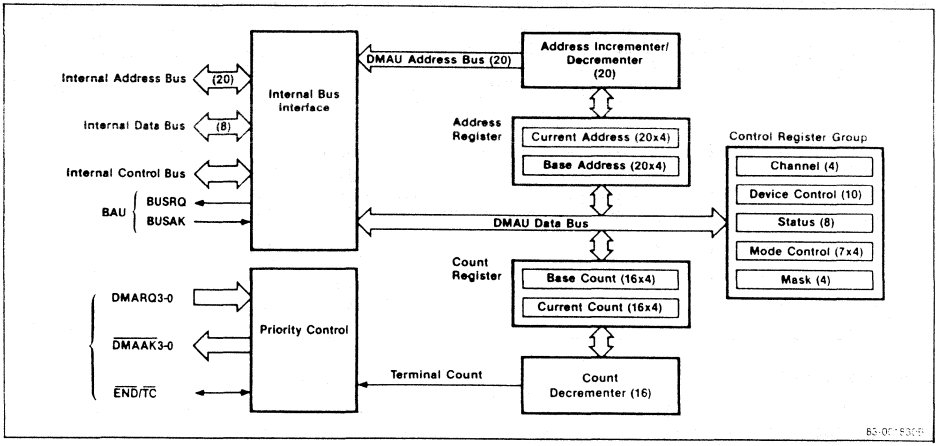
- Direction of the transfer (each channel)
- Transfer mode (each channel)
- Bus mode

Transfer Direction

All DMA transfers use memory as a reference point. Therefore, a DMA read operation transfers data from memory to an I/O port. A DMA write reads an I/O port and writes the data to memory. During memory-to-I/O transfer, the DMA mode (DMD) register is used to select the transfer directions for each channel and activate the appropriate control signals.

Operation	Transfer Direction	Activated Signals
DMA read	Memory → I/O	$\overline{IOWR}$, $\overline{MRD}$
DMA write	I/O → Memory	$\overline{IORD}$, $\overline{MWR}$
DMA verify		Addresses only, no transfer performed

Figure 32. DMAU Block Diagram

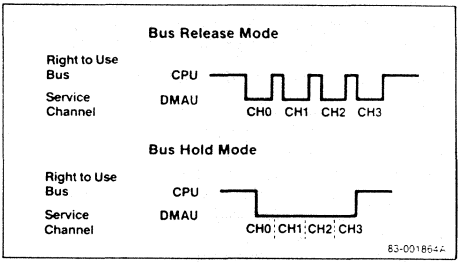


Bus Mode

The DMA device control (DDC) register selects operation in either the bus release or bus hold mode. The selected bus mode determines the DMAU conditions for return of the bus to the BAU. Figure 33 shows that in bus release mode, only one channel is serviced after the DMAU obtains the bus. When DMA service ends (termination conditions depend on the transfer mode), the DMAU returns the bus to the BAU regardless of the state of other DMA requests, and the DMAU reenters the slave mode. When the DMAU regains use of the bus, a new DMA operation can begin.

In bus hold mode, several channels can receive contiguous service without releasing the bus. If there is another valid DMA request when a channel's DMA service is finished, the new DMA service can begin immediately after the previous service without returning the bus to the BAU.

Figure 33. Bus Modes



Transfer Modes

The DMD register also selects either single, demand, or block transfer mode for each channel. The conditions for the termination of each transfer characterize each transfer mode. The following table shows the various transfer modes and termination conditions.

Transfer Mode	Termination Conditions
Single	After each byte/word transfer
Demand	$\overline{END}$ input Terminal count Inactive DMARQ DMARQ of a higher priority channel becomes active (bus hold mode)
Block	$\overline{END}$ input Terminal count

The operation of single, demand, and block mode transfers depends on whether the DMAU is in bus release or bus hold mode. Figure 34 shows the operation flow for the six possible transfer and bus mode operations in DMA transfer.

Single Mode Transfer. In bus release mode, when a channel completes transfer of a single byte or word, the DMAU enters the slave mode regardless of the state of DMA request inputs. In this manner, other lower-priority bus masters will be able to access the bus.

In bus hold mode, when a channel completes transfer of a single byte or word, the DMAU terminates the channel's service even if the DMARQ request signal is asserted. The DMAU will then service any other requesting channel. If there are no requests from any other DMA channels, the DMAU releases the bus and enters the slave state.

Demand Mode Transfer. In bus release mode, the currently active channel continues to transfer data as long as the DMA request of that channel is active, even though other DMA channels are issuing higher-priority requests. When the DMA request of the serviced channel becomes inactive, the DMAU releases the bus and enters the slave state.

In bus hold mode, when the active channel completes a single transfer, the DMAU checks the other DMA request lines without ending the current service. If there is a higher-priority DMA request, the DMAU stops the service of the current channel and starts servicing the highest-priority channel requesting service. If there is no higher request than the current one, the DMAU continues to service the currently active channel. Lower-priority DMA requests are honored without releasing the bus after the current channel service is complete.

Block Mode Transfer. In bus release mode, the current channel continues DMA transfers until a terminal count or the external $\overline{END}$ input becomes active. During this time, the DMAU ignores all other DMA requests. After completion of the block transfer, the DMAU releases the bus and enters the slave state, even if DMA requests from other channels are active.

In bus hold mode, the current channel transfers data until an internal or external $\overline{END}$ signal becomes active. When the service is complete, the DMAU checks all DMA requests without releasing the bus. If there is an active request, the DMAU immediately begins servicing the request. The DMAU releases the bus after it honors all DMA requests or a higher-priority bus master requests the bus.

Byte/Word Transfer

The DMD register can specify DMA transfers in byte or word units for each channel. Addresses and count registers are updated as follows during byte/word transfers.

	Byte Transfer	Word Transfer
Address register	±1	±2
Count register	−1	−1

During word transfers, two bytes starting at an even address are handled as a single word. If the starting address is odd, a DMA transfer is started after first decrementing the address by 1. For this reason, always select even addresses. The AD_0 and $\overline{UBE}$ outputs control byte and word DMA transfers. The following shows the relationship between the data bus width, AD_0 and $\overline{UBE}$ signals, and data bus status.

A_0	UBE	Data Bus Status
0	1	D_7-D_0 valid
1	0	D_{15}-D_8 valid
0	0	D_{15}-D_0 valid

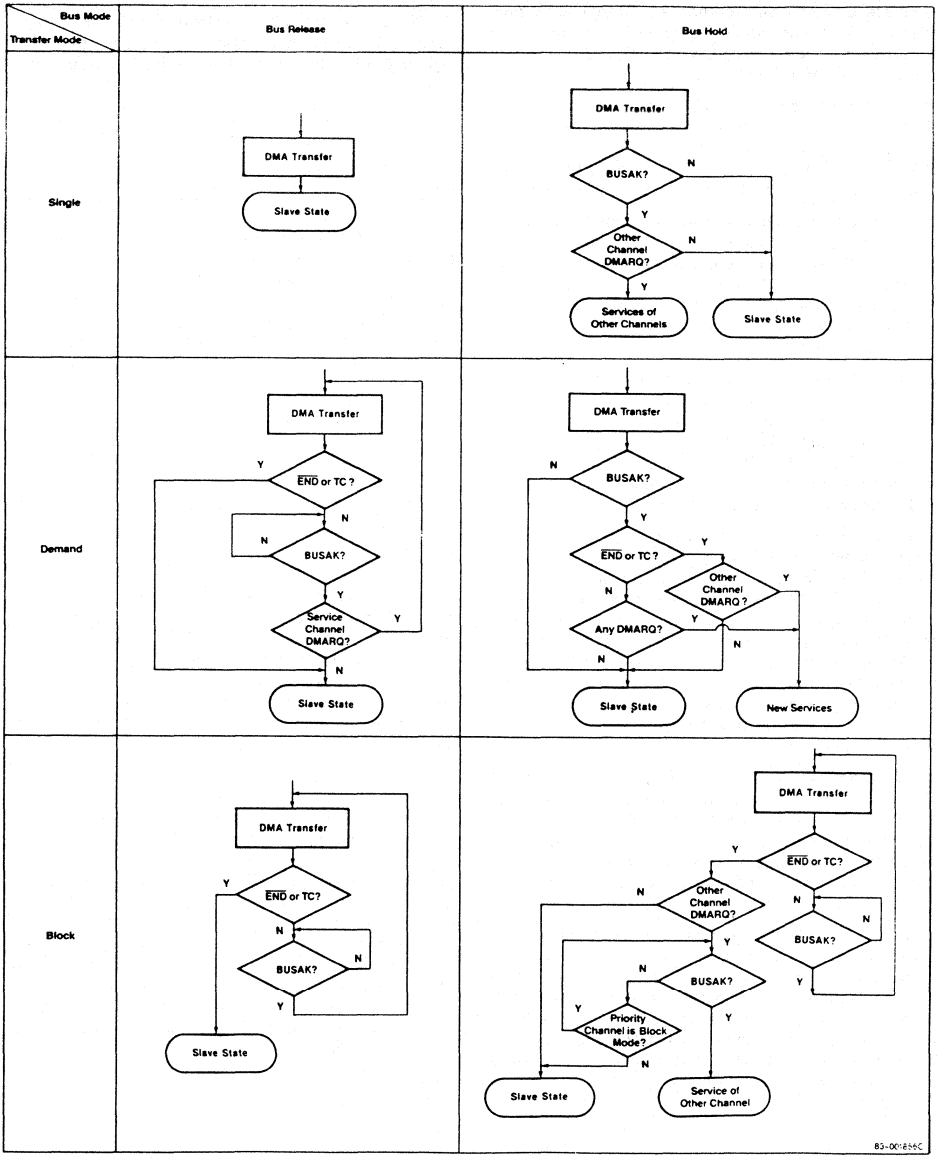
Autoinitialize

When the DMD register selects autoinitialize for a channel, the DMAU automatically reinitializes the address and count registers when $\overline{END}$ is asserted or the terminal count condition is reached. The contents of the base address and base count registers are transferred to the current address and current count registers, and the applicable bit of the mask register remains cleared.

Channel Priority

Each of the four DMAU channels is assigned a priority. When multiple DMA requests from several channels occur simultaneously, the channel with the highest priority will be serviced first. The DDC register selects one of two priority schemes: fixed or rotating (figure 35). In fixed priority, channel 0 is assigned the highest priority and channel 3, the lowest. In rotating priority, priority order is rotated after each service so that the channel last serviced receives the lowest priority. This method prevents the exclusive servicing of higher-priority channels and the lockout of lower-priority DMA channels.

Figure 34. Transfer Modes



Cascade Connection

Slave μPD71071 DMA Controllers can be cascaded to easily expand the system DMA channel capacity to 16 DMA channels. Figure 36 shows an example of cascade connection. During cascade operation, the DMAU acts as a mediator between the BAU and the slave μPD71071s. All other bus outputs are disabled while a slave DMA controller is active.

The DMAU always operates in the bus hold mode while a cascade channel is in service, even when the bus release mode is programmed. Other DMA requests are held pending while a slave μPD71071 channel is in service. When the cascaded μPD71071 ends service and moves into the slave state, the DMAU also moves to the slave state and releases the bus. At this time, all bits of the DMAU request register are cleared. The DMAU continues to operate normally with the other noncascaded channels.

Figure 35. Priority Order

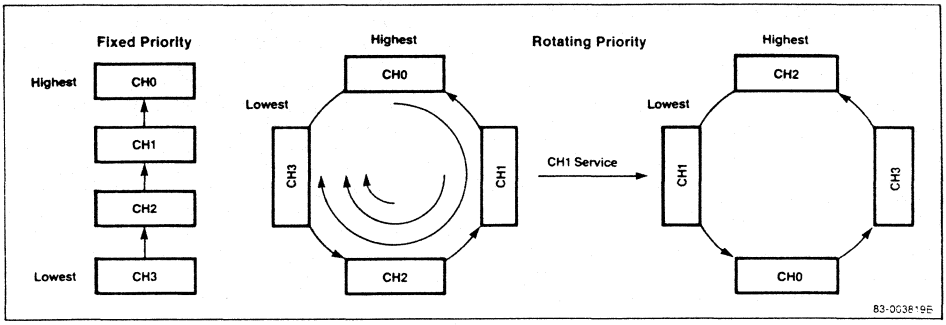
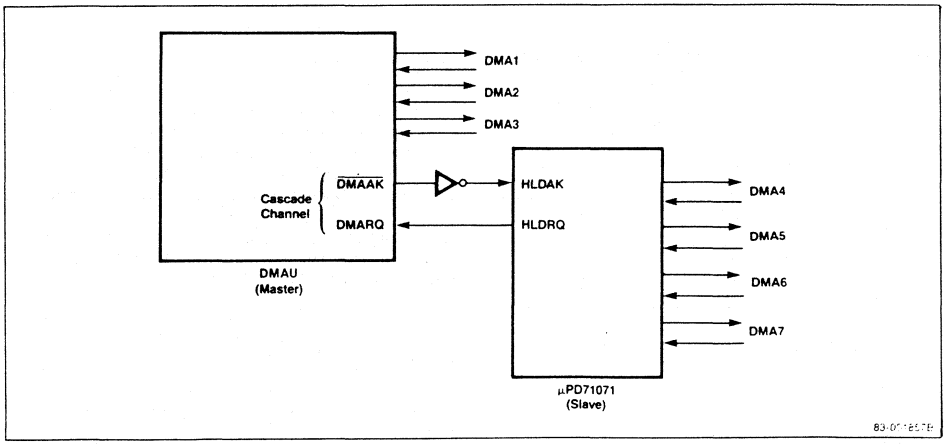


Figure 36. μPD71071 Cascade Example



Bus Waiting Operation

The DMAU will automatically perform a bus waiting operation (figure 37) whenever the RCU refresh request queue fills. When the DMA bus acknowledge goes inactive, the DMAU enters the bus waiting mode and inactivates the DMA bus request signal. Control of the bus is then transferred to the higher-priority RCU by the BAU.

Two clocks later, the DMAU reasserts its internal DMA bus request. The bus waiting mode is continued until the DMA bus acknowledge signal again becomes active and the interrupted DMA service is immediately restarted.

Programming the DMAU

To prepare a channel for DMA transfer, the following characteristics must be programmed.

- Starting address for the transfer
- Transfer count
- DMA operating mode
- Transfer size (byte/word)

The contents of the OPHA and DULA registers determine the base I/O port address of the DMAU. Addresses A_3-A_0 are used to select a particular register as follow:

A_3	A_2	A_1	A_0	Register	Operation
0	0	0	0	DICM	Write
0	0	0	1	DCH	Read/Write
0	0	1	0	DBC/DCC (low)	Read/Write
0	0	1	1	DBC/DCC (high)	Read/Write
0	1	0	0	DBA/DCA (low)	Read/Write
0	1	0	1	DBA/DCA (high)	Read/Write
0	1	1	0	DBA/DCA (upper)	Read/Write
0	1	1	1	Reserved	—
1	0	0	0	DDC (low)	Read/Write
1	0	0	1	DDC (high)	Read/Write
1	0	1	0	DMD	Read/Write
1	0	1	1	DST	Read
1	1	0	0	Reserved	—
1	1	0	1	Reserved	—
1	1	1	0	Reserved	—
1	1	1	1	DMK	Read/Write

Word I/O instructions can be used to read/write the register pairs listed below. All other registers are accessed via byte I/O instructions.

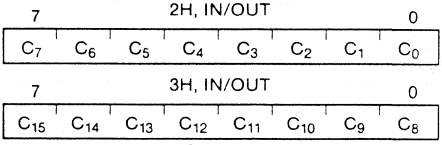
DBC/DCC
DBA/DCA (higher/lower only)
DDC

DMAU Registers

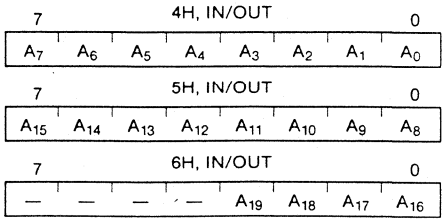
Initialize. The DMA initialize command (DICM) register (figure 38) is used to perform a software reset of the DMAU. The DICM is accessed using the byte OUT instruction.

Channel Register. Writes to the DMA channel (DCH) register (figure 39) select one of the four DMA channels for programming and also the base/current registers. Reads of the DCH register return the currently-selected channel and the register access mode.

Count Registers. When bit 2 of the DCH register is cleared, a write to the DMA count register updates both the DMA base count (DBC) and the DMA current count (DCC) registers with a new count. If bit 2 of the DCH register is set, a write to the DMA count register affects only the DBC register. The DBC register holds the initial count value until a new count is specified. If autoinitialization is enabled, this value is transferred to the DCC register when a terminal count or END condition occurs. For each DMA transfer, the current count register is decremented by one. The format of the DMA count register is shown below. The count value loaded into the DBC/DCC registers is one less than the desired transfer count.



Address Register. Use either byte or word I/O instructions with the lower two bytes (4H and 5H) of the DMA address register. However, byte I/O instructions must be used to access the high-order byte (6H) of this register. When bit 2 of the channel register is cleared, a write to the DMA address register updates both the DMA base address (DBA) and the DMA current address (DCA) registers with the new address. If bit 2 of the DCH register is set, a write to the DMA address register affects only the DBA register.



The DBA register holds the starting address value until a new address is specified. This value is transferred to the DCA register automatically if autoinitialization is selected. For each DMA transfer, the current address register is updated by two during word transfers and by one during byte transfers.

Device Control Register. The DMA device control (DDC) register (figure 40) is used to to program the DMA transfer characteristics common to all DMA channels. It controls the bus mode, write timing, priority logic, and enable/disable of the DMAU.

Status Register. The DMA status (DST) register (figure 41) contains information about the current state of each DMA channel. Software can determine if a termination condition has been reached (TC_3-TC_0) or if a DMA service request is present (RQ_3-RQ_0). The byte IN instruction must be used to read this register.

Figure 37. Bus Waiting Operation

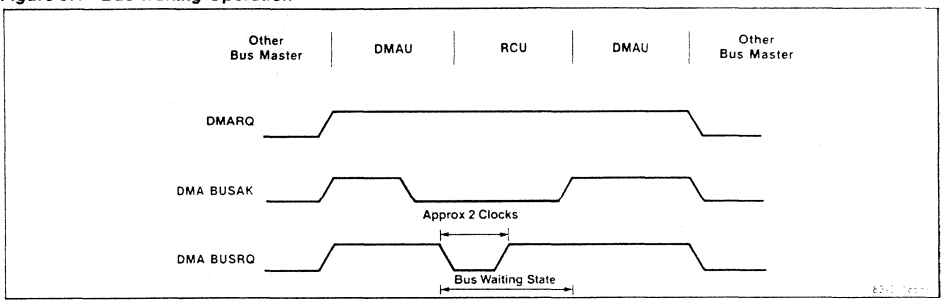
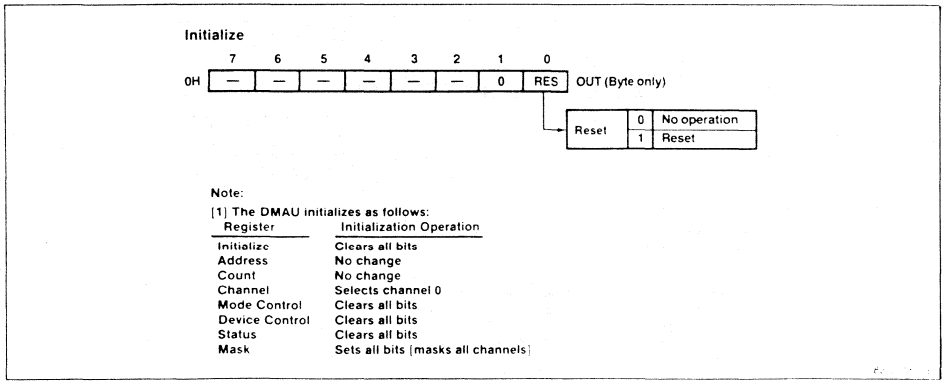


Figure 38. DMA Initialize Command Register



Note:
[1] The DMAU initializes as follows:

Register	Initialization Operation
Initialize	Clears all bits
Address	No change
Count	No change
Channel	Selects channel 0
Mode Control	Clears all bits
Device Control	Clears all bits
Status	Clears all bits
Mask	Sets all bits (masks all channels)

Figure 39. DMA Channel Register

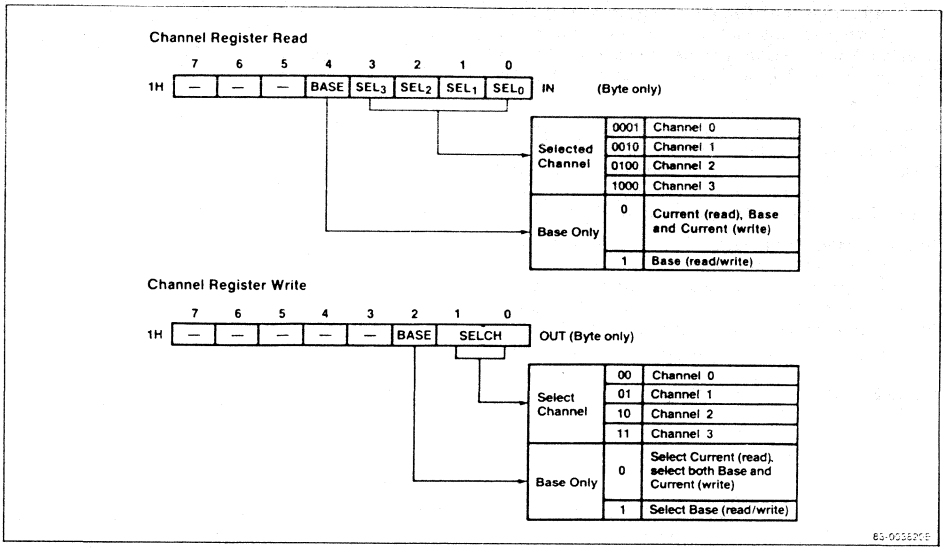
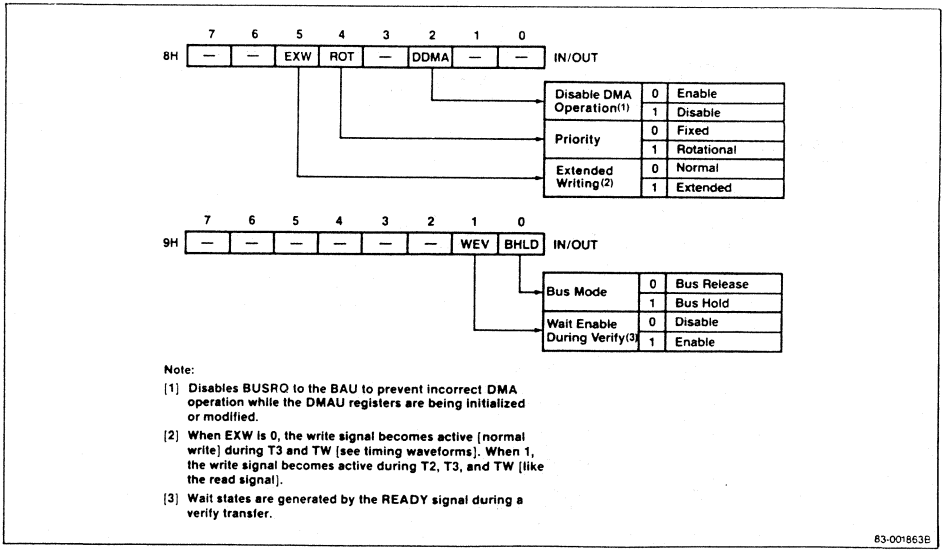


Figure 40. DMA Device Control Register



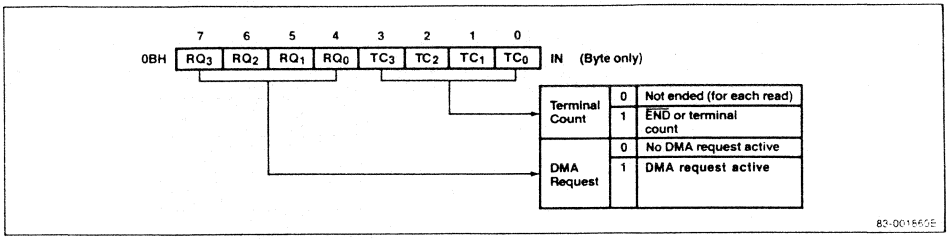
Note:

[1] Disables BUSRQ to the BAU to prevent incorrect DMA operation while the DMAU registers are being initialized or modified.

[2] When EXW is 0, the write signal becomes active [normal write] during T3 and TW [see timing waveforms]. When 1, the write signal becomes active during T2, T3, and TW [like the read signal].

[3] Wait states are generated by the READY signal during a verify transfer.

Figure 41. DMA Status Register



Mode Control Register. The DMA mode (DMD) register (figure 42) selects the operating mode for each DMA channel. The DCH register selects which DMD register will be accessed. A byte IN/OUT instruction must be used to access this register.

Mask Register Read/Write. The DMA mask (DMK) register (figure 43) allows software to individually enable and disable DMA channels. The DMK register can only be accessed via byte I/O instructions.

Reset

The falling edge of the $\overline{RESET}$ signal resets the μPD70216. The signal must be held low for at least four clock cycles to be recognized as valid.

CPU Reset State Register	Reset Value
PFP	0000H
PC	0000H
PS	FFFFH
SS	0000H
DS0	0000H
DS1	0000H
PSW	F002H
AW, BW, CW, DW, IX, IY, BP, SP	Undefined
Instruction queue	Cleared

When $\overline{RESET}$ returns to the high level, the CPU will start fetching instructions from physical address FFFF0H.

Internal Peripheral Devices

Internal peripheral devices initialized on reset are listed in the following table. I/O devices not listed are not initialized on reset and must be initialized by software.

	Register	Reset Value
System I/O area	OPCN	----0000
	OPSEL	----0000
	WCY1	11111111
	WCY2	----1111
	TCKS	---00000
	RFC	x--01000
SCU	SMD	01001011
	SCM	--0000-0
	SIMK	------11
	SST	10000100
	DCH	---00001
	DMD	000000-0
DMAU	DDC (low)	--00-0--
	DDC (high)	------00
	DST	xxxx0000
	DMK	----1111

Symbols: x = unaffected; 0 = cleared; 1 = set; (-) = unused.

Output Pin Status

The following table lists output pin status during reset.

Signal	Status
$\overline{INTAK}$, $\overline{BUFEN}$, $\overline{BUFR}$/W, $\overline{MRD}$, $\overline{MWR}$, $\overline{END}$/$\overline{TC}$, $\overline{IOWR}$, $\overline{IORD}$, $\overline{REFRQ}$, $\overline{UBE}$, BS_2-BS_0, BUSLOCK, RESOUT, $\overline{DMAAK3}$-$\overline{DMAAK0}$	High level
QS_1-QS_0, ASTB, HLDAK	Low level
A_{19}-A_{16}/PS_3-PS_0, TOUT2	High or low level
AD_{15}-AD_0	High impedance
CLKOUT	Continues to supply clock

Figure 42. DMA Mode Register

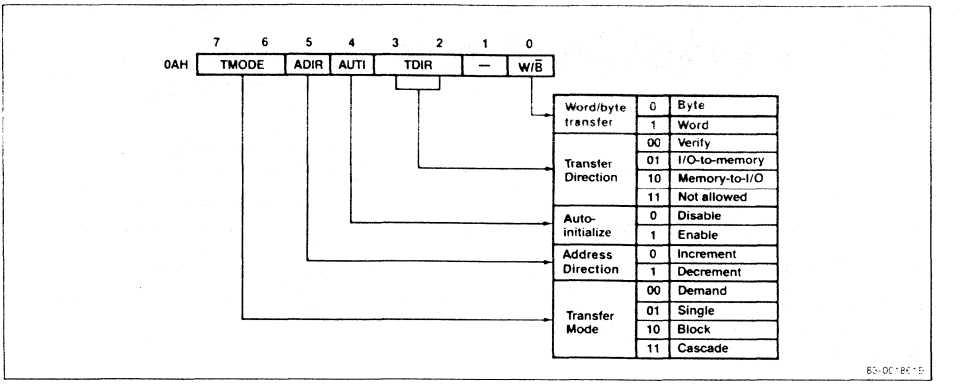
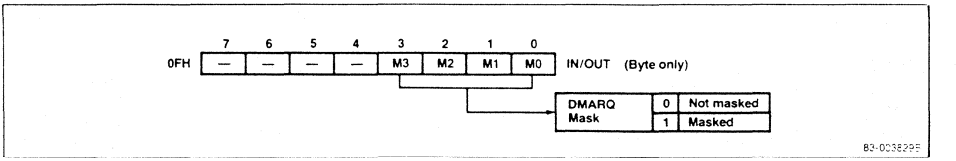


Figure 43. DMA Mask Register



Instruction Set

Symbols

Preceding the instruction set, several tables explain symbols, abbreviations, and codes.

Clocks

In the Clocks column of the instruction set, the numbers cover these operations: instruction decoding, effective address calculation, operand fetch, and instruction execution.

Clock timings assume the instruction has been pre-fetched and is present in the six-byte instruction queue. Otherwise, add four clocks for each pair of bytes not present.

Word operands require four additional clocks for each transfer to an unaligned (odd-addressed) memory operand. These times are shown on the right-hand side of the slash (/).

For conditional control transfer or branch instructions, the number on the left side of the slash is applicable if the transfer or branch takes place. The number on the right side is applicable if it does not take place.

If a range of numbers is given, the execution time depends on the operands involved.

Symbols

Symbol	Meaning
acc	Accumulator (AW or AL)
disp	Displacement (8 or 16 bits)
dmem	Direct memory address
dst	Destination operand or address
ext-disp8	16-bit displacement (sign-extension byte + 8-bit displacement)
far_label	Label within a different program segment
far_proc	Procedure within a different program segment
fp_op	Floating point instruction operation
imm	8- or 16-bit immediate operand
imm3/4	3/4-bit immediate bit offset
imm8	8-bit immediate operand
imm16	16-bit immediate operand
mem	Memory field (000 to 111): 8- or 16-bit memory location
mem8	8-bit memory location
mem16	16-bit memory location
mem32	32-bit memory location
memptr16	Word containing the destination address within the current segment
memptr32	Double word containing a destination address in another segment
mod	Mode field (00 to 10)
near_label	Label within the current segment
near_proc	Procedure within the current segment
offset	Immediate offset data (16 bits)
pop_value	Number of bytes to discard from the stack
reg	Register field (000 to 111): 8- or 16-bit general-purpose register
reg8	8-bit general-purpose register
reg16	16-bit general-purpose register
regptr	16-bit register containing a destination address within the current segment
regptr16	Register containing a destination address within the current segment
seg	Immediate segment data (16 bits)
short_label	Label between −128 and −127 bytes from the end of the current instruction
sr	Segment register
src	Source operand or address
temp	Temporary register (8/16/32 bits)
tmpcy	Temporary carry flag (1 bit)
AC	Auxiliary carry flag
AH	Accumulator (high byte)
AL	Accumulator (low byte)
AND	Logical product
AW	Accumulator (16 bits)
BH	BW register (high byte)
BL	BW register (low byte)
BP	BP register
BRK	Break flag
BW	BW register (16 bits)
CH	CW register (high byte)
CL	CW register (low byte)

Symbols (cont)

Symbol	Meaning
CW	CW register (16 bits)
CY	Carry flag
DH	DW register (high byte)
DIR	Direction flag
DL	DW register (low byte)
DS0	Data segment 0 register (16 bits)
DS1	Data segment 1 register (16 bits)
DW	DW register (16 bits)
IE	Interrupt enable flag
IX	Index register (source) (16 bits)
IY	Index register (destination) (16 bits)
MD	Mode flag
OR	Logical sum
P	Parity flag
PC	Program counter (16 bits)
PS	Program segment register (16 bits)
PSW	Program status word (16 bits)
R	Register set
S	Sign extend operand field S = 0 No sign extension S = 1 Sign extend immediate byte operand
S	Sign flag
SP	Stack pointer (16 bits)
SS	Stack segment register (16 bits)
V	Overflow flag
W	Word/byte field (0 to 1)
X, XXX, YYY, ZZZ	Data to identify the instruction code of the external floating point arithmetic chip
XOR	Exclusive logical sum
XXH	Two-digit hexadecimal value
XXXXH	Four-digit hexadecimal value
Z	Zero flag
( )	Values in parentheses are memory contents
←	Transfer direction
+	Addition
−	Subtraction
x	Multiplication
÷	Division
%	Modulo

Flag Operations

Symbol	Meaning
(blank)	No change
0	Cleared to 0
1	Set to 1
x	Set or cleared according to result
u	Undefined
R	Restored to previous state

Memory Addressing Modes

mem	mod = 00	mod = 01	mod = 10
000	BW + IX	BW + IX + disp8	BW + IX + disp16
001	BW + IY	BW + IY + disp8	BW + IY + disp16
010	BP + IX	BP + IX + disp8	BP + IX + disp16
011	BP + IY	BP + IY + disp8	BP + IY + disp16
100	IX	IX + disp8	IX + disp16
101	IY	IY + disp8	IY + disp16
110	Direct	BP + disp8	BP + disp16
111	BW	BW + disp8	BW + disp16

Register Selection (mod = 11)

reg	W = 0	W = 1
000	AL	AW
001	CL	CW
010	DL	DW
011	BL	BW
100	AH	SP
101	CH	BP
110	DH	IX
111	BH	IY

Segment Register Selection

sr	Segment Register
00	DS1
01	PS
10	SS
11	DS0

Instruction Set

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Data Transfer Instructions																									
MOV	reg, reg	1	0	0	0	1	0	1	W	1	1		reg			reg		2	2						
	mem, reg	1	0	0	0	1	0	0	W	mod			reg			mem		7/11	2-4						
	reg, mem	1	0	0	0	1	0	1	W	mod			reg			mem		10/14	2-4						
	mem, imm	1	1	0	0	0	1	1	W	mod			reg			mem		9/13	3-6						
	reg, imm	1	0	1	1	W		reg										4	2-3						
	acc, dmem	1	0	1	0	0	0	0	W									10/14	3						
	dmem, acc	1	0	1	0	0	0	1	W									9/13	3						
	sr, reg16	1	0	0	0	1	1	1	0	1	1	0	sr			reg		2	2						
	sr, mem16	1	0	0	0	1	1	1	0	mod		0	sr			mem		10/14	2-4						
	reg16, sr	1	0	0	0	1	1	0	0	1	1	0	sr			reg		2	2						
	mem16, sr	1	0	0	0	1	1	0	0	mod		0	sr			mem		8/12	2-4						
	DS0. reg16, mem32	1	1	0	0	0	1	0	1	mod			reg			mem		17/25	2-4						
	DS1, reg16, mem32	1	1	0	0	0	1	0	0	mod			reg			mem		17/25	2-4						
	AH, PSW	1	0	0	1	1	1	1	1									2	1						
	PSW, AH	1	0	0	1	1	1	1	0									3	1	x	x		x	x	x
LDEA	reg16, mem16	1	0	0	0	1	1	0	1	mod			reg			mem		4	2-4						
TRANS	src_table	1	1	0	1	0	1	1	1									9	1						
XCH	reg. reg	1	0	0	0	0	1	1	W	1	1		reg			reg		3	2						
	mem, reg	1	0	0	0	0	1	1	W	mod			reg			mem		13/21	2-4						
	AW. reg16	1	0	0	1	0		reg										3	1						
Repeat Prefixes																									
REPC		0	1	1	0	0	1	0	1									2	1						
REPNC		0	1	1	0	0	1	0	0									2	1						
REP REPE REPZ		1	1	1	1	0	0	1	1									2	1						
REPNE REPNZ		1	1	1	1	0	0	1	0									2	1						
Block Transfer Instructions																									
MOVBK	dst, src	1	0	1	0	0	1	0	W									1 9 (9) + 8n (W = 0) 9 (9) + 8n (W = 1, even addresses) 9 (17) + 16n (W = 1, odd addresses) 9 (13) + 12n (W = 1, odd/even addresses)							
CMPBK	dst, src	1	0	1	0	0	1	1	W									1 7 (13) + 14n (W = 0) 7 (13) + 14n (W = 1, even addresses) 7 (21) + 22n (W = 1, odd addresses) 7 (17) + 18n (W = 1, odd/even addresses)		x	x	x	x	x	x
CMPM	dst	1	0	1	0	1	1	1	W									1 7 (7) + 10n (W = 0) 7 (7) + 10n (W = 1, even addresses) 7 (11) + 14n (W = 1, odd addresses)		x	x	x	x	x	x

Instruction Set (cont)

Mnemonic	Operand	Opcode 7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	Clocks	Bytes	Flags AC CY V P S Z
Block Transfer Instructions (cont)						
LDM	src	1 0 1 0 1 1 0 W			1	
				7 (7) + 9n (W = 0)		
				7 (7) + 9n (W = 1, even addresses)		
				7 (11) + 13n (W = 1, odd addresses)		
STM	dst	1 0 1 0 1 0 1 W			1	
				5 (5) + 4n (W = 0)		
				5 (5) + 4n (W = 1, even addresses)		
				5 (9) + 8n (W = 1, odd addresses)		
			n = number of returns			
		String instruction execution clocks for a single-instruction execution are in parentheses.				
I/O Instructions						
IN	acc, imm8	1 1 1 0 0 1 0 W		9/13	2	
	acc, DW	1 1 1 0 1 1 0 W		8/12	1	
OUT	imm8, acc	1 1 1 0 0 1 1 W		8/12	2	
	DW, acc	1 1 1 0 1 1 1 W		8/12	1	
INM	dst, DW	0 1 1 0 1 1 0 W			1	
				9 (10) + 8n (W = 0)		
				9 (10) + 8n (W = 1, even addresses)		
				9 (18) + 16n (W = 1, odd addresses)		
OUTM	DW, src	0 1 1 0 1 1 1 W			1	
				9 (10) + 8n (W = 0)		
				9 (10) + 8n (W = 1, even addresses)		
				9 (18) + 16n (W = 1, odd addresses)		
		n = number of transfers				
		String instruction execution clocks for a single instruction execution are in parentheses.				
		Use the right side of the slash (/) for DMA I/O accesses.				
BCD Instructions						
ADJBA		0 0 1 1 0 1 1 1		7	1	x x u u u u
ADJ4A		0 0 1 0 0 1 1 1		3	1	x x u x x x
ADJBS		0 0 1 1 1 1 1 1		7	1	x x u u u u
ADJ4S		0 0 1 0 1 1 1 1		3	1	x x u x x x
ADD4S	dst, src	0 0 0 0 1 1 1 1	0 0 1 0 0 0 0 0	7 + 19n	2	u x u u u x
SUB4S	dst, src	0 0 0 0 1 1 1 1	0 0 1 0 0 0 1 0	7 + 19n	2	u x u u u x
CMP4S	dst, src	0 0 0 0 1 1 1 1	0 0 1 0 0 1 1 0	7 + 19n	2	u x u u u x
ROL4	reg8	0 0 0 0 1 1 1 1 1 1 0 0 0 reg	0 0 1 0 1 0 0 0	13	3	
	mem8	0 0 0 0 1 1 1 1 mod 0 0 0 mem	0 0 1 0 1 0 0 0	25	3-5	
ROR4	reg8	0 0 0 0 1 1 1 1 1 1 0 0 0 reg	0 0 1 0 1 0 1 0	17	3	
	mem8	0 0 0 0 1 1 1 1 mod 0 0 0 mem	0 0 1 0 1 0 1 0	29	3-5	
			n = number of BCD digits divided by 2			

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Data Type Conversion Instructions																									
CVTBD		1	1	0	1	0	1	0	0	0	0	0	0	1	0	1	0	15	2	U	U	U	X	X	X
CVTDB		1	1	0	1	0	1	0	1	0	0	0	0	1	0	1	0	7	2	U	U	U	X	X	X
CVTBW		1	0	0	1	1	0	0	0									2	1						
CVTWL		1	0	0	1	1	0	0	1									4/5	1						
Arithmetic Instructions																									
ADD	reg, reg	0	0	0	0	0	0	1	W	1	1	reg			reg			2	2	X	X	X	X	X	X
	mem, reg	0	0	0	0	0	0	0	W	mod		reg			mem			13/21	2-4	X	X	X	X	X	X
	reg, mem	0	0	0	0	0	0	1	W	mod		reg			mem			10/14	2-4	X	X	X	X	X	X
	reg, imm	1	0	0	0	0	0	S	W	1	1	0	0	0	reg			4	3-4	X	X	X	X	X	X
	mem, imm	1	0	0	0	0	0	S	W	mod		0	0	0	mem			15/23	3-6	X	X	X	X	X	X
	acc, imm	0	0	0	0	0	1	0	W									4	2-3	X	X	X	X	X	X
ADDC	reg, reg	0	0	0	1	0	0	1	W	1	1	reg			reg			2	2	X	X	X	X	X	X
	mem, reg	0	0	0	1	0	0	0	W	mod		reg			mem			13/21	2-4	X	X	X	X	X	X
	reg, mem	0	0	0	1	0	0	1	W	mod		reg			mem			10/14	2-4	X	X	X	X	X	X
	reg, imm	1	0	0	0	0	0	S	W	1	1	0	1	0	reg			4	3-4	X	X	X	X	X	X
	mem, imm	1	0	0	0	0	0	S	W	mod		0	1	0	mem			15/23	3-6	X	X	X	X	X	X
	acc, imm	0	0	0	1	0	1	0	W									4	2-3	X	X	X	X	X	X
SUB	reg, reg	0	0	1	0	1	0	1	W	1	1	reg			reg			2	2	X	X	X	X	X	X
	mem, reg	0	0	1	0	1	0	0	W	mod		reg			mem			13/21	2-4	X	X	X	X	X	X
	reg, mem	0	0	1	0	1	0	1	W	mod		reg			mem			10/14	2-4	X	X	X	X	X	X
	reg, imm	1	0	0	0	0	0	S	W	1	1	1	0	1	reg			4	3-4	X	X	X	X	X	X
	mem, imm	1	0	0	0	0	0	S	W	mod		1	0	1	mem			15/23	3-6	X	X	X	X	X	X
	acc, imm	0	0	1	0	1	1	0	W									4	2-3	X	X	X	X	X	X
SUBC	reg, reg	0	0	0	1	1	0	1	W	1	1	reg			reg			2	2	X	X	X	X	X	X
	mem, reg	0	0	0	1	1	0	0	W	mod		reg			mem			13/21	2-4	X	X	X	X	X	X
	reg, mem	0	0	0	1	1	0	1	W	mod		reg			mem			10/14	2-4	X	X	X	X	X	X
	reg, imm	1	0	0	0	0	0	S	W	1	1	0	1	1	reg			4	3-4	X	X	X	X	X	X
	mem, imm	1	0	0	0	0	0	S	W	mod		0	1	1	mem			15/23	3-6	X	X	X	X	X	X
	acc, imm	0	0	0	1	1	1	0	W									4	2-3	X	X	X	X	X	X
INC	reg8	1	1	1	1	1	1	1	0	1	1	0	0	0	reg			2	2	X		X	X	X	X
	mem	1	1	1	1	1	1	1	W	mod		0	0	0	mem			13/21	2-4	X		X	X	X	X
	reg16	0	1	0	0	0	reg											2	1	X		X	X	X	X
DEC	reg8	1	1	1	1	1	1	1	0	1	1	0	0	1	reg			2	2	X		X	X	X	X
	mem	1	1	1	1	1	1	1	W	mod		0	0	1	mem			13/21	2-4	X		X	X	X	X
	reg16	0	1	0	0	1	reg											2	1	X		X	X	X	X
MULU	reg	1	1	1	1	0	1	1	W	1	1	1	0	0	reg			21-30	2	U	X	X	U	U	U
	mem	1	1	1	1	0	1	1	W	mod		1	0	0	mem			26-35	2-4	U	X	X	U	U	U

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Arithmetic Instructions (cont)																									
MUL	reg	1	1	1	1	0	1	1	W	1	1	1	0	1		reg		33-47	2	U	X	X	U	U	U
	mem	1	1	1	1	0	1	1	W	mod			1	0	1	mem		38-52	2-4	U	X	X	U	U	U
	reg16,reg16,imm8	0	1	1	0	1	0	1	1	1	1		reg			reg		28-34	3	U	X	X	U	U	U
	reg16,mem16,imm8	0	1	1	0	1	0	1	1	mod			reg			mem		33-39	3-5	U	X	X	U	U	U
	reg16,reg16,imm16	0	1	1	0	1	0	0	1	1	1		reg			reg		36-42	4	U	X	X	U	U	U
	reg16,mem16,imm16	0	1	1	0	1	0	0	1	mod			reg			mem		41-47	4-6	U	X	X	U	U	U
DIVU	reg	1	1	1	1	0	1	1	W	1	1	1	1	0		reg		19-25	2	U	U	U	U	U	U
	mem	1	1	1	1	0	1	1	W	mod			1	1	0	mem		24-30	2-4	U	U	U	U	U	U
DIV	reg	1	1	1	1	0	1	1	W	1	1	1	1	1		reg		29-43	2	U	U	U	U	U	U
	mem	1	1	1	1	0	1	1	W	mod			1	1	1	mem		34-48	2-4	U	U	U	U	U	U
Comparison Instructions																									
CMP	reg, reg	0	0	1	1	1	0	1	W	1	1		reg			reg		2	2	X	X	X	X	X	X
	mem, reg	0	0	1	1	1	0	0	W	mod			reg			mem		10/14	2-4	X	X	X	X	X	X
	reg, mem	0	0	1	1	1	0	1	W	mod			reg			mem		10/14	2-4	X	X	X	X	X	X
	reg, imm	1	0	0	0	0	0	S	W	1	1	1	1	1		reg		4	3-4	X	X	X	X	X	X
	mem, imm	1	0	0	0	0	0	S	W	mod			1	1	1	mem		12/16	3-6	X	X	X	X	X	X
	acc, imm	0	0	1	1	1	1	0	W									4	2-3	X	X	X	X	X	X
Logical Instructions																									
NOT	reg	1	1	1	1	0	1	1	W	1	1	0	1	0		reg		2	2						
	mem	1	1	1	1	0	1	1	W	mod			0	1	0	mem		13/21	2-4						
NEG	reg	1	1	1	1	0	1	1	W	1	1	0	1	1		reg		2	2	X	X	X	X	X	X
	mem	1	1	1	1	0	1	1	W	mod			0	1	1	mem		13/21	2-4	X	X	X	X	X	X
TEST	reg, reg	1	0	0	0	0	1	0	W	1	1		reg			reg		2	2	U	0	0	X	X	X
	mem, reg	1	0	0	0	0	1	0	W	mod			reg			mem		9/13	2-4	U	0	0	X	X	X
	reg, imm	1	1	1	1	0	1	1	W	1	1	0	0	0		reg		4	3-4	U	0	0	X	X	X
	mem, imm	1	1	1	1	0	1	1	W	mod			0	0	0	mem		10/14	3-6	U	0	0	X	X	X
	acc, imm	1	0	1	0	1	0	0	W									4	2-3	U	0	0	X	X	X
AND	reg, reg	0	0	1	0	0	0	1	W	1	1		reg			reg		2	2	U	0	0	X	X	X
	mem, reg	0	0	1	0	0	0	0	W	mod			reg			mem		13/21	2-4	U	0	0	X	X	X
	reg, mem	0	0	1	0	0	0	1	W	mod			reg			mem		10/14	2-4	U	0	0	X	X	X
	reg, imm	1	0	0	0	0	0	0	W	1	1	1	0	0		reg		4	3-4	U	0	0	X	X	X
	mem, imm	1	0	0	0	0	0	0	W	mod			1	0	0	mem		15/23	3-6	U	0	0	X	X	X
	acc, imm	0	0	1	0	0	1	0	W									4	2-3	U	0	0	X	X	X
OR	reg, reg	0	0	0	0	1	0	1	W	1	1		reg			reg		2	2	U	0	0	X	X	X
	mem, reg	0	0	0	0	1	0	0	W	mod			reg			mem		13/21	2-4	U	0	0	X	X	X
	reg, mem	0	0	0	0	1	0	1	W	mod			reg			mem		10/14	2-4	U	0	0	X	X	X
	reg, imm	1	0	0	0	0	0	0	W	1	1	0	0	1		reg		4	3-4	U	0	0	X	X	X
	mem, imm	1	0	0	0	0	0	0	W	mod			0	0	1	mem		15/23	3-6	U	0	0	X	X	X
	acc, imm	0	0	1	0	0	1	0	W									4	2-3	U	0	0	X	X	X

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Logical Instructions (cont)																									
XOR	reg, reg	0	0	1	1	0	0	1	W	1	1		reg			reg		2	2	u	0	0	x	x	x
	mem, reg	0	0	1	1	0	0	0	W	mod			reg			mem		13/21	2-4	u	0	0	x	x	x
	reg, mem	0	0	1	1	0	0	1	W	mod			reg			mem		10/14	2-4	u	0	0	x	x	x
	reg, imm	1	0	0	0	0	0	0	W	1	1	1	1	0		reg		4	3-4	u	0	0	x	x	x
	mem, imm	1	0	0	0	0	0	0	W	mod		1	1	0		mem		15/23	3-6	u	0	0	x	x	x
	acc, imm	0	0	1	0	0	1	0	W									4	2-3	u	0	0	x	x	x
Bit Manipulation Instructions																									
INS	reg8, reg8	0	0	0	0	1	1	1	1	0	0	1	1	0	0	0	1	31-117/	3						
		1	1		reg				reg									35-133							
	reg8, imm8	0	0	0	0	1	1	1	1	0	0	1	1	1	0	0	1	31-117/	4						
		1	1	0	0	0		reg										35-133							
EXT	reg8, reg8	0	0	0	0	1	1	1	1	0	0	1	1	0	0	1	1	26-55/	3						
		1	1		reg				reg									34-59							
	reg8, imm8	0	0	0	0	1	1	1	1	0	0	1	1	1	0	1	1	26-55/	4						
		1	1	0	0	0		reg										34-59							
TEST1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	0	W	3	3	u	0	0	u	u	x
		1	1	0	0	0		reg																	
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	0	W	7/11	3-5	u	0	0	u	u	x
		mod		0	0	0		mem																	
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	0	W	4	4	u	0	0	u	u	x
		1	1	0	0	0		reg																	
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	0	W	8/12	4-6	u	0	0	u	u	x
		mod		0	0	0		mem																	
SET1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	0	W	4	3						
		1	1	0	0	0		reg																	
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	0	W	10/18	3-5						
		mod		0	0	0		mem																	
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	0	W	5	4						
		1	1	0	0	0		reg																	
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	0	W	11/19	4-6						
		mod		0	0	0		mem																	
	CY	1	1	1	1	1	0	0	1									2	1		1				
	DIR	1	1	1	1	1	1	0	1									2	1						
CLR1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	1	W	5	3						
		1	1	0	0	0		reg																	
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	0	1	W	11/19	3-5						
		mod		0	0	0		mem																	
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1	W	6	4						
		1	1	0	0	0		reg																	
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1	W	12/20	4-6						
		mod		0	0	0		mem																	
	CY	1	1	1	1	1	0	0	0									2	1		0				
	DIR	1	1	1	1	1	1	0	0									2	1						

Instruction Set (cont)

Mnemonic	Operands	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Bit Manipulation Instructions (cont)																									
NOT1	reg, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	1	W	4	3						
		1	1	0	0	0	reg																		
	mem, CL	0	0	0	0	1	1	1	1	0	0	0	1	0	1	1	W	10/18	3-5						
		mod		0	0	0	mem																		
	reg, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	1	W	5	4						
		1	1	0	0	0	reg																		
	mem, imm3/4	0	0	0	0	1	1	1	1	0	0	0	1	1	1	1	W	11/19	4-6						
		mod		0	0	0	mem																		
	CY	1	1	1	1	0	1	0	1									2	1		x				
Shift/Rotate Instructions																									
SHL	reg, 1	1	1	0	1	0	0	0	W	1	1	1	0	0	reg			2	2	u	x	x	x	x	x
	mem, 1	1	1	0	1	0	0	0	W	mod			1	0	0	mem		13/21	2-4	u	x	x	x	x	x
	reg, CL	1	1	0	1	0	0	1	W	1	1	1	0	0	reg			7 + n	2	u	x	u	x	x	x
	mem, CL	1	1	0	1	0	0	1	W	mod			1	0	0	mem		16/24 + n	2-4	u	x	u	x	x	x
	reg, imm8	1	1	0	0	0	0	0	W	1	1	1	0	0	reg			7 + n	3	u	x	u	x	x	x
	mem, imm8	1	1	0	0	0	0	0	W	mod			1	0	0	mem		16/24 + n	3-5	u	x	u	x	x	x
SHR	reg, 1	1	1	0	1	0	0	0	W	1	1	1	0	1	reg			2	2	u	x	x	x	x	x
	mem, 1	1	1	0	1	0	0	0	W	mod			1	0	1	mem		13/21	2-4	u	x	x	x	x	x
	reg, CL	1	1	0	1	0	0	1	W	1	1	1	0	1	reg			7 + n	2	u	x	u	x	x	x
	mem, CL	1	1	0	1	0	0	1	W	mod			1	0	1	mem		16/24 + n	2-4	u	x	u	x	x	x
	reg, imm8	1	1	0	0	0	0	0	W	1	1	1	0	1	reg			7 + n	3	u	x	u	x	x	x
	mem, imm8	1	1	0	0	0	0	0	W	mod			1	0	1	mem		16/24 + n	3-5	u	x	u	x	x	x
SHRA	reg, 1	1	1	0	1	0	0	0	W	1	1	1	1	1	reg			2	2	u	x	0	x	x	x
	mem, 1	1	1	0	1	0	0	0	W	mod			1	1	1	mem		13/21	2-4	u	x	0	x	x	x
	reg, CL	1	1	0	1	0	0	1	W	1	1	1	1	1	reg			7 + n	2	u	x	u	x	x	x
	mem, CL	1	1	0	1	0	0	1	W	mod			1	1	1	mem		16/24 + n	2-4	u	x	u	x	x	x
	reg, imm8	1	1	0	0	0	0	0	W	1	1	1	1	1	reg			7 + n	3	u	x	u	x	x	x
	mem, imm8	1	1	0	0	0	0	0	W	mod			1	1	1	mem		16/24 + n	3-5	u	x	u	x	x	x
ROL	reg, 1	1	1	0	1	0	0	0	W	1	1	0	0	0	reg			2	2		x	x			
	mem, 1	1	1	0	1	0	0	0	W	mod			0	0	0	mem		13/21	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	0	0	reg			7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod			0	0	0	mem		16/24 + n	2-4		x	u			
	reg, imm	1	1	0	0	0	0	0	W	1	1	0	0	0	reg			7 + n	3		x	u			
	mem, imm	1	1	0	0	0	0	0	W	mod			0	0	0	mem		16/24 + n	3-5		x	u			
ROR	reg, 1	1	1	0	1	0	0	0	W	1	1	0	0	1	reg			2	2		x	u			
	mem, 1	1	1	0	1	0	0	0	W	mod			0	0	1	mem		13/21	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	0	1	reg			7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod			0	0	1	mem		16/24 + n	2-4		x	u			
	reg, imm8	1	1	0	0	0	0	0	W	1	1	0	0	1	reg			7 + n	3		x	u			
	mem, imm8	1	1	0	0	0	0	0	W	mod			0	0	1	mem		16/24 + n	3-5		x	u			

n = number of shifts

Instruction Set (cont)

Mnemonic	Operands	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Shift/Rotate Instructions (cont)																									
ROLC	reg, 1	1	1	0	1	0	0	0	W	1	1	0	1	0	reg			2	2		x	x			
	mem, 1	1	1	0	1	0	0	0	W	mod		0	1	0	mem			13/21	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	1	0	reg			7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod		0	1	0	mem			16/24 + n	2-4		x	u			
	reg, imm8	1	1	0	0	0	0	0	W	1	1	0	1	0	reg			7 + n	3		x	u			
	mem, imm8	1	1	0	0	0	0	0	W	mod		0	1	0	mem			16/24 + n	3-5		x	u			
RORC	reg, 1	1	1	0	1	0	0	0	W	1	1	0	1	1	reg			2	2		x	x			
	mem, 1	1	1	0	1	0	0	0	W	mod		0	1	1	mem			13/21	2-4		x	x			
	reg, CL	1	1	0	1	0	0	1	W	1	1	0	1	1	reg			7 + n	2		x	u			
	mem, CL	1	1	0	1	0	0	1	W	mod		0	1	1	mem			16/24 + n	2-4		x	u			
	reg, imm8	1	1	0	0	0	0	0	W	1	1	0	1	1	reg			7 + n	3		x	u			
	mem, imm8	1	1	0	0	0	0	0	W	mod		0	1	1	mem			16/24 + n	3-5		x	u			
										n = number of shifts															
Stack Manipulation Instructions																									
PUSH	mem16	1	1	1	1	1	1	1	1	mod		1	1	0	mem			15/23	2-4						
	reg16	0	1	0	1	0	reg											6/10	1						
	sr	0	0	0	sr		1	1	0									6/10	1						
	PSW	1	0	0	1	1	1	0	0									6/10	1						
	R	0	1	1	0	0	0	0	0									33/65	1						
	imm	0	1	1	0	1	0	S	0									5-6/9-10	2-3						
POP	mem16	1	0	0	0	1	1	1	1	mod		0	0	0	mem			16/24	2-4						
	reg16	0	1	0	1	1	reg											8/12	1						
	sr	0	0	0	sr		1	1	1									8/12	1						
	PSW	1	0	0	1	1	1	0	1									8/12	1	R	R	R	R	R	R
	R	0	1	1	0	0	0	0	1									43/75	1						
PREPARE	imm16, imm8	1	1	0	0	1	0	0	0	*imm8 = 0 : 12 imm8 > 1 : 17 + 8 (imm8 − 1)								*	4						
DISPOSE		1	1	0	0	1	0	0	1									6/10	1						
Control Transfer Instructions																									
CALL	near_proc	1	1	1	0	1	0	0	0									16/20	3						
	regptr	1	1	1	1	1	1	1	1	1	1	0	1	0	reg			14/18	1						
	memptr16	1	1	1	1	1	1	1	1	mod		0	1	0	mem			23/31	2-4						
	far_proc	1	0	0	1	1	0	1	0									21/29	5						
	memptr32	1	1	1	1	1	1	1	1	mod		0	1	1	mem			31/47	2-4						
RET		1	1	0	0	0	0	1	1									15/19	1						
	pop_value	1	1	0	0	0	0	1	0									20/24	3						
		1	1	0	0	1	0	1	1									21/29	1						
	pop_value	1	1	0	0	1	0	1	0									24/32	3						

Instruction Set (cont)

Mnemonic	Operands	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
Control Transfer Instructions (cont)																									
BR	near_label	1	1	1	0	1	0	0	1									13	3						
	short_label	1	1	1	0	1	0	0	1									12	2						
	reg	1	1	1	1	1	1	1	1	1	1	1	0	0	reg			11	2						
	memptr16	1	1	1	1	1	1	1	1	mod		1	0	0	mem			19/23	2-4						
	far_label	1	1	1	0	1	0	1	0									15	5						
	memptr32	1	1	1	1	1	1	1	1	mod		1	0	1	mem			26/34	2-4						
BV	near_label	0	1	1	1	0	0	0	0									14/4	2						
BNV	near_label	0	1	1	1	0	0	0	1									14/4	2						
BC, BL	near_label	0	1	1	1	0	0	1	0									14/4	2						
BNC, BNL	near_label	0	1	1	1	0	0	1	1									14/4	2						
BE, BZ	near_label	0	1	1	1	0	1	0	0									14/4	2						
BNE, BNZ	near_label	0	1	1	1	0	1	0	1									14/4	2						
BNH	near_label	0	1	1	1	0	1	1	0									14/4	2						
BH	near_label	0	1	1	1	0	1	1	1									14/4	2						
BN	near_label	0	1	1	1	1	0	0	0									14/4	2						
BP	near_label	0	1	1	1	1	0	0	1									14/4	2						
BPE	near_label	0	1	1	1	1	0	1	0									14/4	2						
BPO	near_label	0	1	1	1	1	0	1	1									14/4	2						
BLT	near_label	0	1	1	1	1	1	0	0									14/4	2						
BGE	near_label	0	1	1	1	1	1	0	1									14/4	2						
BLE	near_label	0	1	1	1	1	1	1	0									14/4	2						
BGT	near_label	0	1	1	1	1	1	1	1									14/4	2						
DBNZNE	near_label	1	1	1	0	0	0	0	0									14/5	2						
DBNZE	near_label	1	1	1	0	0	0	0	1									14/5	2						
DBNZ	near_label	1	1	1	0	0	0	1	0									13/5	2						
BCWZ	near_label	1	1	1	0	0	0	1	1									13/5	2						
Interrupt Instructions																									
BRK	3	1	1	0	0	1	1	0	0									38/50	1						
	imm8	1	1	0	0	1	1	0	1									38/50	2						
BRKV	imm8	1	1	0	0	1	1	1	1									40/3	1						
RETI		1	1	0	0	1	1	1	0									27/39	1	R	R	R	R	R	R
CHKIND	reg16, mem32	0	1	1	0	0	0	1	0	mod			reg			mem		52-55/ 17-25	2-4						
BRKEM	imm8	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	38/50	3						
CPU Control Instructions																									
HALT		1	1	1	1	0	1	0	0									2	1						
BUSLOCK		1	1	1	1	0	0	0	0									2	1						
FPO1	fp_op	1	1	0	1	1	X	X	X	1	1	Y	Y	Y	Z	Z	Z	2	2						
	fp_op, mem	1	1	0	1	1	X	X	X	mod		Y	Y	Y	mem			10/14	2-4						
FPO2	fp_op	0	1	1	0	0	1	1	X	1	1	Y	Y	Y	Z	Z	Z	2	2						
	fp_op, mem	0	1	1	0	0	1	1	X	mod		Y	Y	Y	mem			10/14	2-4						

Instruction Set (cont)

Mnemonic	Operand	Opcode 7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	Clocks	Bytes	Flags AC	CY	V	P	S	Z
CPU Control Instructions (cont)																									
POLL		1	0	0	1	1	0	1	1									2 + 5n	1						
		n = number of times POLL pin is sampled.																							
NOP		1	0	0	1	0	0	0	0									3	1						
DI		1	1	1	1	1	0	1	0									2	1						
EI		1	1	1	1	1	0	1	1									2	1						
DS0:, DS1:, PS:, SS: (segment override prefixes)		0	0	1	seg		1	1	0									2	1						
8080 Instruction Set Enhancements																									
RETEM		1	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	27/39	2	R	R	R	R	R	R
CALLN	imm8	1	1	1	0	1	1	0	1	1	1	1	0	1	1	0	1	38/58	3						

Description

The μPD70616 (V60™) is a high performance, second generation 32-bit microprocessor designed for a wide range of applications including personal computers, engineering workstations and industrial controllers. The V60 includes advanced features such as thirty-two 32-bit general purpose registers and a powerful instruction set optimized for high level languages and operating systems such as UNIX™ and MS–DOS®. The on-chip demand paged memory management and floating point further increase performance and design flexibility.

Performance in the μPD70616 is enhanced by pipelining internal operations such as instruction prefetch, instruction decode, address translation and instruction execution. Software development and debugging is fully supported by instruction traps, instruction breakpoints and address traps.

Emulation mode allows porting of μPD70108/μPD70116 application software to run without modification and with the full protection of the demand paged virtual memory system. The ability to execute software from the large established base of μPD70108/μPD70116 applications under a host operating system provides an upgrade path from 16-bit architectures yet preserves existing software investments.

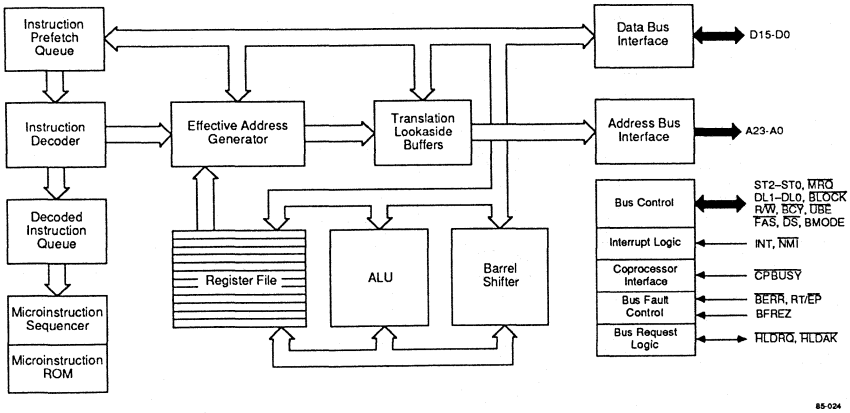
Features

- Thirty-two 32-bit general purpose registers
- On-chip demand paged memory management unit
  - 4 gigabyte virtual address space
  - 2 level translation scheme (area/page)
  - 4 levels of protection
  - 16 megabyte physical address space
  - 16 entry translation look-aside buffer (TLB)
- Supported data types include
  - 8-, 16-, 32-, 64-bit integers
  - 32-, 64-bit floating point
  - packed and unpacked decimal integers
  - 8-, 16-bit characters
  - bit, bit field and bit string data types
  - pointers
- 21 byte addressing modes/18 bit addressing modes
- Context switching and operating system support
- V20™ /V30™ emulation mode
- Flexible hardware debugging support
  - breakpoint trap, instruction trap, address traps
- Functional Redundancy Monitor (FRM)

Ordering Information

Part Number	Package	Maximum Frequency
μPD70616R	68-pin PGA	16 MHz

Block Diagram



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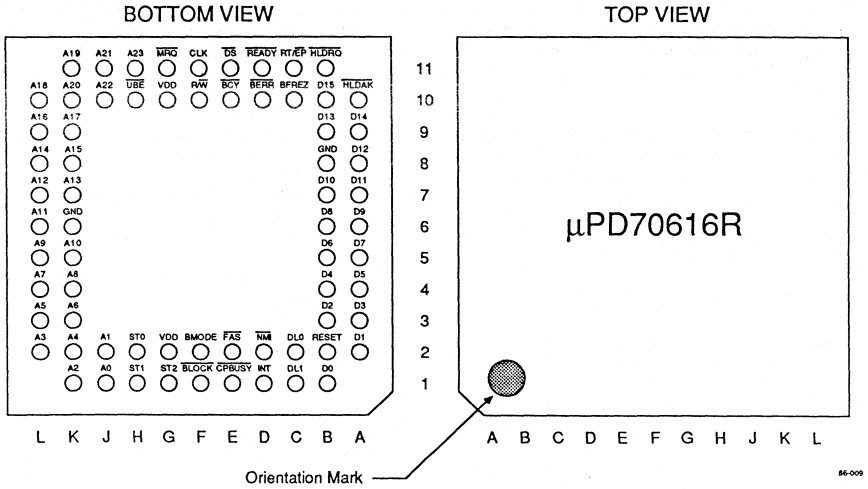
MS–DOS® is a registered trademark of Microsoft Inc.

V20™, V30™ and V60™ are trademarks of NEC Corporation

Pin Identification



Pin	Function	Pin	Function	Pin	Function	Pin	Function
A2	D1	B9	D13	F10	R/$\overline{W}$	K4	A8
A3	D3	B10	D15	F11	CLK	K5	A10
A4	D5	B11	$\overline{HLDRQ}$	G1	ST2	K6	GND
A5	D7	C1	DL1	G2	V_{DD}	K7	A13
A6	D9	C2	DL0	G10	V_{DD}	K8	A15
A7	D11	C10	BFREZ	G11	$\overline{MRQ}$	K9	A17
A8	D12	C11	RT/$\overline{EP}$	H1	ST1	K10	A20
A9	D14	D1	INT	H2	ST0	K11	A19
A10	$\overline{HLDAK}$	D2	$\overline{NMI}$	H10	$\overline{UBE}$	L2	A3
B1	D0	D10	$\overline{BERR}$	H11	A23	L3	A5
B2	RESET	D11	$\overline{READY}$	J1	A0	L4	A7
B3	D2	E1	$\overline{CPBUSY}$	J2	A1	L5	A9
B4	D4	E2	$\overline{FAS}$	J10	A22	L6	A11
B5	D6	E10	$\overline{BCY}$	J11	A21	L7	A12
B6	D8	E11	$\overline{DS}$	K1	A2	L8	A14
B7	D10	F1	$\overline{BLOCK}$ ($\overline{MSMAT}$)	K2	A4	L9	A16
B8	GND	F2	BMODE (FRM)	K3	A6	L10	A18

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Pin Identification

Symbol		I/O	Function
A23-A0	Address bus	3-state OUT	24-bit address bus
D15-D0	Data bus	3-state I/O	16-bit bidirectional data bus
ST2-ST0	Bus Status	3-state OUT	bus cycle access type
MRQ•	Memory Request	3-state OUT	active low memory access strobe
R/W•	Read/Write	3-state OUT	bus cycle direction output
DS•	Data Strobe	3-state OUT	active low data strobe
BCY•	Bus Cycle	3-state OUT	active low bus cycle signal
DL1-DL0	Data Length	3-state OUT	single mode data length, string mode data direction signals
FAS•	First Data Access Status	OUT	first data access/subsequent data access signal
UBE•	Upper Byte Enable	3-state OUT	valid high order 8-bit data bus (D15–D8) signal
READY•	Ready	IN	bus cycle ready input
BMODE (FRM)	Bus Mode (Functional Redundancy Monitor)	IN	processor mode select input 0 V : master mode, short bus cycle 5 V : master mode, normal bus cycle 10V : check mode, normal bus cycle
BLOCK• (MSMAT•)	Bus Lock (Mismatch)	OUT	active low master mode bus lock output signal check mode mismatch error output signal
BERR•	Bus Error	IN	active low bus error input
BFREZ	Bus Freeze	IN	active high bus freeze command
RT/EP•	Retry/Exception	IN	retry/exception decision input
NMI•	Non-Maskable Interrupt	IN	active low non-maskable interrupt input
INT	Maskable Interrupt	IN	active high maskable interrupt input
HLDRQ•	Hold Request	IN	active low processor address, data and control bus request
HLDAK•	Hold Acknowledge	OUT	active low bus external request acknowledgment
CPBUSY•	Coprocessor Busy	IN	coprocessor status polling input
RESET	Reset	IN	active high reset input
CLK	Clock	IN	processor clock input
V_{DD}	Power	–	+5 V power supply
GND	Ground	–	ground

Table of Contents

Section 1
Design Information

Pin Functions

This section describes the operation of the μPD70616 address bus, data bus and control interface. Inputs and outputs are considered at a logic "0" level when a low level signal is present. Likewise, a logic "1" is represented by a high level signal. Bus states are defined and measured from the rising edge of the clock to the rising edge of the next clock.

ST2-ST0 [Bus Status]..... 3-state outputs
The ST2–ST0 outputs (in conjunction with the MRQ* output) indicate the type of bus cycle being performed.

Two separate bus access modes are supported by the μPD70616. String mode bus accesses occur during bus cycles for variable length data types. All other bus cycles are single mode.

$\overline{MRQ}$	ST2	ST1	ST0	Bus Status	
0	0	0	0	Reserved for Future Use	(Single)
0	0	0	1	String Mode Data Access	(String)
0	0	1	0	Short Path Data Access	(Single)
0	0	1	1	Single Mode Data Access	(Single)
0	1	0	0	System Base Table Access	(Single)
0	1	0	1	Translation Table Access	(Single)
0	1	1	0	Demand Mode Instruction Fetch	
0	1	1	1	Instruction Prefetch	
1	0	0	0	Reserved for Future Use	(Single)
1	0	0	1	String Mode I/O Access	(String)
1	0	1	0	Reserved for Future Use	
1	0	1	1	Single Mode I/O Access	(Single)
1	1	0	0	Machine Fault Acknowledge	
1	1	0	1	Halt Acknowledge	
1	1	1	0	Interrupt Acknowledge	(Single)
1	1	1	1	Reserved for Future Use	

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String Mode: variable length data type (character string and bit string) bus cycles
Single Mode: all other data access cycles

String Mode Memory Access..... **(String Mode)**
The processor is performing a character or bit string data access in the memory address space.

Short Path Memory Access..... **(Single Mode)**
A short path memory bus status is substituted for a single mode data access when a read access can be satisfied by the write data for the current bus cycle.

Single Mode Memory Access..... **(Single Mode)**
The processor is performing a single mode access in the memory address space.

System Base Table Access..... **(Single Mode)**
The system base table is being accessed in response to an interrupt or exception condition.

Translation Table Access..... **(Single Mode)**
An area table entry (ATE) or page table entry (PTE) access is taking place for the purpose of address translation.

Demand Mode Instruction Fetch
The instruction prefetch queue has been flushed by a control transfer and a demand mode instruction fetch is taking place.

Instruction Prefetch
An instruction fetch for the 16-byte instruction prefetch queue is taking place.

String Mode I/O Access..... (String Mode)
The processor is performing a character or bit string access in the I/O address space.

Single Mode I/O Access..... (Single Mode)
The processor is performing a single mode access in the I/O address space.

Machine Fault Acknowledge
The machie fault acknowledge status is generated as a result of a fatal double bus error. This status is presented at the end of the bus cycle and remains until RESET is asserted. DS* is not asserted during a machine fault acknowledge bus cycle.

Halt Acknowledge
A privileged HALT instruction has executed and the processor has halted. The halt status will be output until an interrupt occurs or the processor is reset. DS* is not asserted during a halt acknowledge bus cycle.

Interrupt Acknowledge..... (Single Mode)
The interrupt acknowledge status is generated during the pair of interrupt acknowledge bus cycles.

ST2–ST0 are three-state outputs and enter the high impedance state during hold acknowledge.

MRQ* [Memory Request]..... 3-state outputs
MRQ* is asserted during memory address space accesses.

MRQ* is an active-low three-state output and becomes high impedance during hold acknowledge.

A23-A0 [Address Bus]..... 3-state outputs
These three-state outputs form the active-high 24-bit physical address bus. Both memory and I/O address spaces are organized into a pair of byte-wide banks and are addressed by A23-A1. The even addressed bank is selected whenever A0 is driven low during an I/O or memory bus cycle. Selection of the odd addressed bank is controlled by the UBE* signal.

A memory or I/O port address is asserted after the rising edge of a T1 bus cycle. A23-A0 are three-state outputs and enter the high impedance state while HLDAK* or BFREZ is asserted.

D15-D0 [Data Bus]..... 3-state I/O
The sixteen bit bidirectional data bus is organized into a pair of byte-wide data buses, supporting both 8- and 16-bit bus cycles. Eight bit bus cycles and sixteen bit bus cycles are distinguished by A0 and UBE*. During T4 of a read cycle, the contents of D15–D0 are latched internally in the μPD70616. Data is placed on D15–D0 during T1 of a write bus cycle and remains valid until the start of the next bus cycle.

While the RESET input is asserted, D15-D0 are placed in the high impedance state. D15–D0 are also placed in the high impedance state while HLDAK* or BFREZ is asserted.

R/W* [Read/Write]..... 3-state output
R/W* is a three-state output indicating the direction of the current bus cycle. R/W* is driven low during the T1 state to indicate the current bus cycle will transfer data from the μPD70616 to external memory or a peripheral device. Conversely, R/W* is driven high to indicate a transfer from an external device to the μPD70616.

DS* [Data Strobe]..... 3-state output
DS* is a three-state output used to generate memory and I/O read/write strobes for a bus cycle. DS* is asserted during T1 of a bus cycle is held valid until the T4 bus state. DS* is negated during the Halt Acknowledge and Machine Fault Acknowledge and reset states.

DS* is held in the high impedance state during hold acknowledge.

BCY* [Bus Cycle]..... 3-state output
BCY* is a three-state output and indicates a valid bus cycle is in progress. BCY* is asserted following the rising edge of T1 and is negated following the rising edge of a T4.

BCY* is held at a high level during reset.

DL1–DL0 [Data Length]..... 3-state outputs
DL1–DL0 are three-state outputs and are used together with FAS* and the bus status outputs to determine operand size for fixed length data or the position and direction for variable length data types. During instruction fetch accesses, DL1–DL0 are driven low.

- Single Mode Bus Accesses

DL1	DL0	Data Length	
0	0	Byte	(1 byte)
0	1	Halfword	(2 bytes)
1	0	Word	(4 bytes)
1	1	Reserved	

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- String Mode Bus Accesses

DL1	DL0	String Direction
1	0	Address Increment
1	1	Address Decrement

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DL1–DL0 are in an undefined state during reset.

FAS* [First Data Access Status]..... 3-state output
FAS* is a three-state output indicating the type of data bus cycle. FAS* is asserted during the first bus cycle of any multiple bus cycle data transfer. FAS* is negated in any subsequent bus cycle.

FAS* is undefined during an instruction fetch bus access.

Mode	Data Length/String Direction	DL1	DL1	$\overline{FAS}$	$\overline{MRQ}$, ST2–ST0	Notes
Single	Byte	0	0	0	Single Mode	$\overline{FAS}$ = 0 : First bus cycle
	Halfword	0	1	0/1	0000, 0010	
	Word	1	0	0/1	0011, 0100	$\overline{FAS}$ = 1 : Subsequent bus cycles
	Reserved	1	1	0/1	0101, 1000	
					1011, 1110	
String	Start Increment	1	0	0	String Mode	
	Start Decrement	1	1	0	0001, 1001	
	Address Increment	1	0	1		
	Address Decrement	1	1	1		

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UBE* [Upper Byte Enable]..... 3-state output
UBE* is an active low output and is asserted when the upper byte (D15-D8) of the data bus contain valid data. UBE* is used along with A0 by decoding logic to select the even/odd addressed buses as follows:

$\overline{UBE}$	A0	Access Type
0	0	Halfword Access
0	1	Upper Byte Access
1	0	Lower Byte Access
1	1	Reserved

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UBE* is a three-state output and enters the high impedance state during hold acknowledge.

READY* [Ready]..... input
READY* is an active-low input used to synchronize external memory and peripheral devices with the μPD70616. Slow memory and I/O devices can lengthen a bus cycle by negating the READY* input and causing the BCU to insert TW states between states T3 and T4 of a normal bus cycle. When READY* is once again asserted and recognized by the BCU, the BCU will proceed to the T4 state.

The READY* input is ignored during any three clock bus cycle or during Halt Acknowledge and Machine Fault Acknowledge states.

BMODE [Bus Mode]..... input
FRM [Functional Redundancy Monitor]
This three level logic input is used to select the type bus cycle or to enable the FRM (functional redundancy monitor) logic. When at a low level, BMODE selects a three clock bus cycle instead of the normal four clock bus cycle. External logic can select the three clock bus transfer mode when fast memory such as a cache is accessed. The READY* input is ignored during a short bus cycle.

Bus Mode	Bus Cycle Type	BMODE
Master Mode	Short Cycle (3 clocks, $\overline{READY}$ pin ignored)	0 V
	Normal Bus Cycle (4 clocks)	5 V
Checker Mode	Normal Bus Cycle (4 clocks)	10 V

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The FRM mode is selected when this pin is attached to a voltage source of +10V. This places the μPD70616 into the checking mode, allowing the μPD70616 to check the operation of a master mode μPD70616 microprocessor.

BLOCK* [Bus Lock]..... output
MSMAT* [Mismatch]
The BLOCK* output is asserted during a bus cycle to indicate an indivisible read-modify-write bus cycle (TASI, CAXI instructions) is taking place. It is used by external logic to guarantee the integrity of the bus cycle in a multiple bus master system. BLOCK* is also asserted for the duration of an interrupt acknowledge bus cycle.

MSMAT* is an FRM check mode output and is asserted if a discrepancy between master and checker processors is detected.

BERR* [Bus Error]..... input
External logic can assert the BERR* input to indicate the presence of a fault in the current bus cycle and request a retry of the bus cycle or force an exception if the bus fault cannot be corrected. The decision to retry or terminate a bus cycle with an error is determined by the state of the RT/EP* input pin at the rising edge of the T4 state.

BFREZ [Bus Freeze]..... input
The BFREZ input causes bus activity to cease after the falling edge of the T4 state and TI states to be inserted into the bus cycle. Both the address bus and the data bus are placed in the high impedance state and all status outputs are inactivated.

When BFREZ is returned to a low level, the RT/EP* pin is sampled to determine whether to restart the faulted instruction or force an exception.

RT/EP* [Retry/Exception]..... input
The RT/EP* input pin is used along with the BERR* and BFREZ inputs to determine the response to a bus error or halt request.

If BERR* is asserted, RT/EP* will determine whether to retry the faulty bus cycle (RT/EP* = 1) or cause an exception (RT/EP* = 0).

When the BFREZ input is negated, RT/EP* will determine whether to restart instruction execution (RT/EP* = 1) or cause an exception (RT/EP* = 0).

RT/$\overline{EP}$	Bus Error Action	BFREZ Release
1	Retry	Interrupted Instruction Restart
0	Exception	Machine Fault Exception

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NMI* [Non-Maskable Interrupt]..... input
The NMI* pin is an active low interrupt input that cannot be masked by software. At the completion of the current instruction, the PC and PSW are pushed on the stack and control is transferred to a non-maskable interrupt handler.

INT [Interrupt Request]..... input
The INT input is an active high interrupt input that can be masked by the IE bit in the PSW register. If the IE bit is cleared, the INT input is masked and any interrupt requests are held pending until unmasked by software.

If set, the μPD70616 will perform a pair of back-to-back interrupt acknowledge cycles. On the second interrupt acknowledge cycle, an 8-bit interrupt vector is read from the external μPD71059 interrupt controller and used as an offset into the System Base Table. The INT input must be asserted until acknowledged by the μPD70616.

HLDRQ* [Hold Request]..... input
This active-low input is asserted by an external bus master desiring to take control of the μPD70616 address, data, and control buses.

HLDAK* [Hold Acknowledge]..... output
In response to an asserted HLDRQ* input, HLDAK* is asserted indicating that the μPD70616 address, data, and control buses have entered the high impedance state and are available for use by the external bus master.

CPBUSY* [Coprocessor Busy]..... input
This active-low input allows an external coprocessor to indicate the status of the previous operation. By sampling the CPBUSY* input, the μPD70616 can synchronize with asynchronous coprocessors.

RESET [Reset]..... input
When this active-high input is asserted, the μPD70616 terminates all operations and initializes the internal registers and logic. While RESET is asserted, the output buffers of the μPD70616 are in the following states:

State	Output
High	R/$\overline{W}$, $\overline{DS}$, $\overline{BCY}$, $\overline{HLDAK}$, $\overline{BLOCK}$ ($\overline{MSMAT}$)
High-Z	D15–D0
Undefined	A23–A0, DL1–DL0, $\overline{FAS}$, $\overline{MRQ}$, $\overline{UBE}$, ST2–ST0

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When RESET returns to a low level, the registers assume their initial values and program execution commences in physical address mode from address 0FFFFFFF0H.

Register	Reset Value
PSW	1 0 0 0 0 0 0 0 H
PC	F F F F F F F 0 H
SBR	0 0 0 0 0 0 0 0 H
SYCW	0 0 0 0 0 0 7 0 H
TKCW	0 0 0 0 E 0 0 0 H
PSW2	0 0 0 0 F 0 0 2 H
ATBR	Invalid
TLB	Cleared
Others	Undefined

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CLK [Clock]..... input
CLK is the μPD70616 system clock input.

V_{DD} [Power Supply]
The two V_{DD} pins supply +5 Volt power to the μPD70616.

GND [Ground]
The two GND pins are the power supply return.

Absolute Maximum Ratings

T_A = +25°C

Power Supply Voltage, V_{DD}	−0.5 V to +7.0 V
Input Voltage, V_I	−0.5 V to V_{DD} + 0.3 V
CLK Input Voltage, V_K	−0.5 V to V_{DD} + 1.0 V
Output Voltage, V_O	−0.5 V to V_{DD} + 0.3 V
Operating Temperature, T_{OPT}	−40°C to +85°C
Storage Temperature, T_{STG}	−65°C to +150°C

Comment: Exposing the device to stresses above those listed in the Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

T_A = +25°C, V_{DD} = 0 V

		Limits			
Parameter	Symbol	Min	Max	Unit	Conditions
Input Capacitance	C_I		15	pf	F_C = 1 MHz
I/O Capacitance	C_{IO}		15	pf	returned to 0 V

DC Characteristics

T_A = 0°C to +70°C, V_{DD} = +5 V ±5%

		Limits			
Parameter	Symbol	Min	Max	Unit	Conditions
Input Voltage High	V_{IH}	2.2		V	
Input Voltage Low	V_{IL}		0.8	V	
CLK Input Voltage High	V_{KH}	4.0		V	
CLK Input Voltage Low	V_{KL}		0.6	V	
Output Voltage High	V_{OH}	2.4		V	I_{OH} = −400μA
Output Voltage Low	V_{OL}		0.45	V	I_{OL} = 3.2mA
Input Leakage Current	I_{LI}		±10	μA	
Output Leakage Current	I_{LO}		±10	μA	
Supply Current	I_{DD}		400	mA	f_{IN} = 12 MHz

AC Characteristics

T_A = 0°C to +70°C, V_{DD} = +5 V ±5%

Output Pin Load Capacitance: 100 pf

		Limits			
Parameter	Symbol	Min	Max	Unit	Conditions
Clock Cycle Time	t_{CYK}	TBD		ns	
Clock Pulse Width High	t_{KKH}	TBD		ns	
Clock Pulse Width Low	t_{KKL}	TBD		ns	
Clock Rise Time	t_{KR}		5	ns	
Clock Fall Time	t_{KF}		5	ns	
RESET Pulse Width from V_{DD} Valid	t_{HVR}	1000		ns	
RESET Setup to CLK↓	t_{SRK}	10		ns	
RESET Pulse Width	t_{WRE}	20		t_{CYK}	
NMI*, INT, CPBUSY* Setup to CLK↓	t_{SIK}	10		ns	
Address Delay from CLK↑	t_{DKA}		40	ns	
BCY* Delay from CLK↑	t_{DKBC}		40	ns	
DS* Delay from CLK↓	t_{DKDS}		40	ns	
BMODE Setup to CLK↓	t_{SBMK}	10		ns	
BMODE Hold from CLK↓	t_{HKBM}	20		ns	
READY* Setup to CLK↓	t_{SRYK}	10		ns	
READY* Hold from CLK↓	t_{HKRY}	20		ns	
Data Setup to CLK↓	t_{SDK}	10		ns	
Data Hold from CLK↓	t_{HKD}	5		ns	
Data Delay from CLK↓	t_{DKD}		50	ns	
BLOCK* Delay from CLK↑	t_{DKBL}		40	ns	
BERR* Setup to CLK↓	t_{SBEK}	10		ns	
BERR* Hold from CLK↓	t_{HKBE}	20		ns	

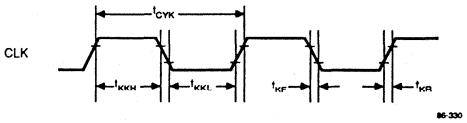
AC Characteristics (cont)

T_A = 0°C to +70°C, V_{DD} = +5 V ±5% Output Pin Load Capacitance: 100 pf

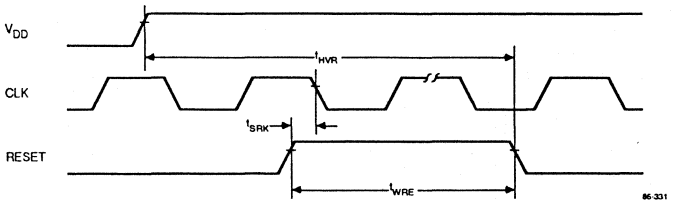
Parameter	Symbol	Limits Min	Limits Max	Unit	Conditions
RT/EP* Setup to CLK↓	t_{SRTK}	10		ns	
RT/EP* Hold from CLK↓	t_{HKRT}	20		ns	
HLDRQ* Setup to CLK↑	t_{SHQK}	10		ns	
HLDRQ* Hold from CLK↑	t_{DKHA}	40		ns	
Output Float Delay from CLK↑	t_{FKA}		50	ns	
BFREZ Setup to CLK↑	t_{SBFR}	10		ns	
RT/EP* Setup to CLK↑	t_{SRFK}	10		ns	
RT/EP* Hold from CLK↑	t_{HKRF}	20		ns	
Address Setup to CLK↓ (FRM Mode)	t_{SFRK}	15		ns	
Address Hold from CLK↓ (FRM Mode)	t_{HKFR}	20		ns	
MSMAT* Delay from CLK↑	t_{DKMS}		40	ns	

Timing Waveforms

Clock Timing

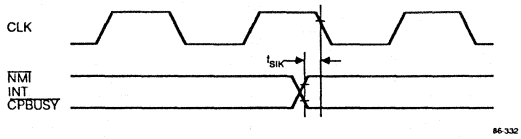


Reset Timing

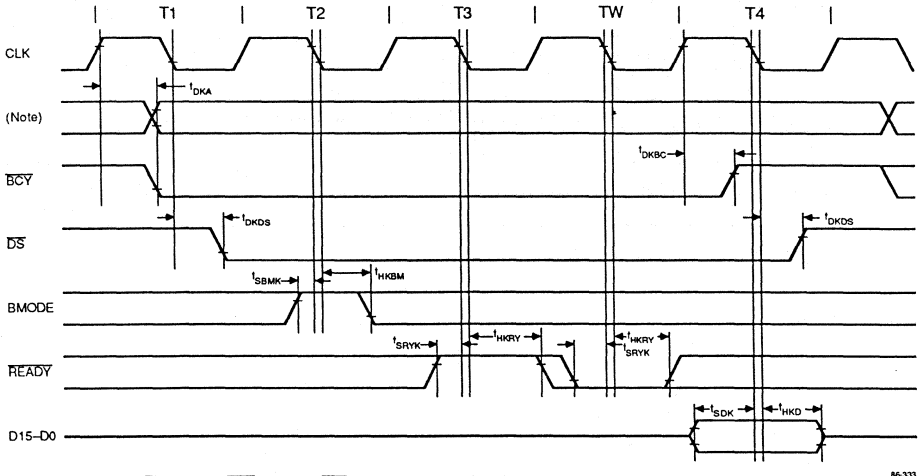


Timing Waveforms (cont)

Asynchronous Input Timing



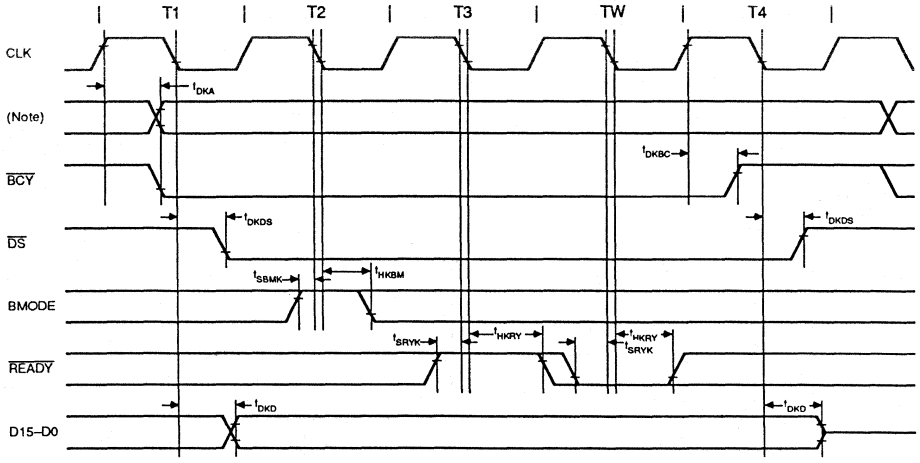
Read Timing



Note – A23–A0, $\overline{UBE}$, R/$\overline{W}$, ST2–ST0, $\overline{MRO}$, DL1–DL0, $\overline{FAS}$

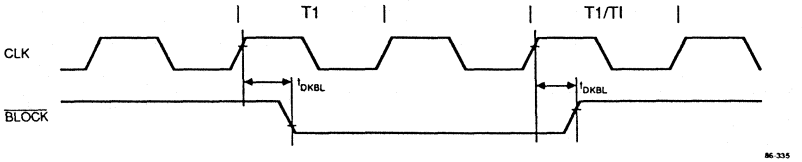
Timing Waveforms (cont)

Write Timing



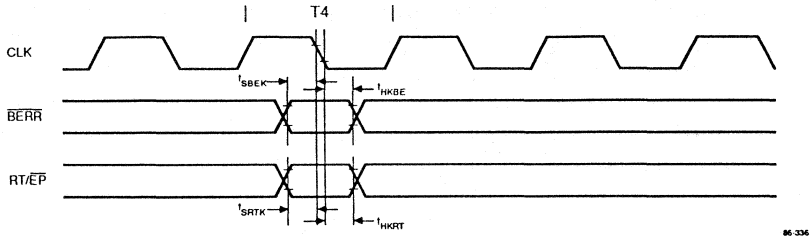
Note – A23–A0, $\overline{UBE}$, R/$\overline{W}$, ST2–ST0, $\overline{MRQ}$, DL1–DL0, $\overline{FAS}$

Bus Lock Timing

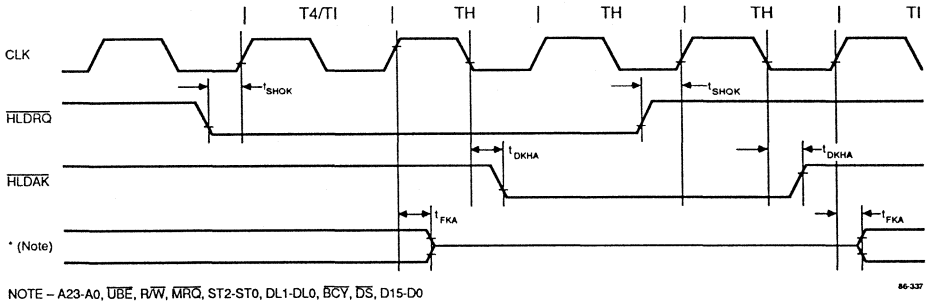


Timing Waveforms (cont)

Bus Error Timing

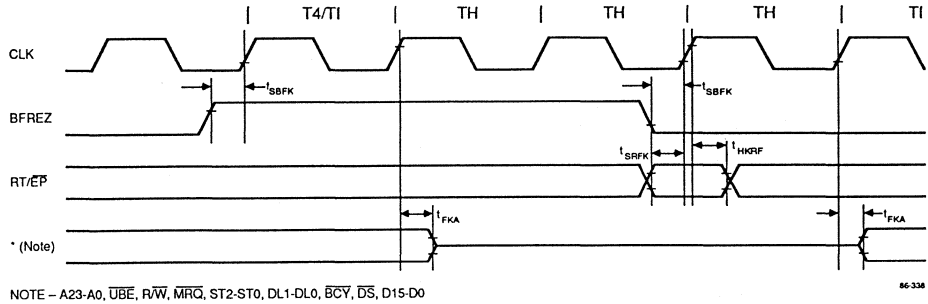


Bus Hold Timing



NOTE – A23-A0, UBE, R/W, MRQ, ST2-ST0, DL1-DL0, BCY, DS, D15-D0

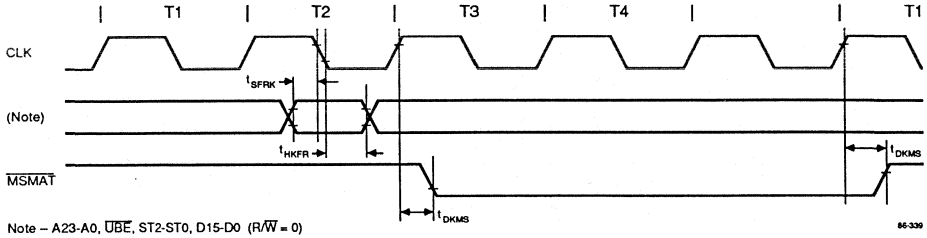
Bus Freeze Timing



NOTE – A23-A0, UBE, R/W, MRQ, ST2-ST0, DL1-DL0, BCY, DS, D15-D0

Timing Waveforms (cont)

FRM Timing

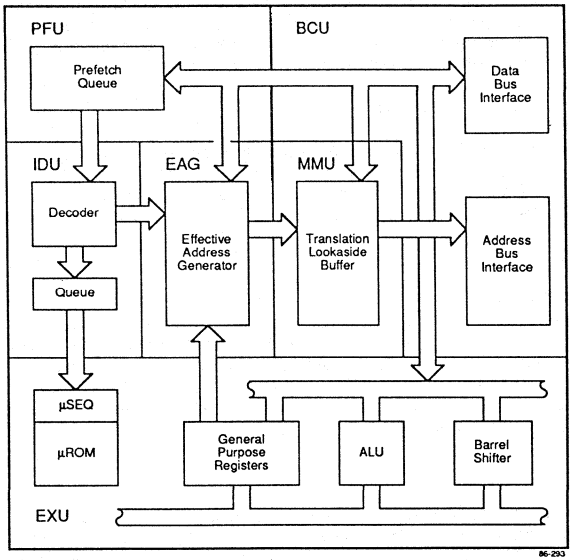


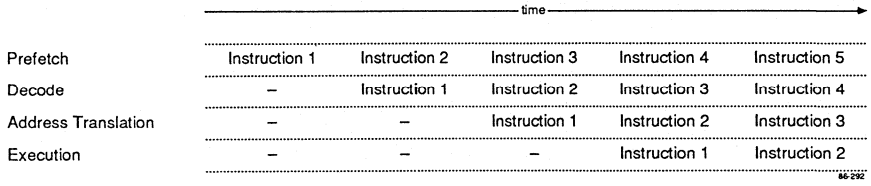
Note – A23-A0, $\overline{UBE}$, ST2-ST0, D15-D0 (R/$\overline{W}$ = 0)

Section 2
Pipeline Operation

The μPD70616 contains six functional units which permit concurrent processing of up to four instructions. Pipelining instructions allows the μPD70616 to take advantage of the inherent parallelism in instruction fetch, decode and execution to increase performance. The μPD70616 pipeline organization contains special logic to recognize pipeline hazards and hold up processing until the hazard not longer exists.. Exceptions such as instruction prefetch page faults or undefined opcodes are delayed until the faulted instruction is ready to execute, in case a control transfer instruction preceded the non-existent or undefined instruction.

μPD70616 Instruction Pipeline Organization





The μPD70616 functional blocks and the associated operations performed are described below.

Bus Control Unit

The BCU (bus control unit) provides the interface between the internal buses of the μPD70616 and external memory and peripheral devices. The BCU accepts requests for bus operations from the other internal units along with a physical address and performs the requested operation. These operations include:

- memory accesses
- I/O accesses
- bus cycle timing (normal/short)
- bus cycle error/retry
- FRM mode comparison

Prefetch Unit

The PFU (prefetch unit) performs prefetching of instructions for the instruction decoding logic. As the lowest priority bus requester, the PFU uses otherwise idle bus cycles to keep the 16 byte instruction prefetch queue filled. Prefetching of instructions attempts to minimize instruction execution time by making available without delay the next instruction for the instruction decode unit. In the event of a control transfer, interrupt or exception, the instruction queue contents are flushed and a demand mode instruction fetch is made.

Instruction Decode Unit

The IDU (instruction decode unit) is another pipeline element which takes advantage of instruction concurrency to decode the next instruction during the execution of the current instruction. The IDU examines the instruction for operand references and passes the operand addressing mode information to the logic performing the effective address calculation. The decoded instruction is then placed in the three instruction decoded instruction queue for execution.

Effective Address Generator

The EAG (effective address generator) accepts both source and destination operand addressing information from the IDU and computes the effective addresses of the operands. Both source and destination operand addresses are computed prior to instruction execution to allow checking of access permissions and availability prior to instruction execution. In the physical address mode, the effective address of an operand is a physical address and is untranslated by the memory management unit. In the virtual address mode, the effective address is a virtual address and requires translation by the MMU before use by the BCU.

Memory Management Unit

The MMU (memory management unit) is responsible for the translation of virtual to physical addresses and checking that the access permissionsfor the requested operation will not be violated. Address translation is performed with the aid of two levels of address translation tables which specify the execution level and access permissions for each virtual address. Because it is desirable to eliminate the overhead of address translation table lookup for each address, the MMU maintains a 16 entry TLB (translation look-aside buffer), containing the sixteen most recently referenced pages, typically eliminating the need for a address translation in 98% of the cases.

Execution Unit

The EXU (execution unit) containing the μPD70616 register set, is responsible for the actual execution of each instruction. The EXU takes decoded instructions from the IDU, source operands that were fetched from memory and executes the instruction. Internally, the EXU uses multiple 32-bit data paths to speed operand access and instruction execution.

Section 3
μPD70616 Architecture

This section contains an overview of the features and implementation of the μPD70616 architecture. For additional information, refer to the μPD70616 Programmer's Reference Manual.

The μPD70616 register set is divided into a program register set and a privileged register set. The program register set consists of the registers and resources visible to application programs. Privileged software such as operating systems also have access to the privileged register set.

Program Register Set

The program register set consists of the general purpose registers, program counter and the lower halfword (16-bits) of the program status word.

• General Purpose Registers

The general purpose register set consists of thirty-two 32-bit registers named R0–R31. Each of these registers can be used as an accumulator, base register, index register or for temporary storage. General purpose registers can be used to hold byte (8-bit), halfword (16-bit) or word (32-bit) data. Any pair of consecutive registers can also be used to hold doubleword (64-bit) data. For the byte (halfword) data types, the high order 3 (2) bytes are unaffected by operations on the low order part.

The top three of the general purpose registers (R29–R31) are also implicitly selected by certain instructions and can be referred to by alternate names.

R29 : AP (Argument Pointer)

The argument pointer is used as a base register to pass arguments by the procedure call instructions.

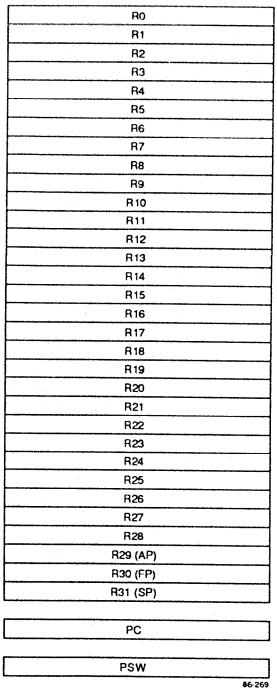
R30 : FP (Frame Pointer)

The frame pointer is used to manage the stack frames generated by high level languages. The FP is referenced by the PREPARE and DISPOSE instructions.

R31 : SP (Stack Pointer)

The stack pointer contains a pointer to the current TOS (top of stack). The SP register is implicitly selected by the push/pop instructions and by the subroutine and procedure call/return instructions.

Program Register Set

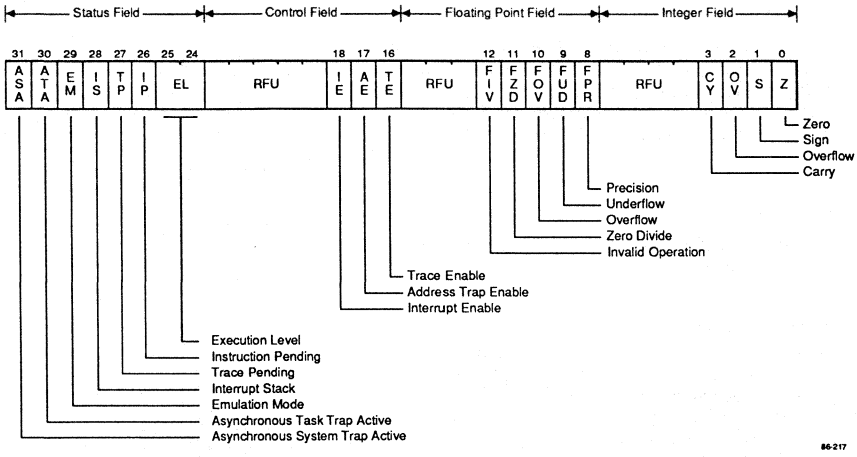


• PC (Program Counter)

The program counter contains the address of the first byte of the current instruction. The PC is also used as a base register in any of the five PC relative addressing modes.

- **PSW (Program Status Word)**

The PSW (program status word) is divided into four 8-bit fields. The lower halfword is accessible to all programs and contains the integer and floating point condition codes. The upper halfword contains the processor control and status fields and can only be modified by programs running at execution level 0.

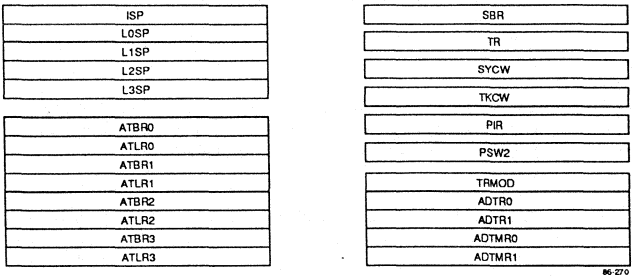


Bit(s)	Name	Meaning
0	Z	Z = 1 : zero integer result
1	S	S = 1 : negative integer result
2	OV	OV = 1 : integer overflow occurred
3	CY	CY = 1 : a carry (borrow) was generated
4–7	RFU	Reserved for future use (Must be 0)
8	FPR	FPR = 1 : floating point precision fault
9	FUD	FUD = 1 : floating point underflow
10	FOV	FOV = 1 : floating point overflow
11	FZD	FZD = 1 : floating point zero divide
12	FIV	FIV = 1 : floating point invalid operand
13–15	RFU	Reserved for future use (Must be 0)
16	TE	TE = 1 : instruction trace enabled
17	AE	AE = 1 : address traps enabled
18	IE	IE = 1 : maskable interrupts enabled
19–23	RFU	Reserved for future use (Must be 0)
24–25	EL	EL = 00 : execution level 0 (privileged execution level) 01 : execution level 1 10 : execution level 2 11 : execution level 3
26	IP	IP = 1 : instruction pending
27	TP	TP = 1 : instruction trace pending
28	IS	IS = 1 : interrupt stack active
29	EM	EM = 1 : V20/V30 emulation mode enabled
30	ATA	ATA = 1 : asynchronous task trap being serviced
31	ASA	ASA = 1 : asynchronous system trap being serviced

Privileged Register Set

The privileged register set consists of registers that are accessible only by programs running at execution level 0. The privileged register set includes the stack pointer cache, processor control registers, task control registers, virtual memory management registers and address trap registers. Generally, only operating system software is allowed access to these registers.

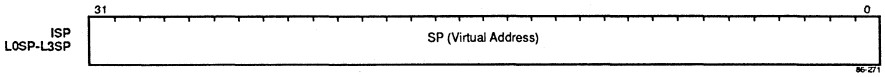
Privileged Register Set



- **SP (Stack Pointers)**

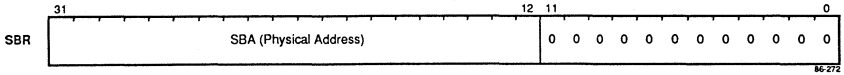
  ISP (Interrupt Stack Pointer)
  L0SP, L1SP, L2SP, L3SP (Level 0, 1, 2, 3 Stack Pointers)

A set of five separate stack pointers are used on the μPD70616 microprocessor. The interrupt stack pointer is used during the processing of interrupts and each execution level has a dedicated stack pointer. The general purpose register R31 contains a pointer to the current TOS and is saved and loaded whenever the execution level changes or the processor switches to the interrupt stack. The active stack pointer can be identified by examining the contents of the PSW.EL and PSW.IS fields.



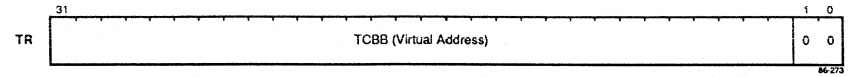
- **SBR (System Base Register)**

The system base register defines the physical base address for the SBT (system base table). The system base table consists of a list of entry points for interrupt and exception handlers. The system base table must be aligned on a page (4KB) boundary, thus the low order 12 bits of the SBR must be zero.



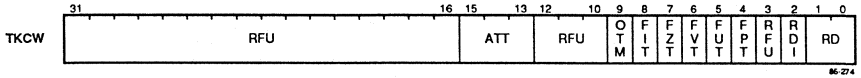
• **TR (Task Register)**

The task register contains the virtual address of the TCB (task control block) for the current task context. The contents of the task register are modified by the LDTASK instruction when a new task context is installed. The task TCB must be aligned on a word boundary and the low order 2 bits of the task register must be 0.



• **TKCW (Task Control Word)**

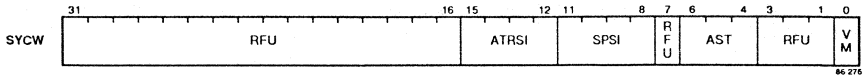
The task control word contains the operating environment for the current task. The TKCW contains the floating point rounding mode, the enables/disables for floating point exceptions and the asynchronous task trap enable/disable. The contents of the task control word are updated with every new task context.



Bit(s)	Name	Meaning
0–1	RD	Floating Point Rounding Control RD = 00 : round toward nearest 01 : round toward −∞ 10 : round toward +∞ 11 : round toward 0
2	RDI	Floating Point Rounding Control for Integer Conversion RDI = 0 : use RD field rounding mode RDI = 1 : round toward 0
3	RFU	Reserved for future use (Must be 0)
4	FPT	Floating Point Precision Trap Enable FPT = 1 : floating point precision traps enabled
5	FUT	Floating Point Underflow Trap Enable FUT = 1 : floating point underflow traps enabled
6	FVT	Floating Point Overflow Trap Enable FVT = 1 : floating point overflow traps enabled
7	FZT	Floating Point Zero Divide Trap Enable FZT = 1 : floating point zero divide traps enabled
8	FIT	Floating Point Invalid Operation Trap Enable FIT = 1 : floating point invalid operation traps enabled
9	OTM	Operand Trap Mask OTM = 0 : floating point invalid operand traps enabled (fixed at 0 on the μPD70616 microprocessor)
10–12	RFU	Reserved for future use (Must be 0)
13–15	ATT	Asynchronous Task Trap Level ATT = 000 : level 0 ATT 001 : level 1 ATT 010 : level 2 ATT 011 : level 3 ATT 1XX : ATT disabled
16–31	RFU	Reserved for future use (Must be 0)

• SYCW (System Control Word)

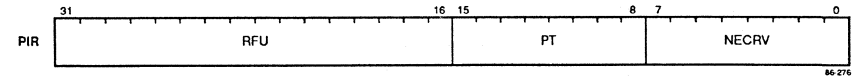
The system control word is used by software to control the system-wide operating environment. The SYCW contains the virtual/physical address mode control, asynchronous system trap enable/disable and the inhibits for area table and stack pointer switching.



Bit(s)	Name	Meaning
0	VM	Virtual Mode VM = 1 : virtual address mode enabled
1–3	RFU	Reserved for future use (Must be 0)
4–5	AST	Asynchronous System Trap Level AST = 000 : level 0 AST 001 : level 1 AST 010 : level 2 AST 011 : level 3 AST 1XX : AST disabled
7	RFU	Reserved for future use (Must be 0)
8–11	SPSI	Stack Pointer Switching Inhibited SPSI = 1 : level 0 (bit 8) / 1 (bit 9)/ 2 (bit 10)/ 3 (bit 11) stack pointers are saved in the TCB during a context switch
12–15	ATRSI	Area Table Register Switching Inhibited ATRSI = 1 : 00 (bit 12) / 01 (bit 13)/ 10 (bit 14)/ 11 (bit 15) section area table registers are saved in the TCB during a context switch
16–31	RFU	Reserved for future use (Must be 0)

• PIR (Processor ID Register)

The processor ID register is used by system software to identify the processor type. When read, the contents of the μPD70616 processor ID register will be of the form 000060XXH.

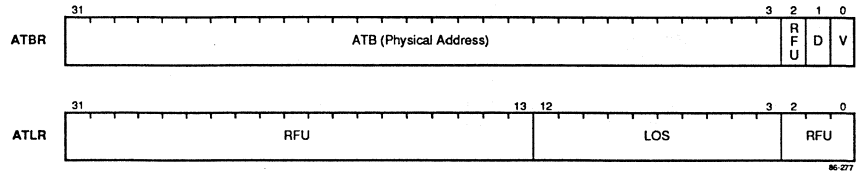


Bit(s)	Name	Meaning
0–7	NECRV	NEC Reserved
8–15	PT	Processor Type
16–31	RFU	Reserved for future use (Must be 0)

- **Area Table Register Pairs**

  ATBR0, ATBR1, ATBR2, ATBR3 (Area Table Base Registers 0, 1, 2, 3)
  ATLR0, ATLR1, ATLR2, ATLR3 (Area Table Length Registers 0, 1, 2, 3)

The area table register pairs operate in the virtual address mode to identify which of the four area tables is to be used during address translation. Each area table register pair consists of an ATBR (area table base register) and an ATLR (area table length register). The area table base register contains the physical base address of the area table. The area table length register defines the length of the area table to allow hardware checking of accesses into variable length address translation tables.



- **ATBR**

Bit(s)	Name	Meaning
0	V	Valid V = 1 : this area table register contains valid information
1	D	Growth Direction D = 0 : the section will grow in the positive direction (increasing addresses) D = 1 : the section will grow in the negative direction (decreasing addresses)
2	RFU	Reserved for future use (Must be 0)
3–31	ATB	Area Table Base the physical address of the first area table entry for this section

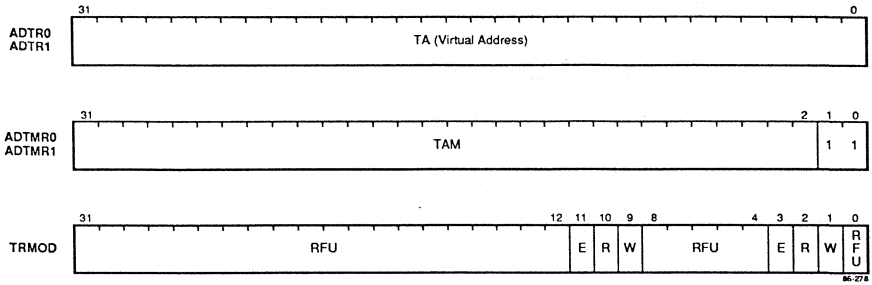
- **ATLR**

Bit(s)	Name	Meaning
0–2	RFU	Reserved for future use (Must be 0)
3–12	LOS	Limit of Section Determines the size of the section as follows: positive growth direction areas 0 → LOS negative growth direction areas 1023 → LOS
13–31	RFU	Reserved for future use (Must be 0)

- **Address Trap Control Registers**

  ADTR0, ADTR1 (Address Trap Registers 0, 1)
  ADTMR0, ADTMR1 (Address Trap Mask Registers 0, 1)
  TRMOD (Trap Mode Register)

The address trap registers define the condition for the occurrence of address traps. Two independent sets of address trap registers are available. The address trap registers and the address trap mask registers contain the virtual base addresses and mask values used to define an address region. The trap mode register is then used for each set of address trap registers to qualify the type access (read/write/execute) necessary to actually cause the trap to occur.

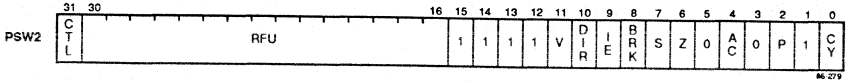


- **TRMOD**

Bit(s)	Name	Meaning
0	RFU	Reserved for future use (must be zero)
1	W	Write Access W = 1 : ADTR0, ADTMR0 address range write access trap enable
2	R	Read Access R = 1 : ADTR0, ADTMR0 address range read access trap enable
3	E	Execute Access E = 1 : ADTR0, ADTMR0 address range execute access trap enable
4–7	RFU	Reserved for future use (must be zero)
8	W	Write Access W = 1 : ADTR1, ADTMR1 address range write access trap enable
9	R	Read Access R = 1 : ADTR1, ADTMR1 address range read access trap enable
10	E	Execute Access E = 1 : ADTR1, ADTMR1 address range execute access trap enable
11–31	RFU	Reserved for future use (must be zero)

- **PSW2 (Program Status Word 2)**

Program status word 2 is used as the PSW by V20/V30 emulation mode programs.

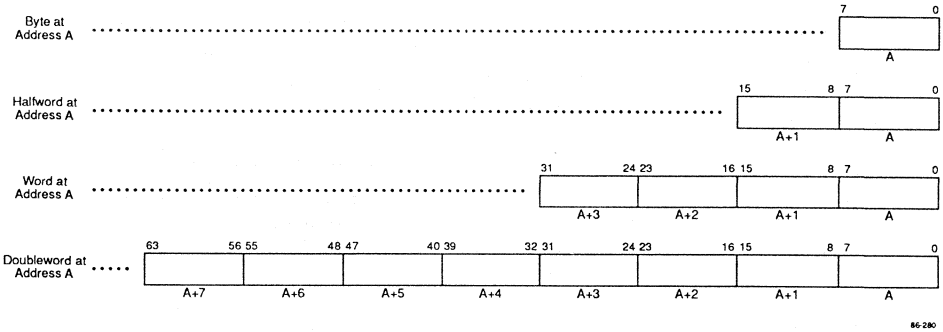


Bit(s)	Name	Meaning
0	CY	CY = 1 : carry (borrow) generated
2	P	P = 1 : even parity
4	AC	AC = 1 : auxilliary carry(borrow)
6	Z	Z = 1 : zero result
7	S	S = 1 : negative result
8	BRK	BRK = 1 : instruction trace enabled (privileged)
9	IE	IE = 1 : maskable interrupts enabled (privileged)
10	DIR	DIR = 1 : address decrement
11	V	V = 1 : overflow occurred
16–30	RFU	Reserved for future use (Must be 0)
31	CTL	CTL = 1 : I/O instruction execution enabled

Memory and I/O Organization

Memory and I/O are organized around a byte addressible, 16 megabyte physical address space. Each byte location in the physical address space has a unique address, determined by the 24-bit address bus. Byte data consists of eight bits with bit 0 designated as the LSB (least significant bit) and bit 7 as the MSB (most significant bit).

For data types larger than a byte, the address of the lowest byte is used as the address of the data. The byte at the lowest address is called the LSB (least significant byte) while the byte at the highest address is the MSB (most significant byte). On the μPD70616, two consecutive bytes of data is called a halfword, four consecutive bytes of data is called a word and eight consecutive bytes of data is called a doubleword. The representation of both memory and I/O data and the corresponding addresses of the component bytes is shown below.



The I/O and memory address spaces are independent and separated by hardware on the μPD70616. However, access to the I/O address space using instructions which normal reference the memory address space can be accomplished by mapping 4KB pages of the virtual address space into the I/O address space.

Data Types

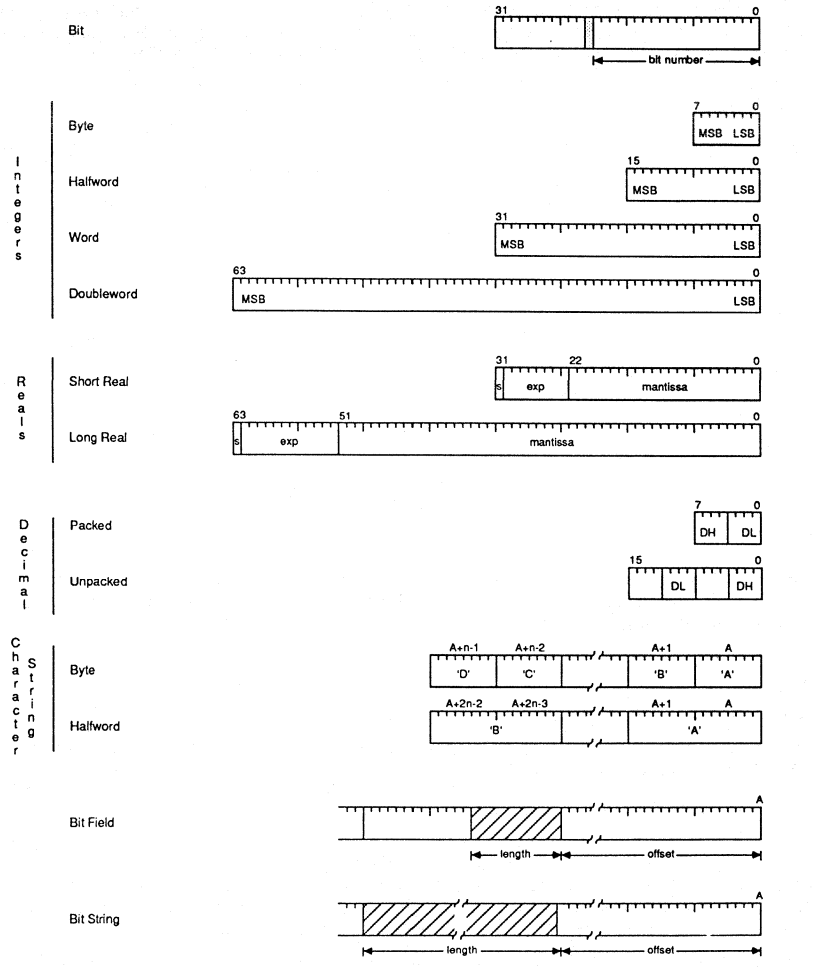
The μPD70616 supports a wide variety of fixed length and variable length data types.

Fixed length data types include signed/unsigned integers and two floating point representations for high performance numeric applications. Business applications can also use the decimal integer data type to speed up decimal calculations. The pointer data type is used to represent addresses for parameter passing between procedures. A bit data type allows fast manipulation of single bits in memory or a register.

The variable length data types include character strings, bit strings and bit fields. A powerful set of character string operations increase performance and minimize the number of bus cycles required to process character data. The bit string data type, unavailable on any other microprocessor, allows logical and data transfer operations on bit strings from 1 to 4 gigabits in length. Bit fields range in length from 0 to 32 bits and simplify packing of integers in high level languages. Both bit fields and bit strings can begin on any bit boundary and are identified by a bit address.

The fixed length data types and bit fields can reside in memory or a register without restriction. The remaining variable length data types can only reside in memory. The format of the data types supported by the μPD70616 are shown below.

Data Type Formats



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Addressing Modes

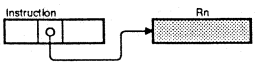
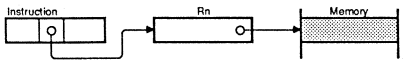
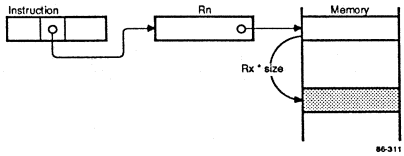
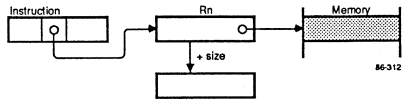
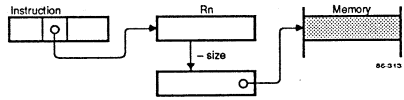
The μPD70616 implements a set of 21 byte and 18 bit addressing modes to allow fast, flexible access to both byte aligned and bit aligned operands.

Byte Addressing Modes

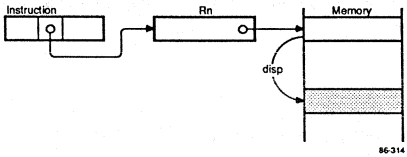
Including all standard operand addressing modes such as register, immediate, base and indexed, the μPD70616 supports a total of twenty-one addressing modes for byte addressible data.

The register addressing mode complements the large general purpose register set, allowing the programmer or compiler to minimize the number of memory transfers. The base, or displacement mode, can use any of the general purpose registers or the PC as a base register. Indexing provides a powerful method of addressing arrays of data without keeping track of the data size. The scaled index addressing modes automatically scale the contents of an index register by the size of the operand (byte / halfword / word / doubleword) before performing the access.

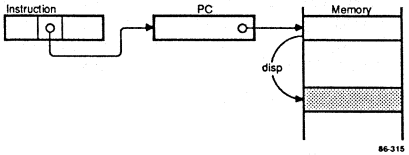
Below is a list of the available byte addressing modes.

Mode	Operation
Register	Rn 
Register Indirect	[Rn] 
Register Indirect Indexed	[Rn](Rx) 
Autoincrement	[+Rn] 
Autodecrement	[–Rn] 

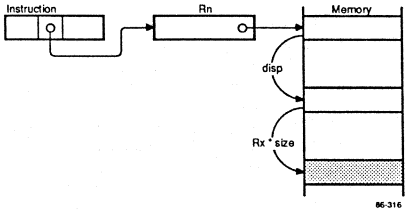
Mode	Operation
Displacement	disp [Rn]



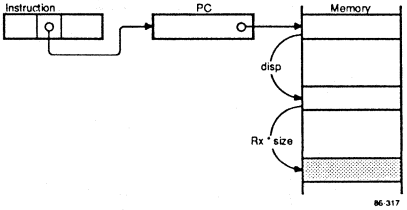
PC Displacement	disp [PC]



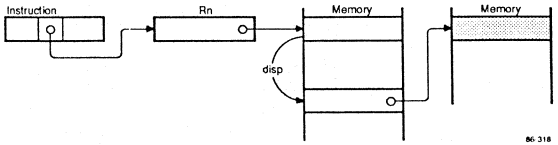
Displacement Indexed	disp [Rn](Rx)



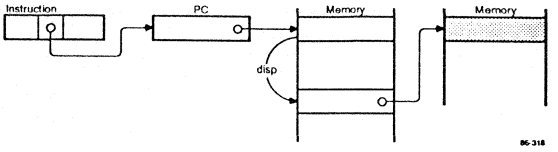
PC Displacement Indexed	disp [PC](Rx)



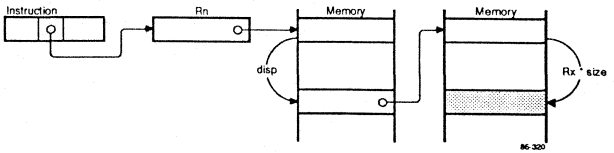
Displacement Indirect	[disp [Rn]]



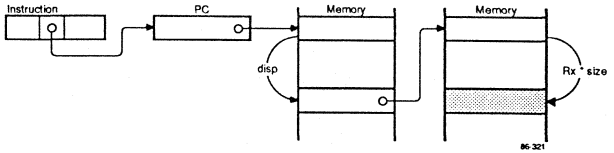
Mode	Operation
PC Displacement Indirect	[disp [PC]]



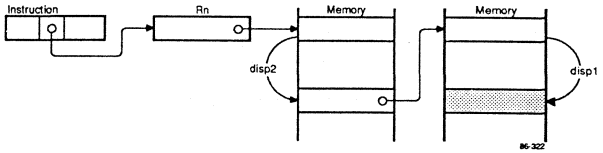
Displacement Indirect Indexed	[disp [Rn]](Rx)



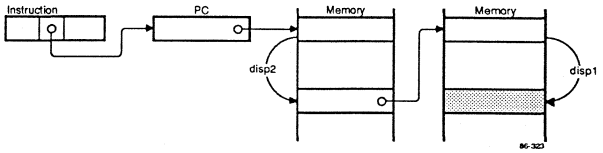
PC Displacement Indirect Indexed	[disp [PC]](Rx)



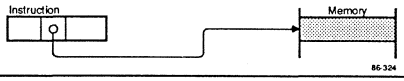
Double Displacement	disp1 [disp2 [Rn]]



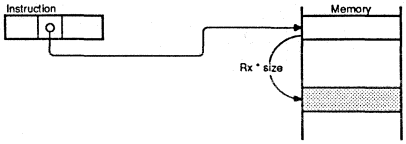
PC Double Displacement	disp1 [disp2 [PC]]



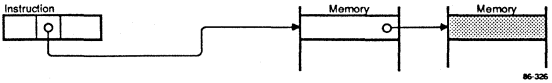
Direct Address	/addr



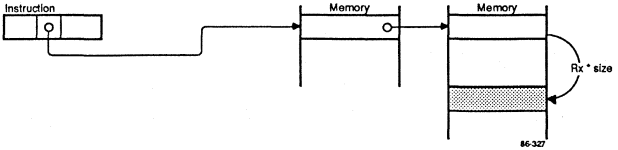
Mode	Operation
Direct Address Indexed	/addr (Rx)



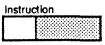
Direct Address Deferred	[/addr]



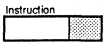
Direct Address Deferred Indexed	[/addr](Rx)



Immediate	#value



Immediate Quick	#value (0–15)



The size values used by the scaled index and the autoincrement/autodecrement address modes are listed in the below table.

Data Type	Scaling Constant	
	Increment/Decrement	Scaled Index
Byte	1	1
Halfword	2	2
Word	4	3
Doubleword	8	8
Packed Decimal	1	1
Unpacked Decimal	2	2
Byte Character	1	1
Halfword Character	2	2
Bit	4	4
Bit Field	4	–
Bit String	1	–

– Not Available

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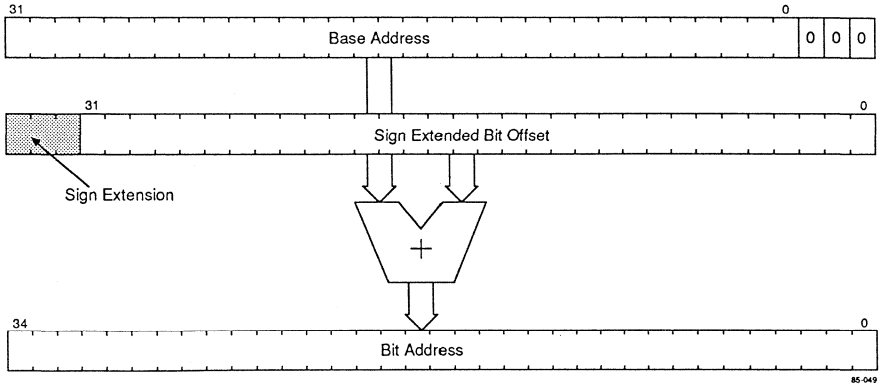
Bit Addressing

In the μPD70616, bit addresses are required to support the bit field and bit string data types which unlike the other data types can be aligned on an arbitrary bit boundary. To address any bit within the 4GB virtual address space, a 35-bit address is required. The μPD70616 generates this 35-bit address using a 32-bit base address and a 32-bit bit offset.

To compute a bit address, the 32-bit base address is zero extended on the right to 35 bit length. Next the 32-bit bit offset is sign extended to 35-bit length and the sum of these two identify the starting address of the bit field or bit string. This process is shown below.



Bit addressing modes are not available for the register or immediate addressing modes.

Bit addressing modes require that a byte base address and an optional non-zero bit offset be specified. In the following table of assembler encodings, the bit offset component of the bit address is shown as underlined. Both address components are combined by the μPD70616 to generate the target bit address.

Bit Addressing Modes

Mode	Assembler Encoding	Notes
Register Indirect	@ [Rn]	bit offset defaults to 0
Register Indirect Indexed	Rx @ [Rn]	
Autoincrement	@ [Rn+]	bit offset defaults to 0
Autodecrement	@ [–Rn]	bit offset defaults to 0
Displacement	offset @ [Rn]	
PC Displacement	offset @ [PC]	
Displacement Indexed	Rx @ disp[Rn]	
PC Displacement Indexed	Rx @ disp[PC]	
Displacement Indirect	@ [disp [Rn]]	bit offset defaults to 0
PC Displacement Indirect	@ [disp [PC]]	bit offset defaults to 0
Double Displacement	offset @ [disp [Rn]]	
PC Double Displacement	offset @ [disp [PC]]	
Direct Address	@ /addr	bit offset defaults to 0
Direct Address Indexed	Rx @ /addr	
Direct Address Deferred	@ [/addr]	bit offset defaults to 0
Direct Address Deferred Indexed	Rx @ [/addr]	

Demand Paged Virtual Memory

The μPD70616 uses on-chip memory management hardware to implement a high performance demand paged virtual memory system. Memory management allows the design of multi-tasking systems with complete isolation of tasks from the operating system and each other. Demand paging further enhances memory management by allowing programs to use adress spaces larger than can be physically addressed in a system. Other advantages include:

- each task can utilize as much of the virtual space as desired
- programs much larger than the physical address space can be accommodated
- protection of tasks is simplified

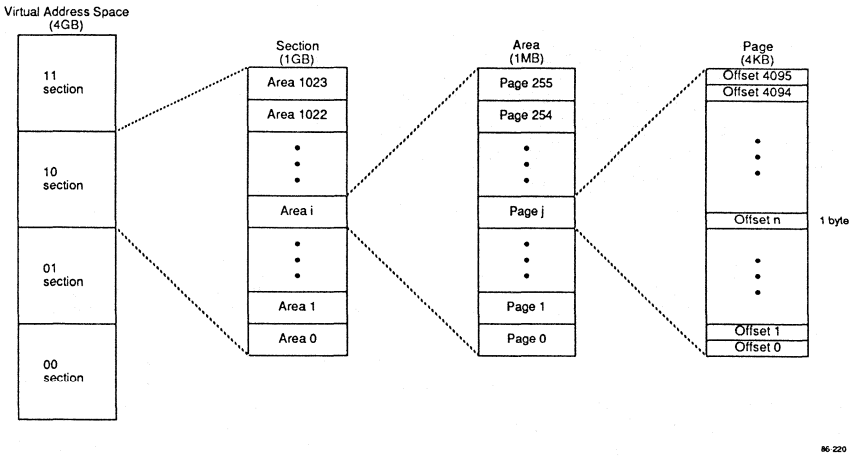
Features of the μPD70616 virtual memory management unit are:

- multiple virtual address spaces
- each virtual address space is 4GB
- three virtual address space partitions (section / area / page)
- 4KB page size
- 16 entry full associative TLB (translation look-aside buffer)
- area / page protection mechanisms
- memory mapped I/O by MMU

Virtual Address Spaces

A 4 GB virtual space is divided into three components called sections, areas and pages. Sections are a 1GB unit and are the basis for sharing of virtual address spaces in a system employing multiple virtual spaces. Each section contains 1024 areas, each area being 1MB in size. Because of their smaller size, areas are ideally suited for private sharing of virtual space between two tasks. Finally, each area is broken down into 256 4KB pages. Pages are the smallest unit of memory management and are the unit for memory mapping I/O and demand paging.

Virtual Address Space Organization

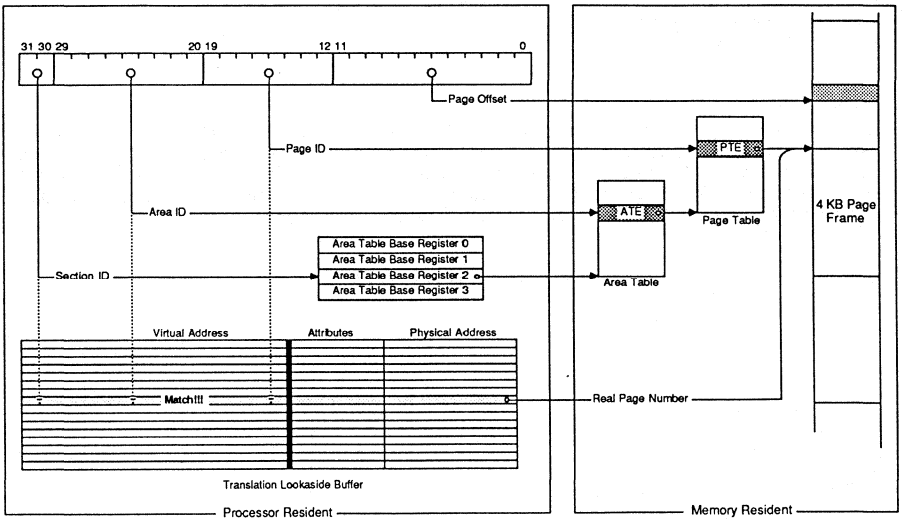


Address Translation

The μPD70616 microprocessor translates virtual addresses into physical addresses using the on-chip memory management unit. Address translation requires the μPD70616 firmware to translate an address using the on-chip memory management registers (area table base and length registers) and the memory resident translation tables (area tables/page tables).

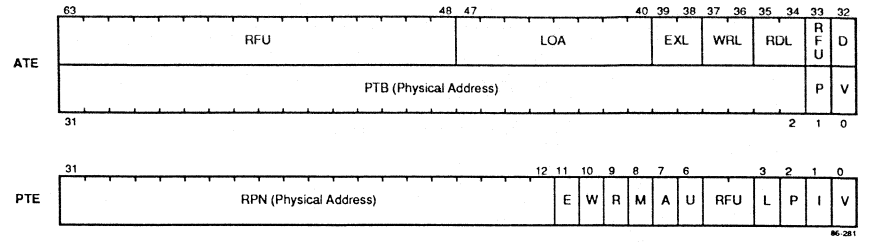
Address translation incurs a great deal of overhead and is unacceptable to perform for each memory access so the results of the last sixteen address translations are cached in a full associative translation look-aside buffer (TLB). Caching of a virtual/physical address pair allows the high speed TLB hardware to access a completed translation the next time the page is referenced, eliminating the address translation overhead. On the μPD70616, the TLB hit ratio is typically over 98%, meaning that for the vast majority of memory references, the address translation tables do not have to be accessed.

μPD70616 Address Translation



If a demand paged system is implemented, during an address translation, if the translation tables or page of memory is not present, a fault condition exists and an exception will occur. It is then up to the operating system to correct the fault and restart the instruction.

Two sets of address translation tables are referenced during address translation. Area tables contain up to 1024 entries called ATEs (area table entries). Area tables exist in the memory address space and must aligned on a doubleword boundary. Each valid area of a virtual address space has an associated page table. Page tables contain up to 256 entries called PTEs (page table entries). Page tables need not be present in memory and can be swapped out to secondary storage if desired. Page tables exist in the memory address space and must aligned on a word boundary. The formats of the area table and page table entries are shown below.



- **ATE (Area Table Entry)**

Bit(s)	Name	Meaning
0	V	Valid V = 1 : this ATE is defined
1	P	Present P = 1 : the page table associated with this ATE is in physical memory
32	D	Growth Direction D = 1 : negative growth direction
33	RFU	Reserved for future use (Must be 0)
34–35	RDL	Read Execution Level RDL = 00 : level 0 01 : level 0, 1 10 : level 0, 1, 2 11 : level 0, 1, 2, 3
36–37	WRL	Write Execution Level WRL = 00 : level 0 01 : level 0, 1 10 : level 0, 1, 2 11 : level 0, 1, 2, 3
38–39	EXL	Execute Execution Level EXL = 00 : level 0 01 : level 0, 1 10 : level 0, 1, 2 11 : level 0, 1, 2, 3
40–47	LOA	Limit of Area Determines the size of the area as follows: positive growth direction pages 0 → LOA negative growth direction pages 255 → LOA
48–63	RFU	Reserved for future use (Must be 0)

- **PTE (Page Table Entry)**

Bit(s)	Name	Meaning
0	V	Valid V = 1 : this PTE is defined
1	I	I/O Mapped I = 1 : this page is I/O mapped
2	P	Present P = 1 : the page associated with this PTE is in physical memory
3	L	Locked L = 1 : page is locked for I/O
4–5	RFU	Reserved for future use (Must be 0)
6	U	User this field is available for use by the operating system
7	A	Accessed A = 1 : this page has been accessed
8	M	Modified M = 1 : this page has been modified
9	R	Readable R = 1 : this page is readable
10	W	Writable W = 1 : this page is writable
11	E	Executable E = 1 : this page is executable
12–31	RPN	Real Page Number page base physical address

Memory Mapped I/O

The μPD70616 hardware provides a 16MB I/O address space in addition to the 16MB memory address space. Because only privileged I/O instructions can directly access the I/O address space, some other means must be provided to allow any instruction to perform I/O without compromising the protection mechanisms.

In the virtual address mode, this mapping of the virtual address space into the I/O address space is supported by the MMU. Each PTE contains a field (I bit) which allows the operating system to specify that the page is I/O mapped. When an I/O mapped page is referenced and all protection checks have been satisfied, the bus cycle will be performed but in the I/O address space rather than the memory address space. This allows any instruction to access I/O at any execution level as determined by the operating system. This feature is not available in the physical address mode.

Virtual Address Mode/Physical Address Mode

Following reset, the μPD70616 is in the physical address mode. In the physical address mode, the demand paging and memory management logic are disabled until the initialization software programs the virtual address mode. Virtual address mode is enabled by setting the VM bit within the SYCW.

In the physical address mode, no address translation is performed and there is no need for address translation tables or memory management exception handlers. The four execution levels are present in the physical address mode and privileged instructions can only be executed at execution level 0. On the other hand, physical address mode is not well suited for the design of multi-tasking systems due to the lack of protection mechanisms and the restricted address space.

	Virtual Address Mode	Physical Address Mode
VM Flag	1	0
Address Space	4 Gbytes per task	16 Mbytes
Address Translation Tables	Area Table Page Table	Not used
Protection Mechanisms	2 level (area, page)	None
Software I/O Mapping	I/O mapped pages	Undefined

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Operating System Support

The μPD70616 architecture contains a number of features designed to aid in the design and implementation of modern multi-tasking operating systems.

Task Management

In a multi-tasking operating system, multiple tasks must share the system resources in a controlled manner. Certain operations must be prohibited if the system is to guarantee the correct execution of all tasks. It is the responsibility of the operating system to maintain separate task contexts in a data structure called a TCB (task control block). Each TCB consists of information related only this particular instance of the task (such as the general purpose register contents) and other system-wide information (such as shared virtual address space registers) common to all tasks.

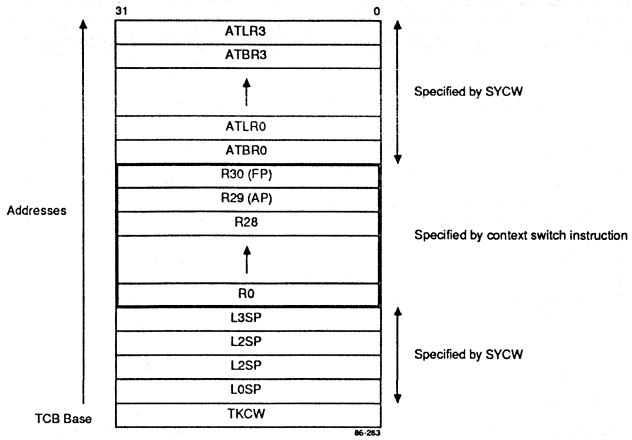
On the μPD70616, the TCB is a variable length data structure consisting of the TKCW (task control word), general purpose registers, stack pointers and memory management register pairs. The TKCW is responsible for the management of local task state which consists of the task's register set. The SYCW (system control word) is responsible for specifying the system-wide context included in the TCB. This information includes the area table register pairs and stack pointers that are to be swapped in and out during context switches. The base address of the TCB for the current task context is contained in the TR (task register). The size of the TCB is determined by the contents of the SYCW and task switch instruction operands.

Instruction set support for the automatic saving and restoring task contexts is provided by the LDTASK and STTASK instructions. The organization of a μPD70616 TCB is shown below.

Protection Mechanisms

A multi-tasking system requires that the operating system and other tasks be kept from interfering with one another. Protection and separation of tasks from each other and the operating system is one of the primary advantages of a virtual memory system. Protection mechanisms enhance the operation of the system by detecting and preventing attempts by tasks to access programs and data without first having established the necessary permissions.

TCB (Task Control Block) Organization



The μPD70616 protection mechanisms are implemented using three levels. First an execution level is established which determines the relative trustworthiness of a task. A check of execution level and access type permissions are performed at the area level while an independent access type check is performed again at the page level. Protection mechanisms are enabled only when the processor is operating in the virtual mode. In the physical address mode, all protection mechanisms are disabled and no exceptions can occur.

Area level protection is specified independently for each access method (read, write and execute) by a 2-bit field in each ATE. Each of the three protection fields contain the minimum execution level necessary to allow access to the area. For example, if

read level..... 2
write level..... 1
execute level..... 0

are specified, then access to the area by program execution level is:

level 0	read, write and execute
level 1	read and execute
level 2	read
level 3	no access

Page protections permit or deny access on the basis of contents of the page. For example, if the page protections are

read	true
write	true
execute	false

then the contents of the page are readable and writable but not executable.

An access is possible only when both area and page permissions have been granted. Any attempt at access without both sets of permissions being satisfied will result in an exception.

Interrupts and Exceptions

An interrupt is an event which occurs asynchronously to the operation of the μPD70616 while an exception is an event which occurs as a direct result of program execution. When an interrupt or exception is recognized, the program is suspended and control is transferred to an interrupt or exception handler. Processing of interrupts and exceptions is similar but differ slightly in the operation of the interrupt enable flag and the stack pointer used during interrupt or exception processing.

Reset is a special type of exception. When reset occurs, all processor activity is stopped and the processor is initialized to the reset state.

System Base Table

When an interrupt or exception is recognized, the SBT (system base table) is used to locate the appropriate vector. The SBT consists of 256 entries, each containing an entry point to an interrupt or exception handler. An SBT entry consists of a 32-bit virtual address in the virtual address mode or a 24-bit physical address in the physical address mode. In the physical address mode, the high order eight address bits are ignored by the μPD70616 but must be zero for compatibility with future NEC microprocessors.

The SBT is located in the memory address space aligned on a page (4KB) boundary by the SBR (system base register). The first 64 SBT entries (0–63) are reserved for use by μPD70616 interrupts and exceptions. The remaining 192 entries (64–255) are available in user applications as maskable interrupt vectors.

Interrupt/Exception Recognition

When an interrupt or exception is recognized, the following actions are performed and control is transferred to the specified interrupt/exception handler.

(i) PSW.EL ← 00
(If a CHLVL instruction exception or an Asynchronous Task Trap then the specified execution level is set.)

(ii) PSW.IE flag modification
- interrupt.....PSW.IE ← 0 (maskable interrupts disabled)
- exception.....PSW.IE unchanged (bus error and stack invalid exceptions disable interrupts)

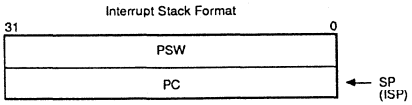
(iii) PSW.TE ← 0
PSW.TP ← 0
PSW.AE ← 0

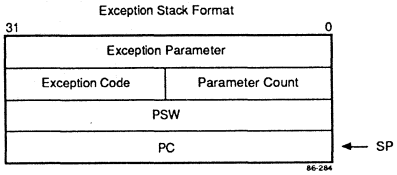
(iv) PSW.EM ← 0 (native mode)

(v) PSW.ASA ← 1 (If an ATT occurs then AST are enabled.)

(vi) temp ← SBT[vector]

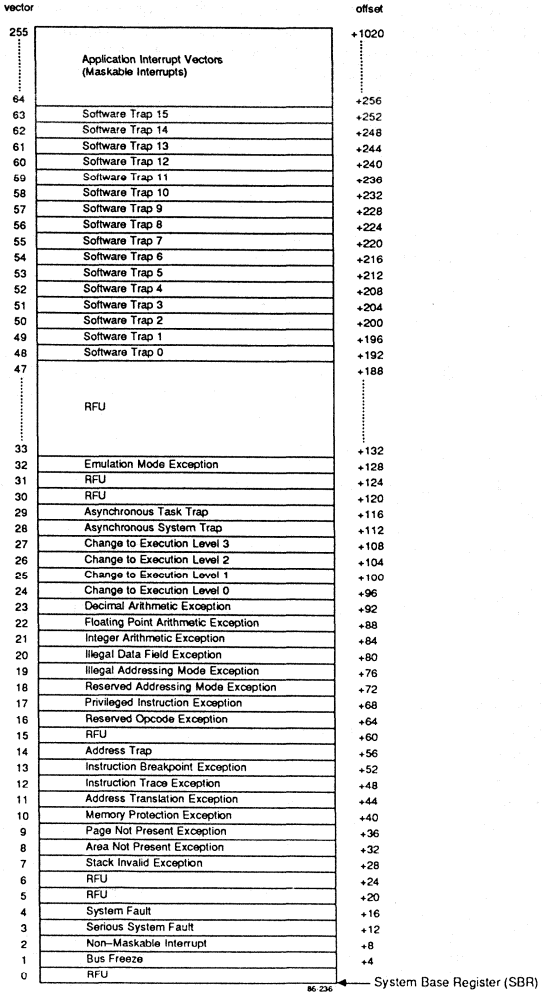
(vii) interrupt/exception information is stored on the stack
- interrupt.....IS (interrupt stack)
- exception.....L0SP (IS if the previous stack was the interrupt stack or LnSP if a change execution level or ATT exception occurs)





(viii) PC ← temp

System Base Table



Interrupts

(i) Maskable Interrupt

Maskable interrupt requests are generated by an external interrupt controller. System software can control the recognition of maskable interrupts by the means of the IE (interrupt enable) bit in the PSW register.

Following the occurrence of a maskable interrupt, further maskable interrupts will be disabled until the PSW.IE is again set.

(ii) Non-Maskable Interrupt (NMI)

Non-maskable interrupts are used to signal the occurrence of catastrophic events such as a loss of power. Non-maskable interrupts cannot be masked by software.

Additional non-maskable interrupts will not be acknowledged until the processing of the first NMI completes and the RETIS instruction is executed.

(iii) Bus Freeze Interrupt

The bus freeze interrupt is used in systems employing functional redundancy monitoring (FRM). If a bus freeze interrupt is detected, the μPD70616 enters the halt state and the address and data buses are placed in the high impedance mode. Actual processing of the bus freeze interrupt is delayed until after the BFREZ input is negated.

During the processing of a bus freeze interrupt, non-maskable interrupts are disabled.

Exceptions

Exceptions are divided into the following categories:

- O Serious System Exceptions
- O Stack Invalid Exceptions
- O Software Debug Exceptions
- O Arithmetic Exceptions
- O Asynchronous Traps
- O Emulation Mode Exceptions
- O System Exceptions
- O Memory Management Exceptions
- O Instruction Exceptions
- O Change Execution Level
- O Software Traps

μPD70616 Instruction Set

The μPD70616 has a large, powerful instruction set characterized by the following features:

- two address instructions
- large number of standard data types
- high level language support
- memory management instructions
- context switch instructions
- multi-processor instructions

A summary of the μPD70616 instruction set can be found in section 5 of this data sheet. For detailed information on the operation of instructions, refer to the μPD70616 Programmer's Reference Manual.

Exception Codes

Code	Serious System Exceptions
0301	string data write bus error
0303	fixed length data write bus error
0305	translation table write bus error
0309	string I/O write bus error
030B	fixed length I/O write bus error
0311	string data read bus error
0313	fixed length data read bus error
0314	system base table read bus error
0315	translation table read bus error
0317	instruction fetch bus error
0319	string I/O read bus error
031B	fixed length I/O read bus error
031E	interrupt vector read bus error
System Exceptions	
0400	illegal interrupt
Stack Invalid Exceptions	
0700	area not present — level 0 stack invalid
0701	page not present — level 0 stack invalid
0702	I/O access violation — level 0 stack invalid
0703	read access violation — level 0 stack invalid
0704	write access violation — level 0 stack invalid
0705	read/write access violation — level 0 stack invalid
0707	invalid section — level 0 stack invalid
0708	section length violation — level 0 stack invalid
0709	invalid area — level 0 stack invalid
070A	area length violation — level 0 stack invalid
070B	invalid page — level 0 stack invalid
0780	area not present — double exception
0781	page not present — double exception
0782	I/O access violation — double exception
0783	read access violation — double exception
0784	write access violation — double exception
0785	read/write access violation — double exception
0787	invalid section — double exception
0788	section length violation — double exception
0789	invalid area — double exception
078A	area length violation — double exception
078B	invalid page — double exception
Memory Management Exceptions	
0800	area not present
0901	page not present
0A02	I/O access violation
0A03	read access violation
0A04	write access violation
0A05	read/write access violation
0A06	execute access violation
0B07	invalid section
0B08	section length violation
0B09	invalid area
0B0A	area length violation
0B0B	invalid page

Code	Software Debug Exceptions
0C00	instruction trace
0D00	instruction breakpoint
0E01	address trap 0
0E02	address trap 1
0E03	address traps 0 and 1
Instruction Exceptions	
1000	reserved instruction
1100	privileged instruction
1200	reserved address mode
1300	illegal addressing mode
1301	illegal instruction format
1400	illegal data field
Arithmetic Exceptions	
1500	integer zero divide
1501	integer overflow
1601	floating point precision — these exception codes can combine in the case of simultaneous exceptions
1602	floating point underflow — these exception codes can combine in the case of simultaneous exceptions
1604	floating point overflow — these exception codes can combine in the case of simultaneous exceptions
1608	floating point zero divide
1610	invalid floating point operation
1680	reserved floating point operand
1780	decimal format exception
Change Execution Level Exceptions	
1800	change to execution level 0
1900	change to execution level 1
1A00	change to execution level 2
1B00	change to execution level 3
Asynchronous Traps	
1C00	asynchronous system trap
1D00	asynchronous task trap
Emulation Mode Exceptions	
2000	emulation mode privileged instruction
2001	emulation mode reserved instruction
2002	emulation mode zero divide
2003	emulation mode single step trap
2004	emulation mode overflow
2005	emulation mode index
2006	emulation mode coprocessor not present
Software Traps	
3000	software trap 0
3100	software trap 1
3200	software trap 2
⋮	⋮
3F00	software trap 15

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Two Address Machine

The μPD70616 is a two address machine. μPD70616 instructions are encoded to accept from zero to two operands, generally using any of the available addressing modes without restriction. Two operands allow the specification of a source and destination operand in the same instruction, minimizing the number of instructions that must be executed, especially when instructions frequently reference memory operands.

Standard Data Types

The μPD70616 includes support for the most common data types encountered in the vast majority of 32-bit applications. The data types include:

- signed and unsigned integers (8-, 16-, 32- and 64-bit sizes)
- IEEE standard binary floating point (32- and 64-bit sizes)
- decimal integers
- bits, bit fields and bit strings
- pointers
- byte (8-bit) and halfword (16-bit) character strings

High Level Language Support

As the number of programs being written in a high level language increases, the ability of an architecture to support the high speed execution of high level languages becomes even more critical. The μPD70616 provides specific support for:

- subroutine call/return
- procedure call/return
- stack frame management instructions

MMU Instructions

The inclusion of an on-chip memory management unit mandated instruction set support for the MMU. Instructions to manage the area/page tables and control the contents of the TLB. MMU instructions are privileged instructions and require the processor to be at execution level 0. In addition, MMU instructions can be executed in the physical address mode.

Context Switching Instructions

A processor must be able to quickly swap out the old context and bring in the new context in a real-time multi-tasking environment. The μPD70616 uses a variable sized TCB to optimize the time and space requirements of the TCB. The instruction set also contains a pair of privileged context switch instructions (LDTASK and STTASK) which simplify the chore of context switching.

Multiprocessor Support

High performance system designers often turn to multi-processing as a solution to a performance bottleneck. To assist in the design of multi-processor system software primitives for μPD70616 systems, test and set (TASI) and compare and interchange (CAXI) instructions are available.

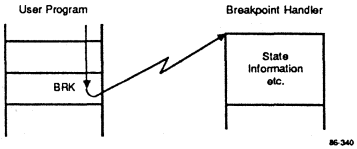
Software Debug Support

This section describes the software debug facilities of the μPD70616 microprocessor. The size and complexity of 32-bit systems demands that on-chip hardware contribute to the problem of debugging complex application and system software. The on-chip software debug support offered by the μPD70616 aids in quickly identifying the errant sections of a program without spending hours over listings and real-time traces.

The μPD70616 provides three independent hardware aids which address the various requirements of debuggers.

Instruction Breakpoints

The instruction breakpoint facility is used to implement program flow debugging. An instruction breakpoint is set by replacing the first byte of an instruction with the one byte BRK instruction. The program then executes at full speed until the breakpoint is reached, causing the breakpoint trap.



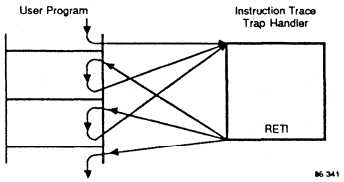
Following the occurrence of an breakpoint trap, the level 0 stack contains the following information:

- PC of the current instruction
- exception code (0D00H)
- PSW image
- parameter count

Note that only the first byte of a multi-byte instruction needs to be replaced with the BRK instruction. Subsequent bytes may be left unmodified without causing an exception since the breakpoint trap guarantees the remaining bytes of the instruction never reach the execution unit.

Instruction Trace

Instruction trace (also referred to as single stepping) is a tool used to force an exception following the execution of each instruction. Instruction trace allows a software engineer to observe the execution of a program at the instruction level to locate and correct software errors.



Instruction trace exceptions are controlled by the TE (trace enable) field in the PSW register.

PSW.TE = 0 instruction trace disabled
PSW.TE = 1 instruction trace enabled

Because this field is in the upper halfword of the PSW, a privileged instruction is required to enable and disable instruction trace.

When instruction trace exceptions are enabled, following the execution of each instruction an instruction trace exception occurs. Prior to entry into the instruction trace exception handler, the PC and PSW are pushed onto the level 0 stack and the PSW.TE field is cleared to allow the debugger to analyze program execution. To return back to the target program, the RETIS (Return from Interrupt – System) instruction is used.

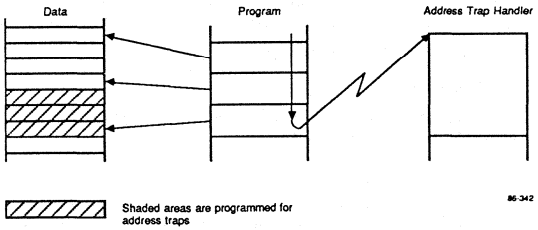
Following the occurrence of an instruction trace exception, the level 0 stack contains the following information:

- PC of the next instruction
- exception code (0C00H)
- PSW image
- parameter count

Refer to the μPD70616 Programmer's Reference Manual for further details.

Address Traps

Address traps are a powerful debugging facility that combine the occurrence of an address (or range of addresses) with one or more access types (read, write, execute) to generate an exception. Address traps differ from instruction trace and breakpoint traps since they operate on data accesses as well as instruction accesses and can span one or more tasks in a multitasking system.



Address traps are setup and controlled by five privileged registers and a field within the PSW register.

- Address Trap Enable (PSW.AE)
  PSW.AE = 0 address traps disabled
  PSW.AE = 1 address traps enabled

- Address Trap Registers (ADTR0/ADTR1)
  The two ADTR registers each contain a 32-bit base trap address. ADTR0 contains the base address for address trap 0 and ADTR1 contains the base address for address trap 1.

- Address Trap Mask Registers (ADTMR0/ADTMR1)
  The ADTMR registers each contain a 32-bit mask value that marks the corresponding bits of the ADTR registers as "don't care". ADTMR0 contains the mask value for ADTR0 and ADTMR1 contains the mask value for ADTR1.

- Trap Mode Register (TRMOD)
  The TRMOD register contains the access type specifiers (read, write and execute) for each set of ADTR/ADTMR registers.

Address Trap Notes

- If a memory indirect addressing mode is used and during the effective address calculation the access of the memory resident pointer is within an address trap region with read access enabled, an address trap will occur.
- Address trap logic is disabled during address translation (ATE, PTE accesses) and system base table accesses.

V20/V30 Emulation Mode

This section describes the operation of the V20/V30 emulation mode. The V20/V30 emulation mode is included in the μPD70616 in order to allow system designers to take advantage of the large installed base of 16-bit software while simultaneously providing an upgrade path to a high performance 32-bit architecture for new applications. V20/V30 emulation mode does not include the μPD8080 emulation mode of the V20/V30.

I/O Emulation Option

The I/O emulation option permits emulation mode programs to override the privileged status of IN and OUT instructions and permit selective execution of these I/O instructions without the generation of an exception. This option is controlled by the CTL bit in the PSW2 register as follows:

- CTL = 0 I/O emulation enabled (I/O instructions privileged)
- CTL = 1 I/O emulation disabled

Control of the trapping of I/O instructions is particularly useful in the design of virtual machine monitors for device drivers and other software with real-time I/O requirements.

Mode Switching

μPD70616 native and emulation modes are controlled by the EM (emulation mode) field in the PSW. When the EM field is cleared, the μPD70616 is operating in native mode. When the bit is set, the μPD70616 is operating in emulation mode.

(i) Native Mode → Emulation Mode
The EM flag is in a privileged field in the upper halfword of the PSW and only software running at execution level 0 can change processor modes. Because both the flag and the instruction streams must change simultaneously, V20/V30 emulation mode is entered by pushing the emulation mode PC on the stack along with a PSW image with the PSW.EM=1 and PSW.EL=11 and executing a RETIS instruction.

(ii) Emulation Mode → Native Mode

Return to native mode from emulation mode programs occurs as the result of an interrupt or exception. Emulation mode will be automatically restored upon completion of the interrupt/exception handler.

- Interrupts

  All interrupts on the μPD70616 microprocessor are processed in native mode. Upon the detection of an interrupt, the emulation mode program will be suspended and native mode will be restored.

- Exceptions

  Emulation mode exceptions occur as a result of program execution and require processing by a native mode handler to correct a fault or take some other predetermined action.

  - Emulation Mode Privileged Instructions

    The emulation mode system instructions listed below have been made privileged to allow operation in a protected environment:

    IN*, OUT*, INM, OUTM, HALT, BRK, RETI, POP PSW*, EI, DI (*conditionally trapped)

  - Emulation Mode Reserved Opcode
  - Emulation Mode Zero Divide
  - Emulation Mode Single Step Trap
  - Emulation Mode Overflow
  - Emulation Mode Index
  - Emulation Mode Floating Point Operation

In either case, the return to emulation mode after processing of the exception or interrupt is by the RETIS instruction.

Termination of an emulation program is accomplished by the reserved 63H opcode. Attempted execution of this opcode will cause the Reserved Emulation Mode Opcode exception to be generated along with a specific exception code identifying the exception as an emulation mode terminate operation.

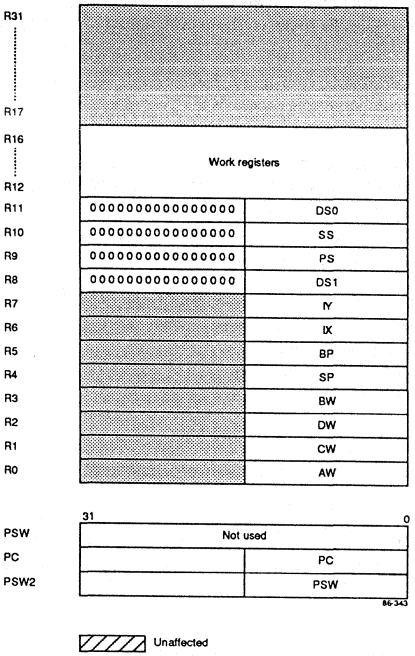
Emulation Mode Notes

(i) Emulation mode operates in both the virtual and physical address modes.

(ii) Emulation mode programs must run at execution level 3, attempts to enter emualtion mode at a level other than 3 will cause and exception.

(iii) In virtual mode, emulation mode uses virtual addresses in the range 00000H to FFFFFH. The address translation tables are used to provide multiple virtual emulation mode address spaces. Physical address mode is limited to a single emulation address space.

Emulation Mode Register Assignments



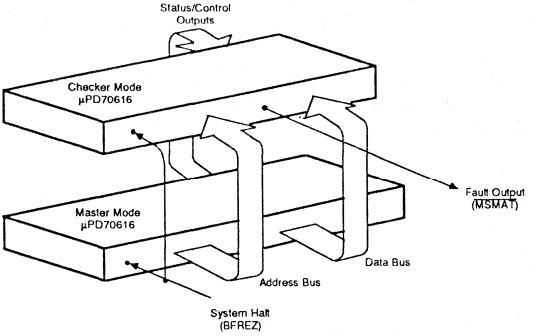
FRM (Functional Redundancy Monitor)

The μPD70616 is ideally suited for the design of fault tolerant computing systems. Fault tolerant computer design is driven by requirement to detect and recover from faults without affecting the applications through the use of redundancy. The μPD70616 uses FRM (function redundancy monitor) logic to simplify the hardware design of fault tolerant systems by including on-chip the comparison logic needed to detect and recover from faults.

FRM requires that one processor operate as the master and one or more μPD70616 microprocessors be configured as checkers. This is accomplished by the BMODE/FRM pin which when programmed to operate in the FRM mode, causes checker processors to three-state their output buffers and compare the state of the master with their internal computed state. Should a difference be detected, the MSMAT (mismatch) signal is output to allow external logic to stop the processors, isolate the fault and reconfigure the system.

Following the detection of a fault, the BFREZ (bus freeze) input of each processor must asserted to halt all further processing. The isolation and reconfiguration is then under the control of external hardware which can either quickly reconfigure the system or perform individual testing on each processor to determine the exact cause of the fault. In the case of a transient fault, all processors can be re-initialized to the same state and processing can continue.

FRM System Example



Section 4
Bus Operation

This section describes the operation of each of the μPD70616 bus cycles. Each bus cycle consists of a combination of the seven bus states, each state being defined as the interval from the rising edge of one clock to the rising edge of the next clock. The seven bus states are:

- TI : bus idle state
- T1 : bus cycle start state
- T2 : bus cycle state 2
- T3 : bus cycle state 3
- T4 : bus cycle ending state
- TW : wait state
- TH : bus hold state

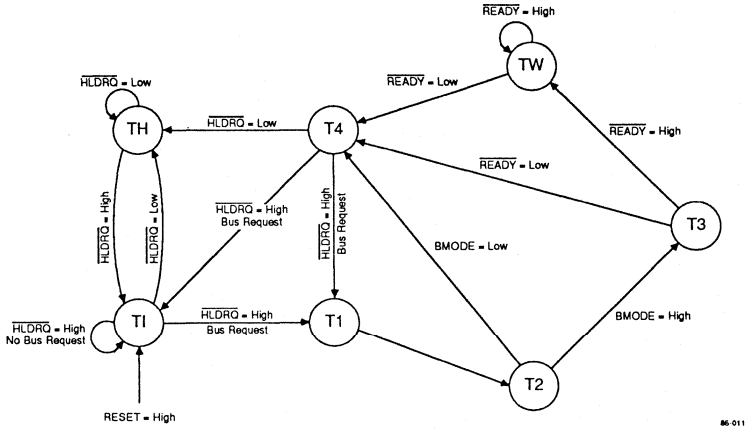
Bus Cycle Modes

The standard μPD70616 bus cycle is a four clock bus cycle consisting of bus states T1, T2, T3 and T4. In addition to these states, external hardware can force the insertion of TW states between the T3 and T4 states of memory and I/O bus cycles by negating the READY* input.

In addition to the standard four clock bus cycle, a high speed three clock bus cycle is available. The three clock mode eliminates the T3 bus state by passing from bus state T2 directly to T4 without the opportunity of inserting wait states. This mode is provided for accessing high speed memory and I/O peripheral devices. Bus mode selection is made on a cycle by cycle basis by the BMODE input pin. BMODE is sampled at the falling clock edge of the T2 state to determine whether a normal or short bus cycle will be run.

Below is a diagram showing the state transitions of the various bus cycles.

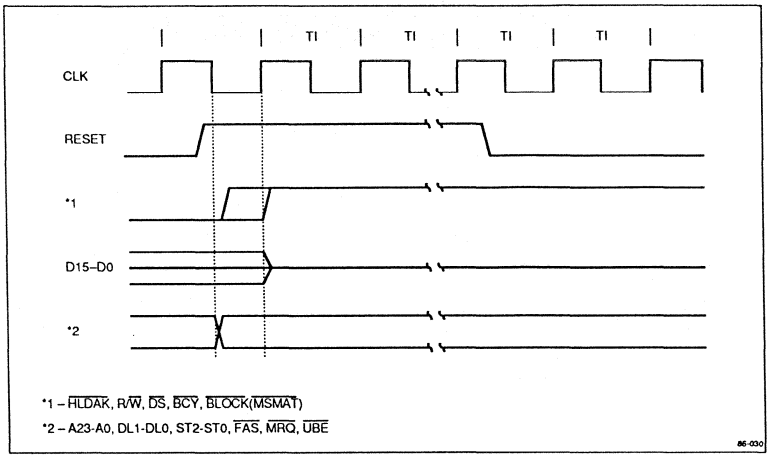
μPD70616 Bus States



RESET Timing

When the active high RESET input is asserted, the μPD70616 stops all processing and enters the reset state.

Reset Timing



RESET must be held asserted for a minimum of 20 clock cycles before returning to a low level. Following the release from the reset state, the μPD70616 will exit the idle state and begin execution by performing a memory read (instruction fetch) bus cycle from address 0FFFFF0H.

Register	Reset Value
PSW	1 0 0 0 0 0 0 0 H
PC	F F F F F F F 0 H
SBR	0 0 0 0 0 0 0 0 H
SYCW	0 0 0 0 0 0 7 0 H
TKCW	0 0 0 0 E 0 0 0 H
PSW2	0 0 0 0 F 0 0 2 H
ATBR	Invalid
TLB	Cleared
Others	Undefined

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While in the reset state, the bus interface unit is idle and output pins are in following states:

State	Output
High	R/$\overline{W}$, $\overline{DS}$, $\overline{BCY}$, $\overline{HLDAK}$, $\overline{BLOCK}$ ($\overline{MSMAT}$)
High–Z	D15–D0
Undefined	A23–A0, DL1–DL0, $\overline{FAS}$, $\overline{MRQ}$, $\overline{UBE}$, ST2–ST0

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Memory Read Bus Cycles

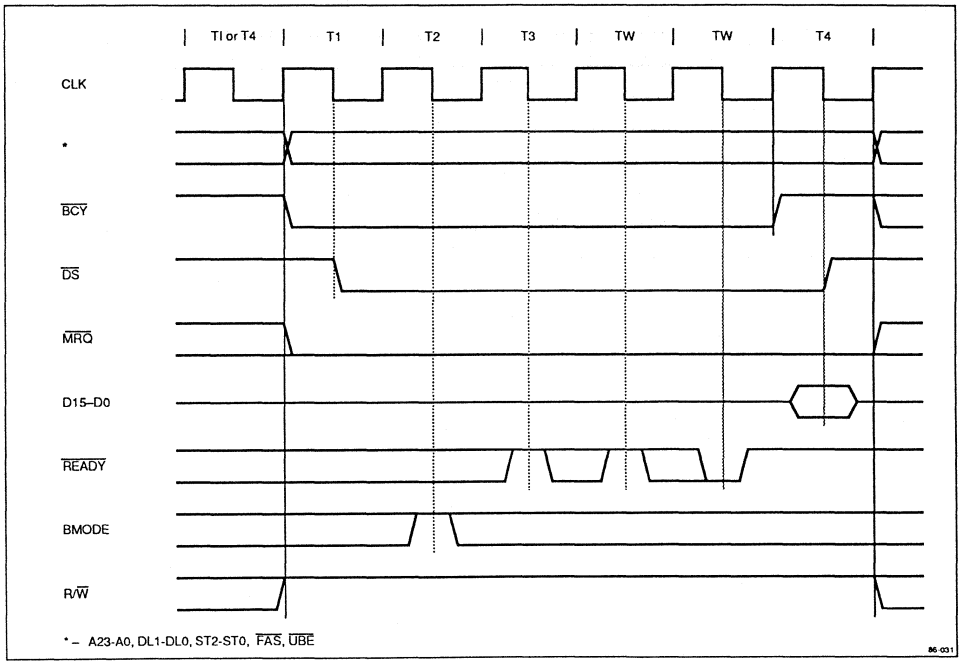
Memory read bus cycles consist of bus states T1, T2, T3 and T4. Memory read bus cycles are distinguished by MRQ* (memory request) being asserted and R/W* being at a high level.

At the rising edge of the T1 bus state, the A23–A0, DL1–DL0, ST2–ST0, FAS*, MRQ*, R/W* and UBE* outputs are asserted and remain valid until the end of the bus cycle. At the same time, the BCY* pin is asserted indicating the start of a bus cycle. At the falling edge of the T1 clock, the DS* pin is asserted, indicating that external data bus transceivers can be enabled. At the falling edge of the T2 state, the BMODE input is sampled to determine if the bus cycle is normal (logic high) or a short (logic low) bus cycle. If the normal mode is selected, the T2 state progresses to the T3 state. Otherwise the T3 state is skipped, the READY input ignored and T4 is the next bus state.

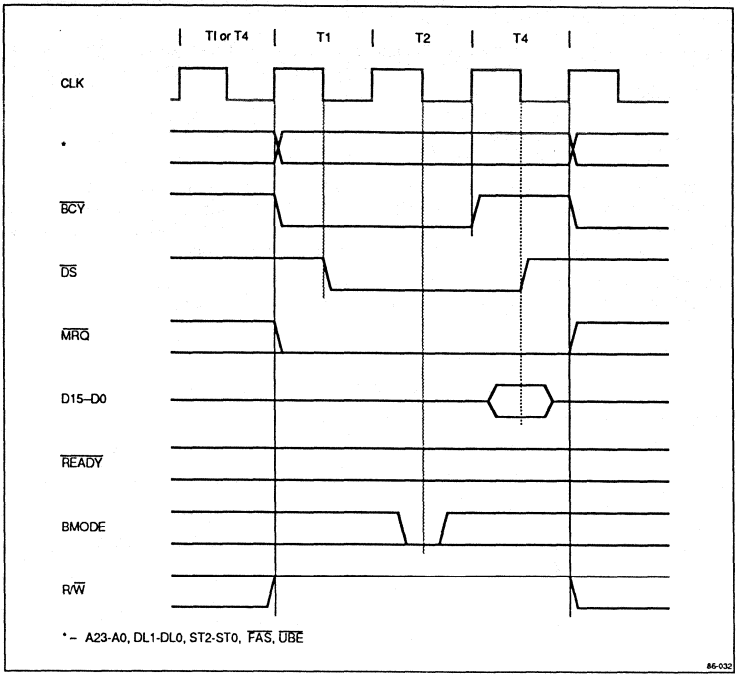
The falling edge of the T3 state is used to sample the READY* input and if found low, the transition to the T4 state occurs. External hardware can extend the read cycle by negating READY* and forcing the insertion of TW states after the completion of the T3 state. The READY* input is continued to be sampled at the falling edge of TW until it returns to a low level. At this time the TW states will end and T4 will occur as the next state.

In both normal and short bus cycle modes, the BCY* output is negated at the rising edge of the T4 bus state. The read data on the D15–D0 inputs is latched internally at the falling edge of T4 and simultaneously the DS* output is negated, completing the bus cycle.

Memory Read Timing (Normal Mode)



Memory Read Timing (Short Mode)

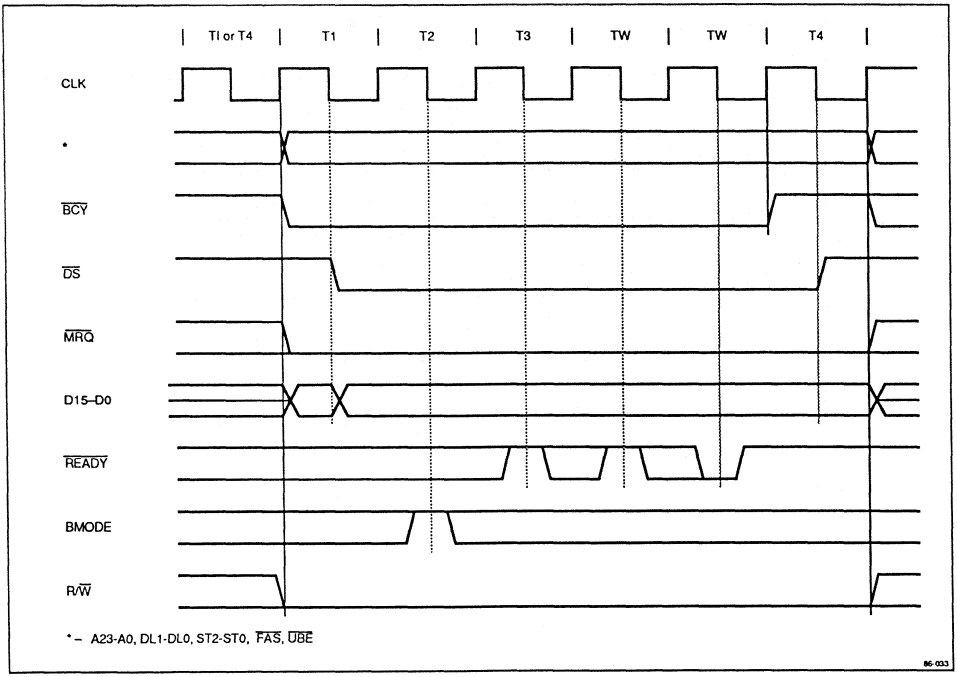


Memory Write Bus Cycles

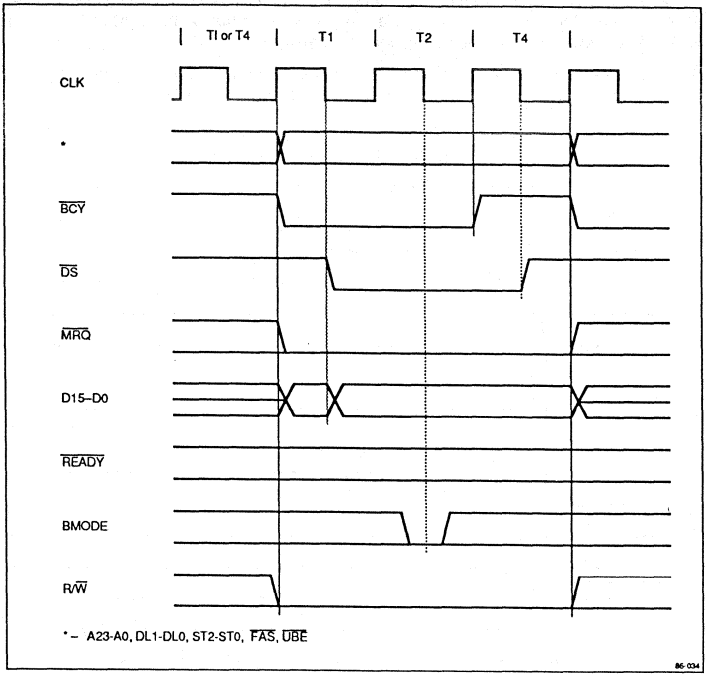
Memory write bus cycles consist of bus states T1, T2, T3 and T4. Memory write bus cycles are distinguished by MRQ* (memory request) being asserted and R/W* being at a low level. All other outputs (A23–A0, DL1–DL0, ST2–ST0, FAS*, MRQ*, UBE*) and the bus mode selection function are identical.

The D15–D0 output buffers are enabled at the start of the T1 state but valid data is not presented until one half clock period later at the falling edge of T1. Write data remains valid until the end of the T4 bus state.

Memory Write Timing (Normal Mode)



Memory Write Timing (Short Mode)



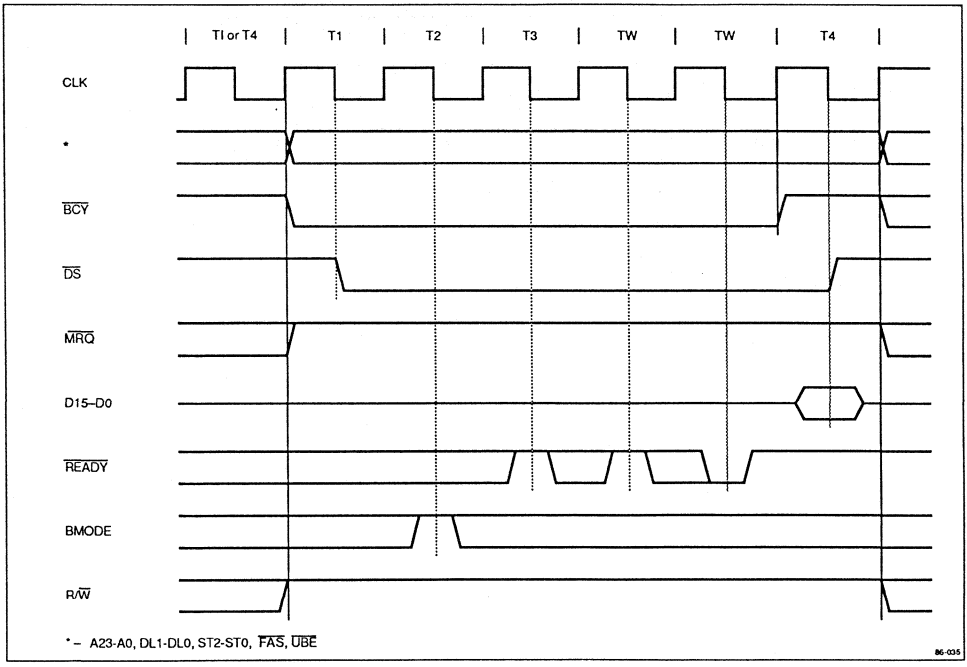
I/O Read Bus Cycles

I/O read bus cycles consist of bus states T1, T2, T3 and T4. I/O read bus cycles are distinguished by MRQ* (memory request) being negated and R/W* being at a high level.

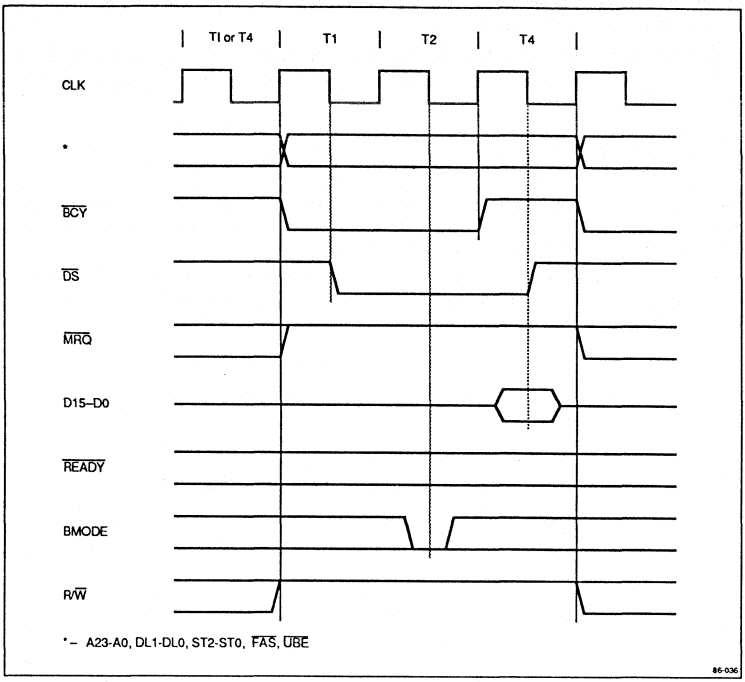
At the rising edge of the T1 bus state, the A23–A0, DL1–DL0, ST2–ST0, FAS*, MRQ*, R/W* and UBE* outputs are asserted and remain active until the end of the bus cycle. At the same time, the BCY* pin is asserted indicating the start of a bus cycle. At the falling edge of the T1 clock, the DS* pin is asserted, indicating that external data bus transceivers can be enabled. At the falling edge of the T2 state, the BMODE input is sampled to determine if the bus cycle will be normal (logic high) or a short (logic low) bus cycle. If the normal bus mode is selected, the T2 state progresses to the T3 state. Otherwise the T3 state is skipped and the READY input ignored. The falling edge of the T3 state is used to sample the READY* input and if found low, the transition to the T4 state occurs. External hardware can extend an I/O read bus cycle by negating READY* and forcing the insertion of TW states after the completion of the T3 state. The READY* input is continued to be sampled at the falling edge of TW until it returns to a low level. At this time the TW states will end and T4 will occur as the next state.

In both normal and short bus cycle modes, the BCY* output is negated at the rising edge of the T4 bus state. The read data on the D15–D0 inputs is latched internally at the falling edge of T4 and simultaneously the DS* output is negated, completing the bus cycle.

I/O Read Timing (Normal Mode)



I/O Read Timing (Short Mode)

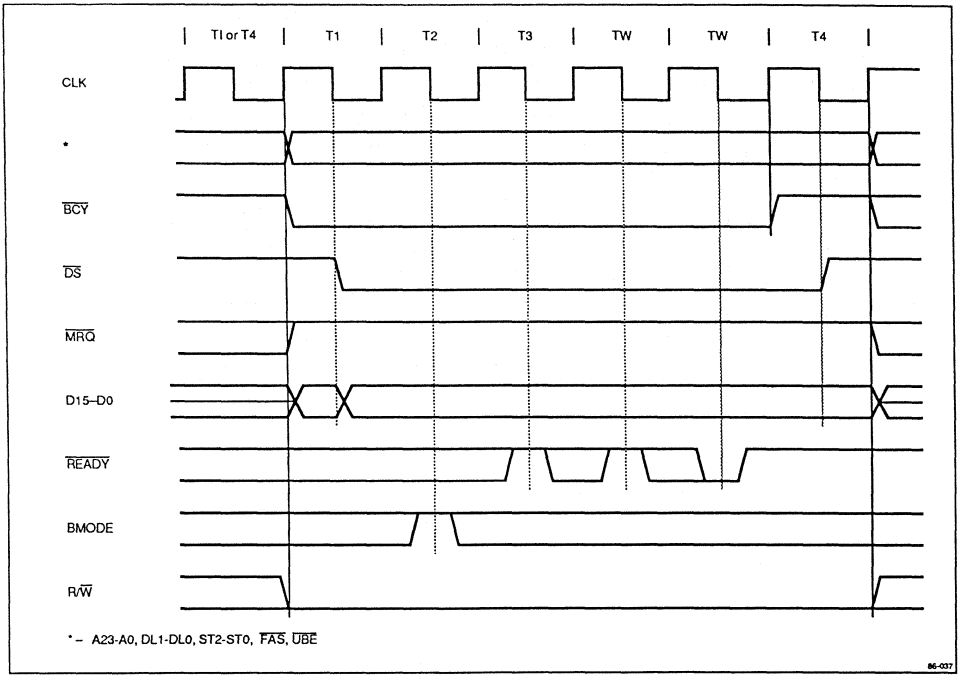


I/O Write Bus Cycles

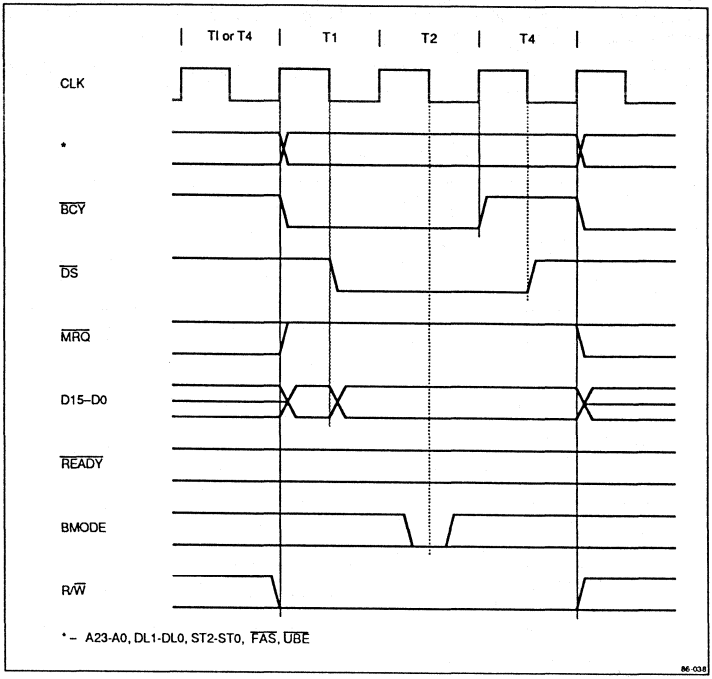
I/O write bus cycles consist of bus states T1, T2, T3 and T4. I/O write bus cycles are distinguished by MRQ* (memory request) being negated and R/W* being at a low level. All other outputs (A23–A0, DL1–DL0, ST2–ST0, FAS*, MRQ*, UBE*) and the bus mode selection function are identical.

The D15–D0 output buffers are enabled at the start of the T1 state but valid write data is not presented until one half clock period later at the falling edge of T1. Write data remains valid until the end of the T4 bus state.

I/O Write Timing (Normal Mode)



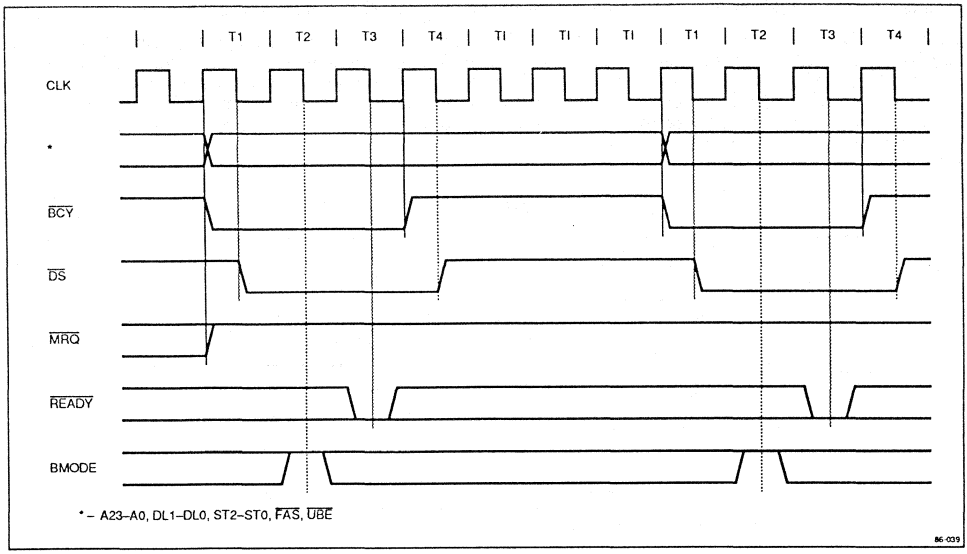
I/O Write Timing (Short Mode)



Back-to-Back I/O Bus Cycles

I/O bus cycle timing is automatically modified during the execution of back-to-back I/O bus cycles. In order to meet the read and write recovery times of peripheral devices without the need for external logic, three TI states are inserted between any consecutive pair of I/O bus cycles.

Back-to-Back I/O Bus Cycles



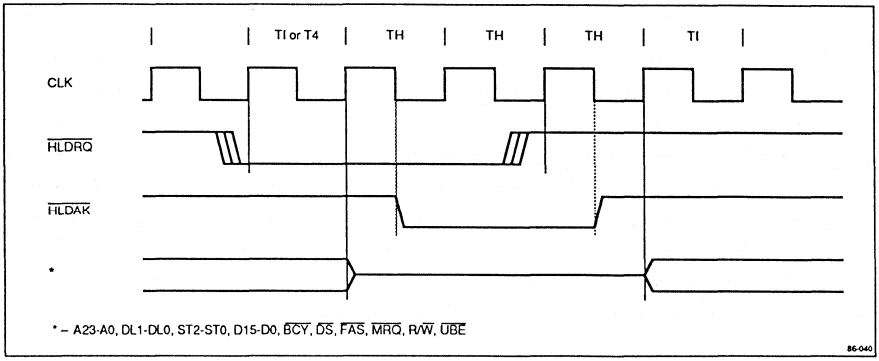
Bus Hold Timing

External bus masters such as DMA controllers can request the μPD70616 to relinquish the bus to allow external control of the address, data and control buses.

The rising edge of the clock in the T4 or TI state is used to sample the HLDRQ* input for external bus requests. If the HLDRQ* input is asserted (low level), the next bus state will be the TH or bus hold state. The rising edge of the clock in the TH state will see A23–A0, D15–D0, DL1–DL0, ST2–ST0, BCY*, DS*, FAS*, MRQ*, R/W* and UBE* outputs enter the high impedance state. One half clock cycle later at the falling edge of the initial TH state, the HLDAK* output will asserted, indicating the bus as been released and the external bus master can begin driving the buses.

While in the TH state, the HLDRQ* input is sampled at the rising edge of each clock and the TH states will continue as long as the HLDRQ* input remains at a low level. When the μPD70616 detects that the HLDRQ* input has returned to a high level, the next TH state will be the last. The falling edge of the clock in the final TH state negates the HLDAK* output and the next state becomes the TI state. The rising edge of the TI state is used to enable the μPD70616 output buffers. The state following the TI state will be T1 if any internal μPD70616 bus requester has an active request, otherwise, the TI state is continued.

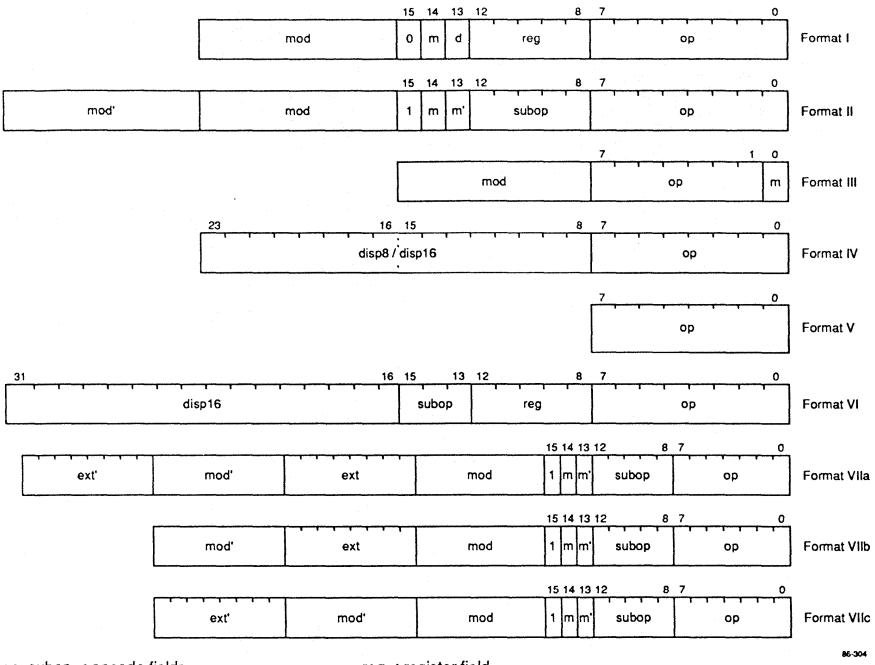
Bus Hold Cycle



Section 5
Instruction Set

The μPD70616 instruction set operation codes are described by seven instruction formats. This section presents the instruction formats, addressing mode encodings, mnemonics and the effect of instructions on the flags and condition codes.

Instruction Formats



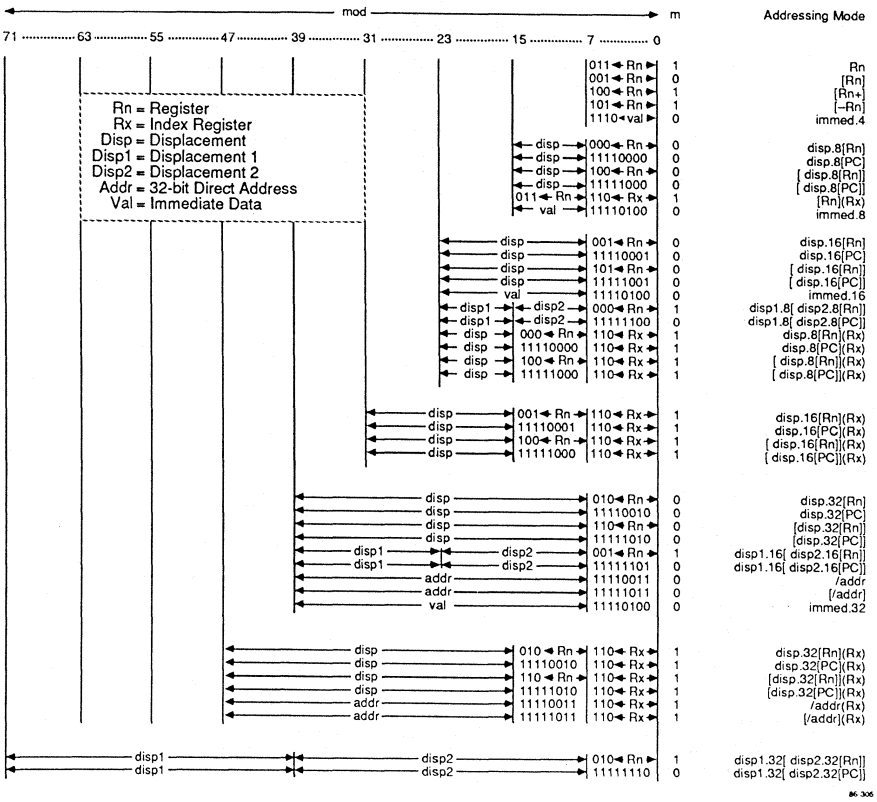
op, subop : opcode fields
disp : signed displacement
d : direction field
' : second operand identifer
reg : register field
mod, m : address mode field
ext : operand extension field

The extension field is used to specify the length of a variable length data type and is encoded as follows:

bit 7 (ext) = 0 → bits 6:0 (ext) are the operand length
bit 7 (ext) = 1→ bits 6:0 (ext) contain a pointer (register ID) to the general purpose register containing the operand length

Instructions formats have a 1 to 9 byte mod (modifier) field to specify along with the m field the addressing mode for each operand reference within an instruction. The mod field also contains additional information such as the optional base register, index register and signed displacement fields. The table below lists the byte addressing modes. Bit addressing modes use the same encodings as the equivalent byte addressing modes, only the assembler format differs.

mod Field – Addressing Mode Encoding



μPD70616 Instruction Set

Condition Encodings

c3	c2	c1	c0	Name	Condition
0	0	0	0	Overflow	OV = 1
0	0	0	1	No overflow	OV = 0
0	0	1	0	Carry / Lower	CY = 1
0	0	1	1	No carry / Not lower	CY = 0
0	1	0	0	Zero / Equal	Z = 1
0	1	0	1	Not zero / Not equal	Z = 0
0	1	1	0	Not higher	(CY ∨ Z) = 1
0	1	1	1	Higher	(CY ∨ Z) = 0
1	0	0	0	Sign / Negative	S = 1
1	0	0	1	Not sign / Positive	S = 0
1	0	1	0	True	Always
1	0	1	1	False	Never
1	1	0	0	Less than	(S ⊕ OV) = 1
1	1	0	1	Greater or equal	(S ⊕ OV) = 0
1	1	1	0	Less or equal	((S ⊕ OV) ∨ Z) = 1
1	1	1	1	Greater than	((S ⊕ OV) ∨ Z) = 0

Register Selection

reg	Register
0 0 0 0 0	r0
0 0 0 0 1	r1
0 0 0 1 0	r2
• • •	
1 1 1 0 11	r29
1 1 1 1 00	r30
1 1 1 1 11	r31

Integer Data Type Selection

siz	Data Type
00	byte
01	halfword
10	word
11	reserved

Floating Point Data Type Selection

s	Data Type
0	short real
1	long real

String Direction

d	Direction
0	increment
1	decrement

Character Data Type Selection

c	Character Data Type
0	byte
1	halfword

Bit Field Extension

ext	Data Type
00	signed
01	unsigned
10	right justified
11	reserved

Branch Displacements

b	Displacement
0	byte
1	halfword

Mnemonic	Opcode 7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	Instruction Format	Clocks	Flags CY	OV	S	Z	Exceptions
Data Transfer Instructions									
MOV.B	0 0 0 0 1 0 0 1		I, II						1, 3
MOV.H	0 0 0 1 1 0 1 1		I, II						1, 3
MOV.W	0 0 1 0 1 1 0 1		I, II						1, 3
MOV.D	0 0 1 1 1 1 1 1		I, II						1, 3
MOVS.BH	0 0 0 0 1 0 1 0		I, II						1
MOVS.BW	0 0 0 0 1 1 0 0		I, II						1
MOVS.HW	0 0 0 1 1 1 0 0		I, II						1
MOVZ.BH	0 0 0 0 1 0 1 1		I, II						1
MOVZ.BW	0 0 0 0 1 1 0 1		I, II						1
MOVZ.HW	0 0 0 1 1 1 0 1		I, II						1
MOVT.HB	0 0 0 1 1 0 0 1		I, II		–	*	–	–	1
MOVT.WB	0 0 1 0 1 0 0 1		I, II		–	*	–	–	1
MOVT.WH	0 0 1 0 1 0 1 1		I, II		–	*	–	–	1
XCH	0 1 0 0 0 siz 1		I, II						1, 3
MOVEA	0 1 0 0 0 siz 0		I, II						1
RVBYT	0 0 1 0 1 1 0 0		I, II						1
RVBIT	0 0 0 0 1 0 0 0		I, II						1
Integer Arithmetic Instructions									
ADD	1 0 0 0 0 siz 0		I, II		*	*	*	*	1
ADDC	1 0 0 1 0 siz 0		I, II		*	*	*	*	1
SUB	1 0 1 0 1 siz 0		I, II		*	*	*	*	1
SUBC	1 0 0 1 1 siz 0		I, II		*	*	*	*	1
MUL	1 0 0 0 0 siz 1		I, II		–	*	*	*	1
MULU	1 0 0 1 0 siz 1		I, II		–	*	*	*	1
MULX	1 0 0 0 0 1 1 0		I, II		–	*	*	*	1
MULUX	1 0 0 1 0 1 1 0		I, II		–	*	*	*	1
DIV	1 0 1 0 0 siz 1		I, II		–	*	*	*	1, 4
DIVU	1 0 1 1 0 siz 1		I, II		–	0	*	*	1, 4
DIVX	1 0 1 0 0 1 1 0		I, II		–	*	*	*	1, 4
DIVUX	1 0 1 1 0 1 1 0		I, II		–	*	*	*	1, 4
REM	0 1 0 1 0 siz 0		I, II		–	0	*	*	1, 4
REMU	0 1 0 1 0 siz 1		I, II		–	0	*	*	1, 4
INC	1 1 0 1 1 siz –		III		*	*	*	*	1
DEC	1 1 0 1 0 siz –		III		*	*	*	*	1
NEG	0 0 1 1 1 siz 1		I, II		*	*	*	*	1
CMP	1 0 1 1 1 siz 0		I, II		*	*	*	*	
TEST	1 1 1 1 0 siz –		III		0	0	*	*	
Logical Instructions									
AND	1 0 1 0 0 siz 0		I, II		–	0	*	*	1
OR	1 0 0 0 1 siz 0		I, II		–	0	*	*	1
XOR	1 0 1 1 0 siz 0		I, II		–	0	*	*	1
NOT	0 0 1 1 1 siz 0		I, II		–	0	*	*	1

Mnemonic	Opcode 7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	Instruction Format	Clocks	Flags CY	OV	S	Z	Exceptions
Shift/Rotate Instructions									
SHA	1 0 1 1 0 siz 1		I, II		*	*	*	*	1
SHL	1 0 1 0 0 siz 1		I, II		*	0	*	*	1
ROT	1 0 0 0 1 siz 1		I, II		*	0	*	*	1
ROTC	1 0 0 1 1 siz 1		I, II		*	0	*	*	1
Floating Point Instructions									
MOVF	0 1 0 1 1 1 s 0	0 0 0 0 1 0 0 0	II		*	0	*	*	1, 3, 7, 9
ADDF	0 1 0 1 1 1 s 0	0 0 0 1 1 0 0 0	II		*	0	*	*	1, 3, 6, 7, 8, 9
SUBF	0 1 0 1 1 1 s 0	0 0 0 1 1 0 0 1	II		*	0	*	*	1, 3, 6, 7, 8, 9
MULF	0 1 0 1 1 1 s 0	0 0 0 1 1 0 1 0	II		*	0	*	*	1, 3, 6, 7, 8, 9
DIVF	0 1 0 1 1 1 s 0	0 0 0 1 1 0 1 1	II		*	0	*	*	1, 3, 6, 7, 8, 9, 10, 11
CMPF	0 1 0 1 1 1 s 0	0 0 0 0 0 0 0 0	II		*	*	*	*	1, 3, 6, 7, 8, 9
NEGF	0 1 0 1 1 1 s 0	0 0 0 0 1 0 0 1	II		*	0	*	*	1, 3, 7, 9
ABSF	0 1 0 1 1 1 s 0	0 0 0 0 1 0 1 0	II		0	0	0	*	1, 3, 7, 9
SCLF	0 1 0 1 1 1 s 0	0 0 0 1 0 0 0 0	II		*	0	*	*	1, 3, 6, 7, 8, 9
CVTF	0 1 0 1 1 1 1 1	0 0 0 0 1 0 0 0	II		*	0	*	*	1, 3, 6, 7, 8, 9
CVT.WS	0 1 0 1 1 1 1 1	0 0 0 0 0 0 0 0	II		*	0	*	*	1, 3, 6, 7, 8, 9
CVT.WL	0 1 0 1 1 1 1 1	0 0 0 1 0 0 0 1	II		*	0	*	*	1, 3, 6, 7, 8, 9
CVT.SW	0 1 0 1 1 1 1 1	0 0 0 0 0 0 0 1	II		–	*	*	*	1, 3, 6, 7, 8, 9
CVT.LW	0 1 0 1 1 1 1 1	0 0 0 0 1 0 0 1	II		–	*	*	*	1, 3, 6, 7, 8, 9
TRAPFL	1 1 0 0 1 0 1 1		V						1, 3, 6, 7, 9
Decimal Arithmetic Instructions									
ADDDC	0 1 0 1 1 0 0 1	0 0 0 0 0 0 0 0	VIIc		*	–	–	*	1, 5
SUBDC	0 1 0 1 1 0 0 1	0 0 0 0 0 0 0 1	VIIc		*	–	–	*	1, 5
SUBRDC	0 1 0 1 1 0 0 1	0 0 0 0 0 0 1 0	VIIc		*	–	–	*	1, 5
CVTD.PZ	0 1 0 1 1 0 0 1	0 0 0 1 0 0 0 0	VIIc		–	–	–	*	1, 5
CVTD.ZP	0 1 0 1 1 0 0 1	0 0 0 1 1 0 0 0	VIIc		–	–	–	*	1, 5
Bit Manipulation Instructions									
TEST1	1 0 0 0 0 1 1 1		I, II		*	–	–	*	1, 2
SET1	1 0 0 1 0 1 1 1		I, II		*	–	–	*	1, 2
CLR1	1 0 1 0 0 1 1 1		I, II		*	–	–	*	1, 2
NOT1	1 0 1 1 0 1 1 1		I, II		*	–	–	*	1, 2
Bit Field Instructions									
EXTBF	0 1 0 1 1 1 0 1	0 0 0 0 1 0 ext	VIIb						1, 2
INSBF	0 1 0 1 1 1 0 1	0 0 0 1 1 0 ext	VIIc						1, 2
CMPBF	0 1 0 1 1 1 0 1	0 0 0 0 0 0 ext	VIIb		*	*	*	*	1, 2
Bit String Instructions									
MOVBS	0 1 0 1 1 0 1 1	0 0 0 0 1 0 0 d	VIIb						1
NOTBS	0 1 0 1 1 0 1 1	0 0 0 0 1 0 1 d	VIIb						1
ANDBS	0 1 0 1 1 0 1 1	0 0 0 1 0 0 0 d	VIIb						1
ANDNBS	0 1 0 1 1 0 1 1	0 0 0 1 0 0 1 d	VIIb						1
ORBS	0 1 0 1 1 0 1 1	0 0 0 1 0 1 0 d	VIIb						1

Mnemonic	Opcode 7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	Instruction Format	Clocks	Flags CY OV S Z	Exceptions
Bit String Instructions (cont)						
ORNBS	0 1 0 1 1 0 1 1	0 0 0 1 0 0 1 d	VIIb			1
XORBS	0 1 0 1 1 0 1 1	0 0 0 1 1 0 0 d	VIIb			1
XORNBS	0 1 0 1 1 0 1 1	0 0 0 1 0 0 1 d	VIIb			1
SCH0BS	0 1 0 1 1 0 1 1	0 0 0 0 0 0 0 d	VIIb			1
SCH1BS	0 1 0 1 1 0 1 1	0 0 0 0 1 0 1 d	VIIb			1
Character Manipulation Instructions						
MOVC	0 1 0 1 1 0 c 0	0 0 0 0 1 0 0 d	VIIa			1, 3
MOVCF	0 1 0 1 1 0 c 0	0 0 0 0 1 0 1 d	VIIa			1, 3
MOVCS	0 1 0 1 1 0 0 0	0 0 0 0 1 1 0 0	VIIa			1, 3
CMPC	0 1 0 1 1 0 c 0	0 0 0 0 0 0 0 0	VIIa		– – * *	1, 3
CMPCF	0 1 0 1 1 0 c 0	0 0 0 0 0 0 0 1	VIIa		– – * *	1, 3
CMPCS	0 1 0 1 1 0 c 0	0 0 0 0 0 0 1 0	VIIa		– – * *	1, 3
SCHC	0 1 0 1 1 0 c 0	0 0 0 1 1 0 0 d	VIIb		– – – *	1, 3
SKPC	0 1 0 1 1 0 c 0	0 0 0 1 1 0 1 d	VIIb		– – – *	1, 3
Stack Manipulation Instructions						
PUSH	1 1 1 0 1 1 1 –		II			1, 3
POP	1 1 1 0 0 1 1 –		II			1, 3
PUSHM	1 1 1 0 1 1 0 –		II			1, 3
POPM	1 1 1 0 0 1 0 –		II		R R R R	1, 3 (Note 1)
PREPARE	1 1 0 1 1 1 1 –		II			1, 3
DISPOSE	1 1 0 0 1 1 0 0		V			
Control Transfer Instructions						
Bcc	0 1 1 b c_3 c_2 c_1 c_0		IV			
DBcc	1 1 0 0 0 1 1 c_0	reg $c_3c_2c_1$	VI			
TB	1 1 0 0 0 1 1 1	reg 1 0 1	VI			
JMP	1 1 0 1 0 1 1 –		III			1
BSR	0 1 0 0 1 0 0 0		IV			
JSR	1 1 1 0 1 0 0 –		III			1
RSR	1 1 0 0 1 0 1 0		V			
CALL	0 1 0 0 1 0 0 1		II			1
RET	1 1 1 0 0 0 1 –		III			
BRK	1 1 0 0 1 0 0 0		V			
BRKV	1 1 0 0 1 0 0 1		V			
TRAP	1 1 1 0 1 0 0 –		III			
RETIU	1 1 1 0 1 0 1 –		III			
Miscellaneous Instructions						
NOP	1 1 0 0 1 1 0 1		V			
GETPSW	1 1 1 1 0 1 1 –		III			1
UPDPSW.H	0 1 0 0 1 0 1 0		I, II		* * * *	
CHLVL	0 1 0 0 1 0 1 1		I, II			1
CHKAR	0 1 0 0 1 1 0 1		I, II		* – * *	1

Mnemonic	Opcode 7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	Instruction Format	Clocks	Flags CY	OV	S	Z	Exceptions
Miscellaneous Instructions (cont)									
CHKAW	0 1 0 0 1 1 1 0		I, II		*	–	*	*	1
CHKAE	0 1 0 0 1 1 1 1		I, II		*	–	*	*	1
TASI	1 1 1 0 0 0 0 –		III		*	*	*	*	1
CAXI	0 1 0 0 1 1 0 0		I		*	*	*	*	1
SETF	0 1 0 0 0 1 1 1		I, II						1
Privileged Instructions									
LDPR	0 0 0 1 0 0 1 0		I, II						2, 12
STPR	0 0 0 0 0 0 1 0		I, II						1, 2, 12
CLRTLB	1 1 1 1 1 1 1 –		III						12
CLRTLBA	0 0 0 1 0 0 0 0		V						12
GETATE	0 0 0 0 0 1 0 1		I, II		–	–	–	*	1, 12
UPDATE	0 0 0 1 0 1 0 1		I, II		–	–	–	*	1, 12
GETPTE	0 0 0 0 0 1 0 0		I, II		*	–	–	*	1, 12
UPDPTE	0 0 0 1 0 1 0 0		I, II		*	–	–	*	12
GETRA	0 0 0 0 0 0 1 1		I, II		*	–	–	*	1, 12
IN	0 0 1 0 0 siz 0		I, II						1, 12
OUT	0 0 1 0 0 siz 1		I, II						1, 12
LDTASK	0 0 0 0 0 0 0 1		I, II						12
STTASK	1 1 1 1 1 1 0 –		III						12
RETIS	1 1 1 1 1 0 1 –		III		*	*	*	*	2, 12
UPDPSW.W	0 0 0 1 0 0 1 1		I, II		*	*	*	*	12
HALT	0 0 0 0 0 0 0 0		V						12

Exceptions

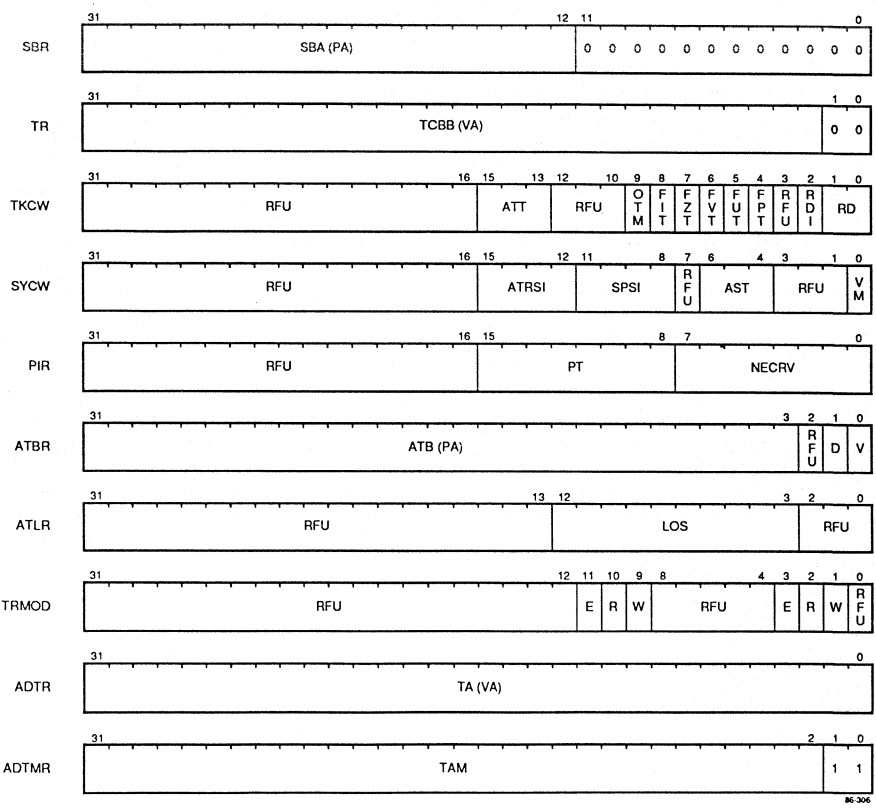
1. Illegal Addressing Mode
2. Illegal Data Type
3. Reserved Addressing Mode
4. Integer Zero Divide
5. Illegal Decimal Format
6. Floating Point Overflow
7. Floating Point Undeflow
8. Floating Point Precision
9. Reserved Floating Point Operand
10. Invalid Floating Point Operation
11. Floating Point Zero Divide
12. Privileged Instruction

Notes

1. Flags updated if PSW is specified in the register list

Appendix

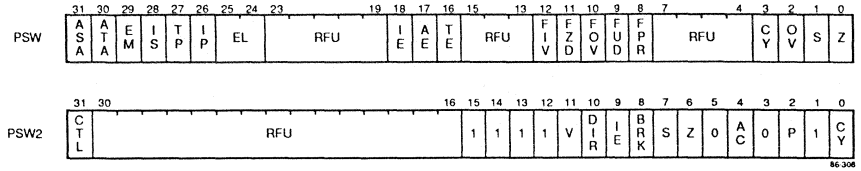
Privileged Register Set



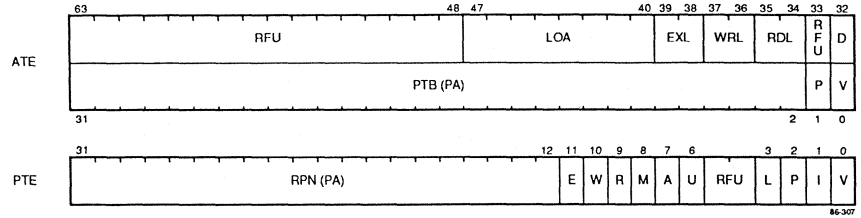
Note 1 (V) → virtual address
(R) → real (physical) address

Note 2 Fields marked as RFU (Reserved for Future Use) must be 0

Program Status Words



Address Translation Table Entries



NEC

μPD72191 (FPP)
FLOATING POINT PROCESSOR

PRELIMINARY INFORMATION

Description

The μPD72191 is a high performance, low power CMOS Floating Point Processor (FPP) for the NEC V-Series microprocessors. Using an innovative architecture coupled with a powerful instruction set, the μPD72191 enhances the performance of μPD70108/116 and μPD70208/216 microprocessors in numeric intensive applications such as graphic displays and scientific data processing. A powerful set of arithmetic, transcendental and processor control instructions increase performance and decrease code size yet maintain code compatibility. Hardware features such as dual data buses, barrel shifter, and normalization logic contribute significantly to the μPD72191 throughtput. Operating in either the μPD70108/116 or μPD70208/216 mode, the need for additional external logic is eliminated. Low power CMOS technology for the first time makes high performance numeric calculation in portable scientific applications realizable.

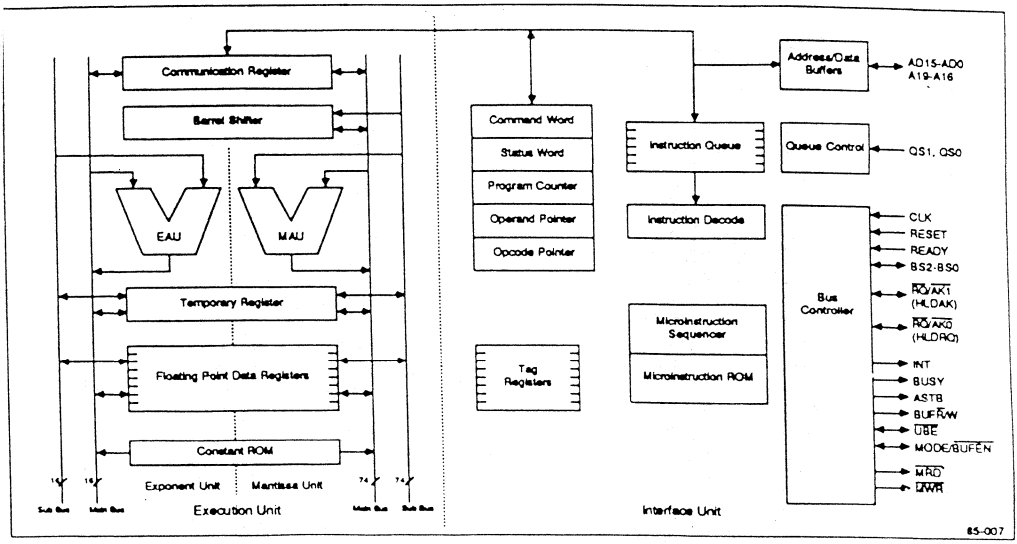
Features

- High performance Floating Point Processor (FPP)
- Conforms to the IEEE 754 floating point standard
- Seven hardware supported data types
  - 16, 32, and 64-bit binary integer
  - 32, 64, and 80-bit binary floating point
  - Packed decimal
- Complete set of transcendental functions including
  - Exponential
  - Logarithmic
  - Trigonometric and inverse trigonometric
  - Hyperbolic
- High speed exponent and mantissa ALU's
- Barrel shifter and normalization logic
- Built-in exception handling
- Wait state generator for μPD70208/216 systems
- Low power CMOS technology

Ordering Information

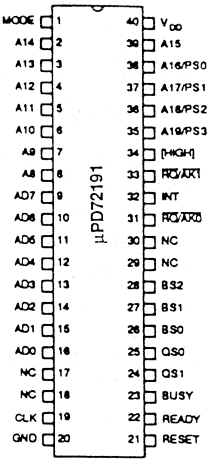
Part Number	Package	Maximum Frequency
μPD72191D	40-pin Cerdip	8 MHz

Block Diagram

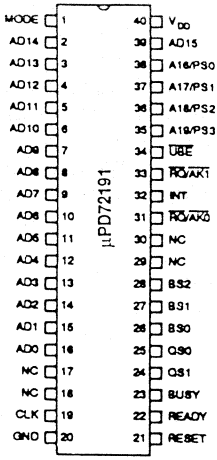


Pin Configurations

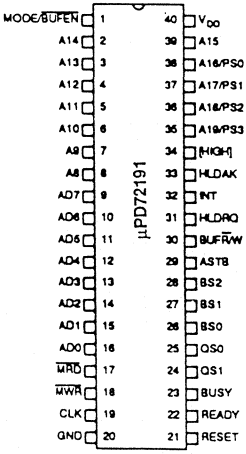
μPD70108 Mode



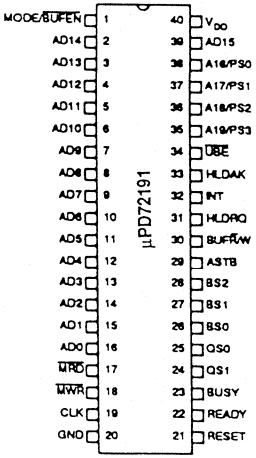
μPD70116 Mode



μPD70208 Mode



μPD70216 Mode



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Pin Identification

Pin	Symbol	Direction	Function
1	MODE/BUFEN*	In/Out	Mode select, external data buffer enable
2-8	AD14-AD8 A14-A8	In/Out Out	Multiplexed address/data bus Address bus
9-16	AD7-AD0	In/Out	Multiplexed address/data bus
17	[MRD*]	Out	High impedance [Memory read strobe]
18	[MWR*]	Out	High impedance [Memory write strobe]
19	CLK	In	CPU clock
20	GND		Ground
21	RESET	In	Reset
22	READY	In	Ready
23	BUSY	Out	Execution Unit busy
24-25	QS1 - QS0	In	CPU queue status
26-28	BS2 - BS0	In/Out	Bus status
29	[ASTB]	Out	High impedance [Address strobe]
30	[BUFR*/W]	Out	High impedance [Buffer read/write]
31	RQ*/AK0* [HLDRQ]	In/Out Out	Request/Acknowledge 0 [Hold request]
32	INT	Out	Interrupt request
33	RQ*/AK1* [HLDAK]	In/Out In	Request/Acknowledge 1 [Hold acknowledge]
34	UBE*	In/Out	Upper byte enable
35-38	A19/PS3 A18/PS2 A17/PS1 A16/PS0	In/Out	Multiplexed address/status
39	AD15 A15	In/Out Out	Multiplexed address/data bus Address bus
40	V_{DD}		+5 V power supply

Pin Functions

AD15-AD0 [Address/Data Bus]

These three-state pins form the active high time multiplexed address/data bus. During T1 of a μPD72091 bus cycle, AD15-AD0 output the lower 16-bits of the 20-bit memory address. During the T2, T3, Tw, and T4 states, AD15-AD0 form the 16-bit data bus. When not in control of the bus, the μPD72191 monitors these input pins.

A0 is analogous to UBE* in μPD70116/216 systems and enables the transfer of data on the lower byte of the 16-bit wide data bus. Address outputs A15-A8 are not multiplexed and are not required to be latched in a μPD70108/208 system.

A19/PS3-A16/PS0 [Address/Status Bus]

These three-state outputs contain the upper 4-bits of the 20-bit address during T1 and status information during T2, T3, Tw, and T4. During CPU bus cycles, the μPD72191 monitors these input pins and uses PS3 to distinguish native mode CPU bus cycles (PS3=0) from 8080 emulation mode, DMA and refresh bus cycles (PS3=1).

When actively driving the bus, the μPD72191 are PS3-PS0 outputs are as follows:

	PS3	PS2	PS1	PS0
μPD72191 Bus Cycle	1	0	1	1

BS2-BS0 [Bus Status]

During μPD72191 bus cycles, BS2-BS0 indicate the type of bus cycle being performed as follows:

BS2	BS1	BS0	Bus Cycle
0	-	-	Unused
1	0	0	Unused
1	0	1	Memory Read
1	1	0	Memory Write
1	1	1	Passive State

Any change in the BS2-BS0 signals after the start of T4 is used by the external bus controller to start the μPD72191 bus cycle. BS2-BS0 are three-state outputs and are used by the μPD72191 during host CPU bus cycles to distinguish instruction fetch from operand read/write bus cycles.

QS1-QS0 [Queue Status]

The QS1 and QS0 inputs are used to maintain synchronization between the μPD72191 and the CPU instruction queues. These inputs are interpreted as follows:

QS1	QS0	Instruction Queue Status
0	0	No Operation
0	1	First byte of instruction fetched
1	0	Flush queue contents
1	1	Subsequent byte of instruction fetched

UBE* [Upper Byte Enable]

UBE* is asserted to indicate that the upper byte of the 16–bit data bus contains valid data. It is used along with A0 by the memory decoding logic in μPD70116/216 systems to select the memory banks as follows:

Operation	UBE*	A0	Bus Cycles
Word, Even Address	0	0	1
Word, Odd Address	0	1†	2
	1	0††	
Byte, Even Address	1	0	1
Byte, Odd Address	1	1	1

† First Bus Cycle
†† Second Bus Cyce

UBE* is a three–state output and is monitored by the μPD72191 when not in control of the bus. In μPC70108/208 systems, UBE* is held at a high level during μPD72191 bus cycles.

INT [Interrupt]

INT is asserted by the μPD72191 when an unmasked exception has occured during execution of an instruction and interrupts have been enabled in the μPD72191 Command Word. Once asserted, INT will remain at a high level until reset by software.

BUSY [Busy]

The BUSY output indicates the internal state of the μPD72191 and is used to synchronize operation of the μPD72191 with the host CPU. BUSY is connected to the host CPU POLL* input and is tested by the POLL instruction.

In the event of an unmasked exception, BUSY will be continuously asserted until the exception has been cleared.

READY [Ready]

READY is used to synchronize a μPD72191 bus cycle with external memory. If unable to respond in time with data, the system can negate READY and force the μPD72191 to insert Tw states into the bus cycle until READY is again asserted.

In the μPD70208/216 mode, the READY input operates in parallel with the internal wait state generator.

RESET [Reset]

This active–high input pin terminates all internal operations and places the μPD72191 in the reset state. RESET must be asserted for at least four clock periods to guarantee recognition.

CLK [Clock]

The CLK input signal is used to generate all internal timing for the μPD72191 CLK is the same as the CPU clock output from a μPD71011/84 clock generator in μPD70108/116 systems or the CLKOUT signal in μPD70208/216 systems.

RQ*/AK0* [Request/Acknowledge 0]

This active low I/O pin is used by the μPD72191 in the μPD70108/116 mode to request control of the local bus. The bus request follows RQ*/AK* protocol of the μPD70108/116 microprocessors.

1. RQ*/AK0* is pulsed low for one clock period, indicating the intent of the μPD72191 to acquire the local bus.
2. The μPD70108/116 CPU responds by asserting RQ*/AK0*, indicating the local bus is available. The acknowledge signal is either used internnal by the μPD72191 to initiate a bus cycle or is routed to the RQ*/AK1* pin.
3. When the μPD72191 has completed the data transfer, RQ*/AK0* is again pulsed low for one clock period, signalling that the bus is released and the host CPU can again resume control of the address, data and control buses.

RQ*/AK1* [Request/Acknowledge 1]

This pin is used in the μPD70108/116 mode by a external bus master to force the μPD72191 to request the local bus on behalf of the RQ*/AK1* bus master. Operation of this pin depends on whether the μPD72191 is in control of the bus.

If not in control of the bus:

1. RQ*/AK0* is pulsed low for one clock period after receiving a bus request on RQ*/AK1*.
2. The μPD72191 issues a low level acknowledge on RQ*/AK1* after the bus grant is received from the host CPU.
3. RQ*/AK0* is pulsed low for one clock period after receiving the bus release on the RQ*/AK1* pin.

If currently in control of the bus:

1. An external bus master asserts RQ*/AK1* for one clock period to request the use of the bus.
2. RQ*/AK1* is pulsed low for one clock period after completing the current bus cycle.
3. The μPD72191 again assumes bus mastership after receiving the bus release signal from the external bus master.

RQ*/AK1* has an internal pullup and may be left unconnected.

HLDRQ [Hold Request]

This active high output is asserted by the μPD72191 in μPD70208/216 systems to request the use of the bus. HLDRQ is held at a high level until all data transfers complete or forced off the bus by a higher priority bus master.

HLDAK [Hold Acknowledge]

When the μPD70208/216 processor has recognized the μPD72191 HLDRQ, it will assert the HLDAK pin, indicating the bus is free and available for use.

Should HLDAK be negated while HLDRQ is asserted, the μPD72191 will release the bus and allow a higher priority bus master to take control of the bus at the end of the current bus cycle. If additional μPD72191 bus cycles remain, HLDRQ will be negated for one clock period and then reasserted.

MODE/BUFEN* [Mode/Buffer Enable]

This three-state pin selects the operating mode of the μPD72191 and functions as a external data buffer enable output.

While RESET is asserted, the μPD72191 will check the state of this pin. If low, the μPD72191 will configure itself to operate in the μPD70108/116 mode. In this mode the μPD72191 uses an external μPD71088 Bus Controller and operates using the RQ*/AK* protocol of large-scale μPD70108/116 microprocessors. If high, the μPD72191 enables the internal bus controller and modifies the bus request protocol to match the protocol of the μPD70208/216 microprocessors.

MODE/BUFEN*	UBE*	CPU
0	0	μPD70116
0	1	μPD70108
1	0	μPD70216
1	1	μPD70208

Following reset, this μPD70208/216 mode output functions as a buffer enable for external data bus buffers during μPD72191 bus cycles. BUFEN* is in the high impedance state when the μPD72091 is not in control of the bus.

ASTB [Address Strobe]

This μPD70208/216 mode pin outputs an active high strobe signal to an external latch to latch the address from the multiplexed address/data bus.

This pin is kept in the high impedance state during μPD70108/116 mode.

MRD* [Memory Read Strobe]

This three-state μPD70208/216 mode pin outputs an active low memory read strobe during T2, T3, and Tw of a μPD72191 bus cycle.

MRD* is kept in the high impedance state when not in control of the bus and in μPD70108/116 mode.

MWR* [Memory Write Strobe]

This three-state μPD70208/216 mode pin outputs an active low memory write strobe during T2, T3, and Tw of a μPD72191 bus cycle.

MWR* is kept in the high impedance state when not in control of the bus and in μPD70108/116 mode.

BUFR*/W [Buffer Read/Write]

BUFR*/W is a three-state output used to control the direction of external data bus buffers. BUFR*/W is driven low during data read bus cycles and high during data write bus cycles.

BUFR*/W is kept in the high impedance state when not in control of the bus and in μPD70108/116 mode.

V_{DD} [Power Supply]

V_{DD} is the +5 Volt power supply pin.

GND [Ground]

GND is the ground pin.

Figure 1. μPD70108/μPD70116 Configuration

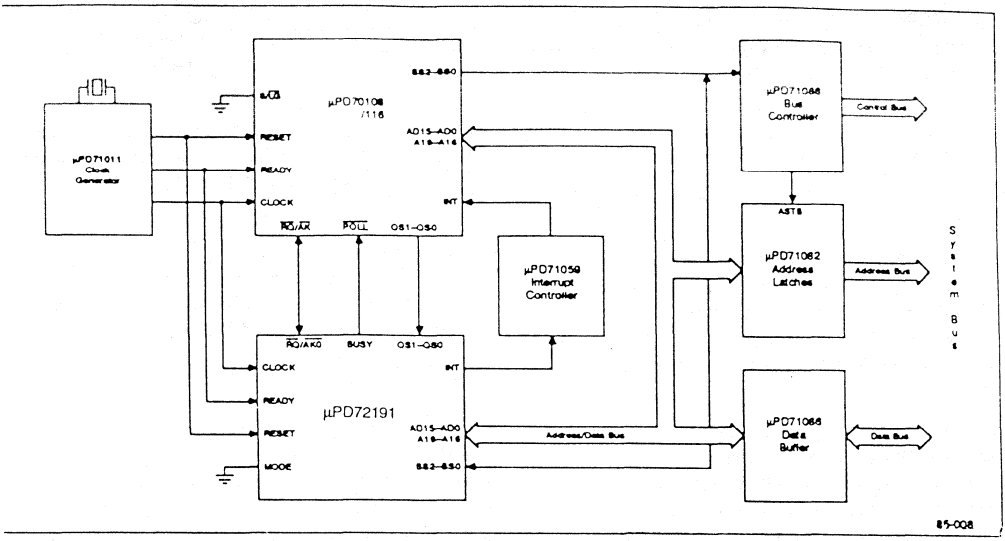
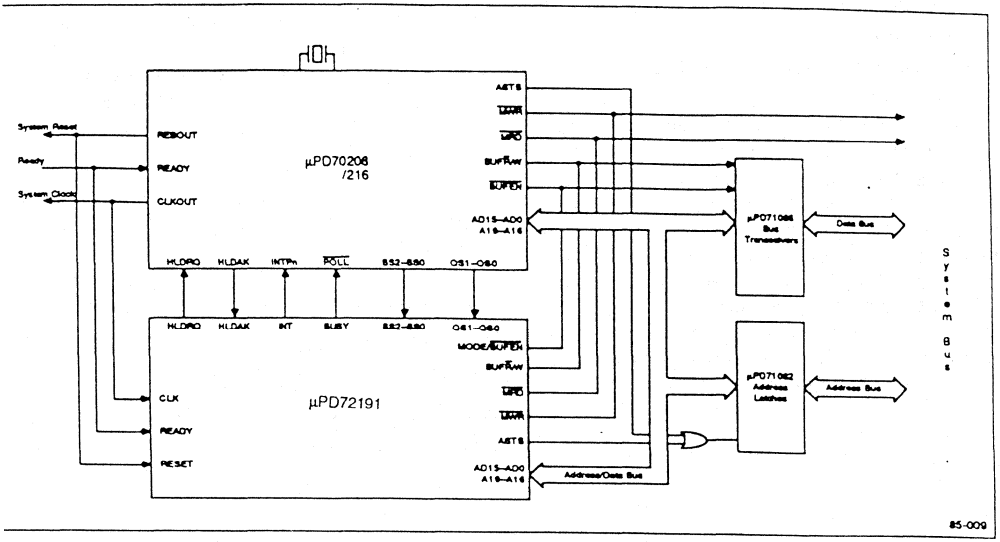


Figure 2. μPD70208/μPD70216 Configuration



Hardware Interface

The μPD72191 Floating Point Processor connects directly to address, data and control buses of the μPD70108/116 and μPD70208/216 microprocessors as shown in Figure 1 and Figure 2. The μPD72191 operating mode is selected by examining the MODE/BUFEN* pin following reset to choose either the μPD70108/116 mode or the μPD70208/216 mode. The μPD72191 also determines the correct data bus and instruction queue sizes by examining the UBE* pin in first CPU bus cycle following a hardware reset.

In a μPD70108/116 system, the MODE/BUFEN* pin is tied to ground. This forces the internal bus controller output pins used in a μPD70208/216 system to enter the high impedance state and configures the bus request logic to use the single wire RQ*/AK* protocol of the μPD70108/116 microprocessors operating in the large scale.

In a μPD70208/216 system, the MODE/BUFEN* pin is pulled up through a resistor to the positive supply. Following reset, the state of this pin is sensed by the μPD72191 and if asserted, the internal bus controller and associated output pins are enabled. Simultaneously, the bus request logic is also configured to match the two wire HLDRQ/HLDAK protocol of the μPD70208/216 microprocessors.

Hardware Architecture

The μPD72191 consists of an Interface Unit (IU) and Execution Unit (EU) operating independently of each other. While the EU is processing the current instruction, the IU continues to monitor the instruction stream with the host CPU. By separating the functions of bus interface and execution of numeric instructions, the overall throughput is enhanced.

Interface Unit

The Interface Unit remains in constant sychronism with the host CPU, using the CPU bus and queue status outputs to load the internal instruction queue and decode the instruction stream in parallel. When a Floating Point Operation (FPO) instruction is detected, the following chain of events takes place.

1. Both the μPD72191 and host CPU decode the instruction to see if a memory operand is specified. If no operand is indicated, the CPU continues with the next instruction and the μPD72191 initiates execution the current instruction.
2. If a memory operand is specified, the host CPU will compute the physical address of the operand and perform a memory read cycle. Both the address and the data bus contents are latched by the μPD72191 if the bus cycle is a memory read, otherwise only the address of the operand is latched.
3. If the operand length is greater than the data fetched during the CPU bus cycle or a write operation was specified, the μPD72191 requests the local bus from the CPU and performs the remaining memory read/write cycles.

The μPD72191 also distinguishes between the CPU native mode and 8080 emulation mode by observing the state of the PS3 status input. While all instruction fetch bus cycles are entered into the instruction queue, the μPD72191 uses the PS3 input to prevent instruction execution until PS3 again indicates native mode (PS3=0).

Figure 3. μPD72191 *MODE Configuration*

	μPD70108	μPD70116	μPD70208	μPD70216
Instruction Queue Size	4 bytes	6 bytes	4 bytes	6 bytes
Data Bus Size	8 bit	16 bit	8 bit	16 bit
Bus Request Protocol	$\overline{RQ}$/$\overline{AK}$		HLDRQ/HLDAK	
Bus Control Signals	μPD71088		Internal Bus Controller	
Programmable Wait State Logic	Disabled		Enabled	

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Execution Unit

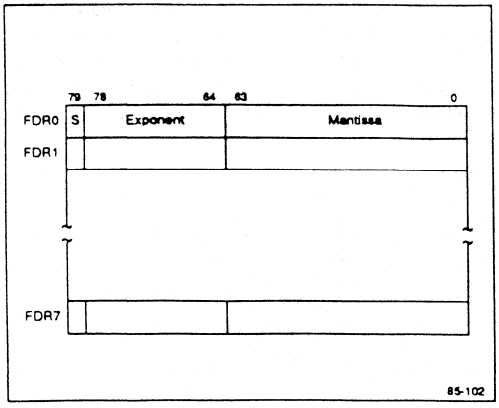
The μPD72191 EU contains the logic to perform arithmetic calculations, data type conversion and operand checking required by the IEEE standard. To speed up internal operations and optimize throughput, the EU consists of separate mantissa and exponent processing units each with internal dual data buses and separate ALUs. The mantissa unit also contains a 74–bit barrel shifter, leading one detection hardware and normalization logic to further enhance performance.

Register Set

The μPD72191 register set consists of eight 80–bit wide floating point data registers and a pair of 16–bit wide status and control registers. The data registers are organized in a Last In–First Out (LIFO) stack with the Top Of Stack (TOS) denoted as FR0 and register FRn being the n^{th} register below the current FR0. Along with each floating point data register (Figure 4) is a four bit tag to identify the current contents of each data register.

The μPD72191 contains three additional registers available for use by exception handlers. The 20–bit address of the last executed instruction, the 12–bit opcode and a 20–bit operand address of the instruction causing the exception are saved for examination. This state information can be saved to memory using a Move Environment (MVF) instruction and be used by exception handlers to assist in determining the cause of an exception.

Figure 4. μPD72191 *Floating Point Registers*



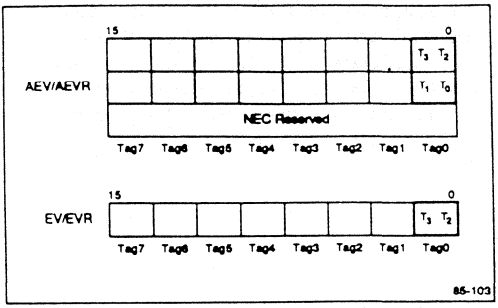
Tag Register

The μPD72191 tag register is used to record the current contents of the floating point data registers. Each four bit tag field is interpreted as follows:

T3	T2	T1	T0	Data Type
0	0	0	0	Normalized Number (NmN)
0	0	0	1	Unnormalized Number (UnN)
0	0	1	0	Unnormalized Zero (UnZ)
0	1	x	x	Zero
1	0	0	0	Not a Number (NaN)
1	0	0	1	∞
1	0	1	0	Denormalized Number (DeN)
1	1	x	x	Empty

Note that the memory representation of the tag register differs depending on whether the μPD72191 Environment (EV) or All Enviroment (AEV) is specified as the destination operand.

Figure 5. μPD72191 *Tag Registers*



Status Word Register

The μPD72191 Status Word (STW) contains the results of μPD72191 instruction execution as shown in Figure 6. Each STW field is interpreted as follows:

Exception Flags (Bits 0-5)

These six flags indicate that the μPD72191 has detected an exception during the execution of an instruction. Exception flags are 'sticky' and can be cleared by the RESETF or CLREXF instructions or by a hardware reset.

Interrupt Request Flag (Bit 7)

The Interrupt Request (IR) flag is set if any unmasked exception flag is set. If μPD72191 interrupts are enabled, the interrupt is propagated to the external INT output.

Condition Code Flags (Bits 8-10, 14)

The Condition Code flags (C3-C0) indicate the execution status of the REMF, MODF, EXAMF, comparison and other instructions.

Stack Pointer (Bits 11-13)

The Stack Pointer field points to the data register currently defined as the Top Of Stack Pointer (TOSP). The value '000' corresponds to the FDR0 register designated as the TOSP, '111' to the FDR7 register being designated the TOSP.

Busy Flag (Bit 15)

When set, the Busy (B) flag indicates that the μPD72191 EU is currently executing an instruction. The state of his flag also appears on the BUSY output pin and is used to synchronize the execution of the host CPU with the μPD72191

Figure 6. μPD72191 ***Status Word***

please see page 3-313

Command Word Register

The μPD72191 Command Word (CMW) is used to select and control the operating mode and exception handling characteristics of the μPD72191. The CMW is manipulated using the μPD72191 MVF instruction.

The CMW (Figure 7) is defined as follows:

Exception Mask (Bits 0-5)

Exception mask bits may be cleared to explicitly handle the occurance of an exception or if set, to allow the default action to take place. Following reset all exceptions are masked.

EM	Exception Mask
0	Exceptions Unmasked
1	Exceptions Masked (Default)

Invalid if Unordered (Bit 6)

The Invalid if Unordered (IU) flag allows masking or unmasking invalid exceptions that can occur.

IU	Invalid if Unordered
0	Invalid Exception is masked when the results of a compare instruction is unordered.
1	An Invalid Exception occurs when the result of a compare instruction is unordered. (Default)

Under the rules of IEEE754 standard, an unordered result should not cause an invalid exception when used with the condition code representation. This flag is set when using the predicate (True/False) representation, causing an Invalid Exception if the result of a comparison is unordered.

This bit can be manipulated only by specifying the ACMW as the destination register.

Disable Interrupt Mask (Bit 7)

The Disable Interrupt Mask (DI) allows enabling or disabling μPD72191 interrupts using the DIF or EIF instructions.

DI	Interrupt Mode
0	Interrupts Enabled
1	Interrupts Disabled (Default)

Precision Control (Bits 8-9)

Bits PC1 and PC0 select the size of the mantissa. Precision control is provided for compatibility with the specifications of certain programming languages and the IEEE standard and does not affect execution time, only the accuracy of the stored result.

PC1	PC0	Precision
0	0	24-bit mantissa
0	1	Reserved
1	0	53-bit mantissa
1	1	64-bit mantissa (Default)

Rounding Control (Bits 10-11)

The μPD72191 can be programmed to operate in one of four rounding modes, round to nearest, round up, round down or truncate toward zero.

RC1	RC0	Rounding Mode
0	0	Round to Nearest or Even (Default)
0	1	Round toward $-\infty$
1	0	Round toward $+\infty$
1	1	Round toward 0

Infinity Control (Bit 12)

The choice of the projective or affine closure mode is selected by this bit. Clearing the IC bit selects projective closure while setting the IC bit selects affine closure.

IC	Infinity Mode
0	Projective Closure (Default)
1	Affine Closure

Programmable Wait States (Bits 13-14)

The PW1 and PW0 flags allow the μPD72191 to insert from 0 to 3 wait states during μPD72191 bus cycles when operated in the μPD70208/216 mode. In μPD70108/116 mode, insertion of wait states is disabled and this field has no effect on operation.

PW1	PW0	Wait States Inserted
0	0	0 Wait States
0	1	1 Wait State
1	0	2 Wait States
1	1	3 Wait States†

† μPD70208/μPD70216 default mode

The PW1 and PW0 bits can be manipulated only by specifying the ACMW as the destination register.

Integer Rounding Mode (Bit 15)

This bit controls the rounding of the Extended Real data type to an integer data type for compatibility with FORTRAN and C language definitions. When cleared, rounding will take place as defined by the Rounding Control field. If set, real to integer conversions are rounded toward zero regardless of the setting of the Rounding Control field.

RM	Integer Rounding Mode
0	Use RC1, RC0 field (Default)
1	Round toward 0

The RM bit can be manipulated only by specifying the ACMW as the destination register.

Figure 7. μPD72191 ***Command Word***

please see page 3-313

Data Formats

The μPD72191 supports seven data formats, three binary integers, three binary reals, and a packed decimal data format (Figure 8).

Binary Integers

- WI (Word Integer)

  A 16-bit binary integer in two's complement format.

  Range : $-32768 \leq X \leq +32767$

- DWI (Double Word Integer)

  A 32-bit binary integer in two's complement format.

  Range : $-2.15 \times 10^9 \leq X \leq +2.15 \times 10^9$

- QWI (Quad Word Integer)

  A 64-bit binary integer in two's complement format.

  Range : $-9.22 \times 10^{18} \leq X \leq +9.22 \times 10^{18}$

Fig. 6. μPD72191 Status Word

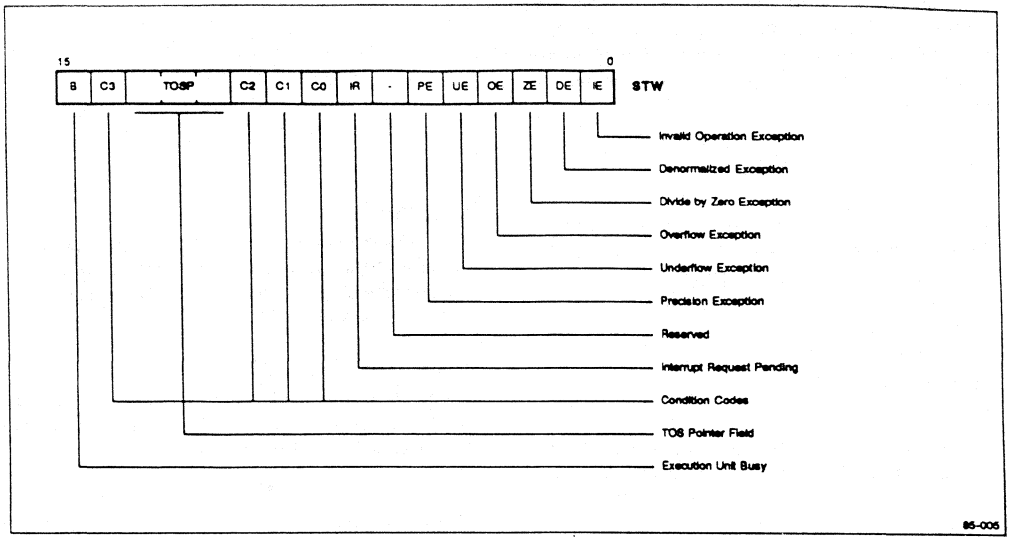
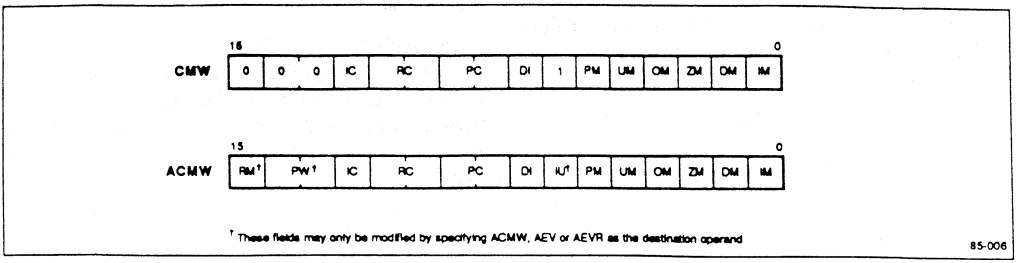


Fig. 7. μPD72191 Command Word



Binary Reals

- SR (Short Real)

A 32–bit binary real consisting of a 23–bit mantissa, an 8–bit biased exponent and a mantissa sign bit. The mantissa is always normalized (integer bit assumed to be 1) unless the number is denormalized.

Range : $8.43 \times 10^{-37} \leq |X| \leq 3.37 \times 10^{38}$
Exponent Bias : 127 (7FH)

- LR (Long Real)

A 64–bit binary real consisting of a 52–bit mantissa, an 11–bit biased exponent and a mantissa sign bit. The mantissa is always normalized (integer bit assumed to be 1) unless the number is denormalized.

Range : $4.19 \times 10^{-307} \leq |X| \leq 1.67 \times 10^{308}$
Exponent Bias : 1023 (3FFH)

- XR (Extended Real)

An 80–bit binary real consisting of a 64–bit mantissa, an 15–bit biased exponent and a mantissa sign bit.

Range : $3.4 \times 10^{-4932} \leq |X| \leq 1.2 \times 10^{4932}$
Exponent Bias : 16383 (3FFFH)

Decimal Integer

- PD (Packed Decimal)

An 80–bit decimal integer consisting of 18 BCD digits and a sign bit.

Range : -999999999999999999 ≤ X ≤
+999999999999999999

Internally, all binary representations and the packed decimal data type are internally stored in the Extended Real format. Conversions to and from the Extended Real format are performed automatically as a result of instruction execution.

Figure 8. Internal Data Formats

please see page 3-315

Figure 9. External Data Formats

please see page 3-316

Data Types

The μPD72191 contains all of the data types specified in the IEEE 754 standard. Note that these data types are defined in the binaryreal format and in some cases do not conform to the integer format.

Normalized Number (NmN)

In this format, the mantissa is normalized. This means that except for the value zero, the mantissa consists of an integer and a fraction in the form

$1\Delta mmmmm...mm$

where Δ indicates the assumed binary point and *m* is the binary digits of the mantissa. The leading integer bit is never stored in the SR and LR formats.

Denormalized Number (DeN)

A denormalized number is an XR number whose exponent has the minimum value of zero and a zero integer bit. This data type cannot be represented in the other binary real data formats and causes an exception if the execution result cannot be stored in the destination as a normalized number.

Unnormalized Number (UnN)

A unnormalized number is an XR number whose exponent has a value between the minimum and maximum values and whose mantissa is denormalized. An unnormal can occur when computing with denormal data.

Fig. 8. Internal Data Formats

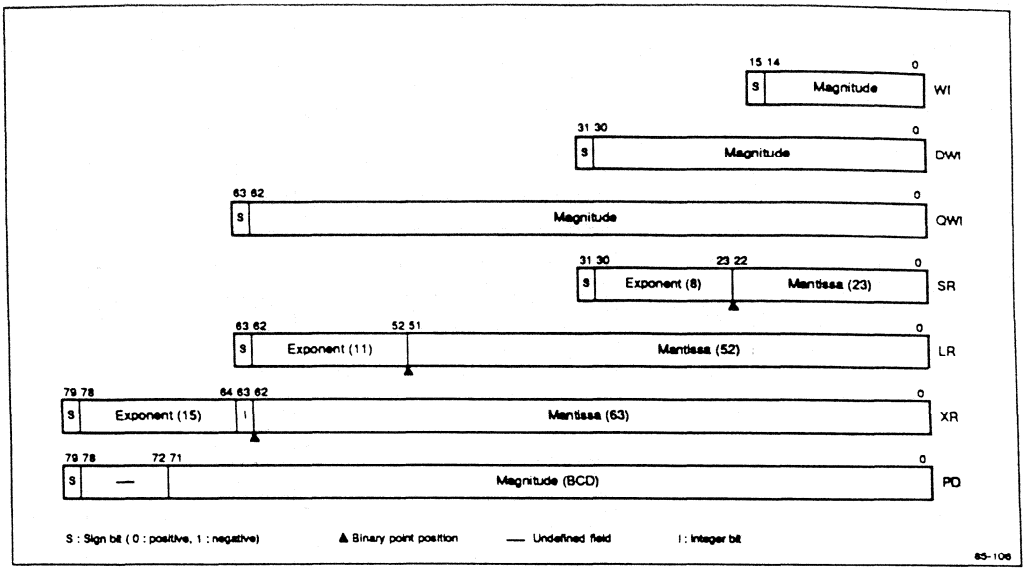
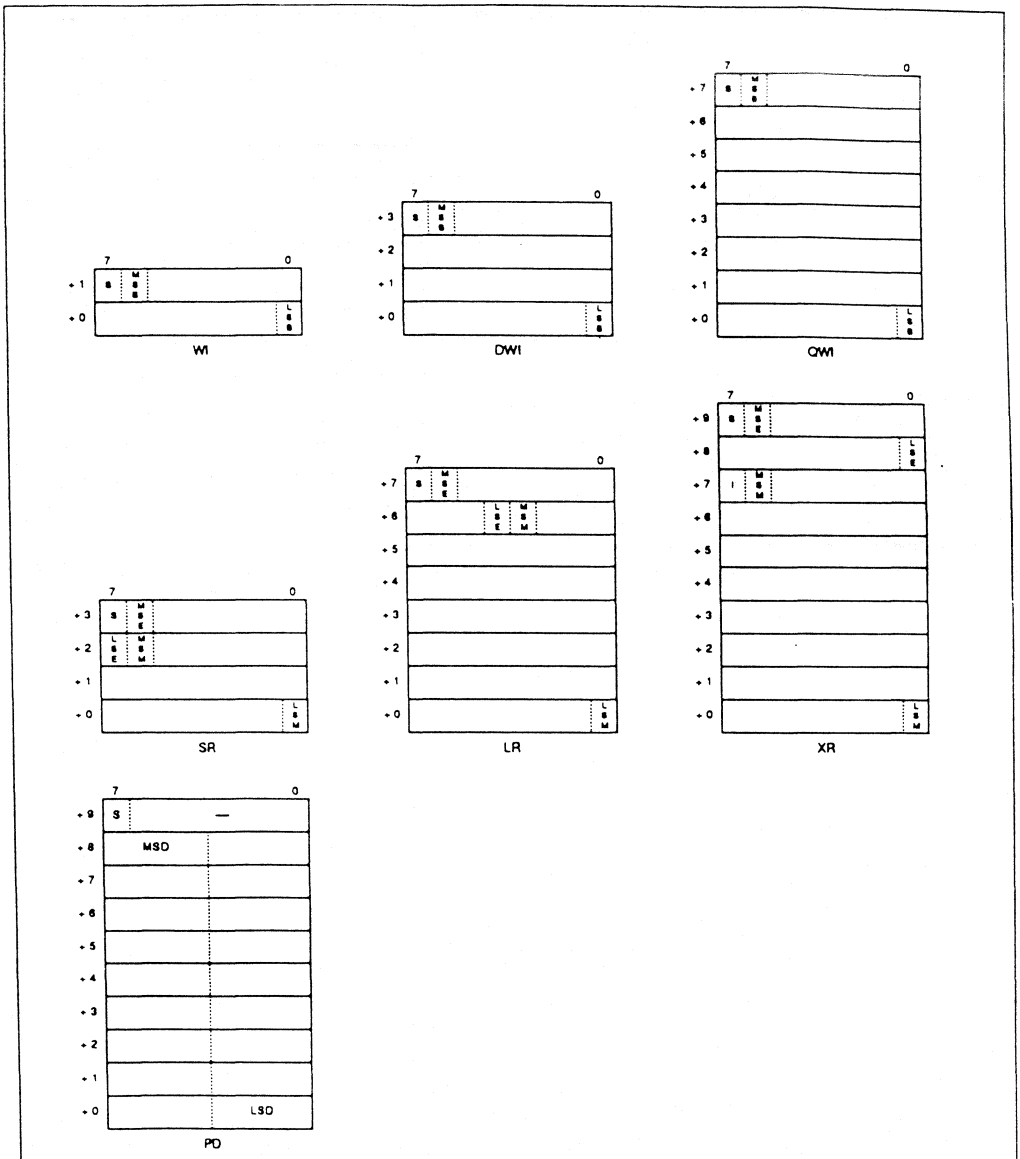


Fig. 9 External Data Formats



Unnormalized Zero (UnZ)

This data type is a special case of an unnormalized number but is treated as zero by the following instructions

- Divide instructions
- Compare instructions
- ROUNDIF

Zero (0)

Zero is a number with both the mantissa and exponent components set to zero. Both positive and negative zeros are representable and are called "true zero" to distinguish them from an unnormal zero.

Infinity (∞)

Infinity is represented by a number whose exponent has the maximum value and whose mantissa is zero (in the XR format the integer bit is 1). There are two values for infinity, positive and negative, depending on the value of the sign bit.

Calculations involving infinity can occur using either the affine mode ($+\infty$ and $-\infty$ are distinguisable) or in the projective mode ($+\infty$ and $-\infty$ are equivalent). The infinity mode is selected by bit 12 in the CMW.

Not a Number (NaN)

A NaN is a value with the exponent set to the maximum value and is treated as a symbol rather than a number. The values for infinity are excluded from the NaN representation.

Indefinite

Indefinite is a special case of NaN. In the XR format, the two most significant bits are set to one and rest cleared to zero.

Figure 10. Binary Integer Formats

please see page 3-318

Figure 11. Binary Real (SR, LR) Formats

please see page 3-318

Figure 12. Binary Real (XR) Formats

please see page 3-318

Figure 13. Packed Decimal Formats

please see page 3-318

Instruction Set

The μPD72191 adds 75 powerful enhancements to the V20–V50 instruction set, including full support for the IEEE binary floating point standard. The μPD72191 instructions include a wide range of data transfer, arithmetic, transcendental, comparison and control instruction types.

Floating point instructions transfer data between stack registers or between a stack register and a memory operand. μPD72191 instructions consist of four types; unary, push, pop and normal. Each instruction type is identified by the affect the instruction has on the stack pointer.

Fig. 10. Binary Integer Formats

	Value	Sign	Absolute value
Positive	Maximum	0	111 • • • • • • • • • • 11
	Minimum		000 • • • • • • • • • • 01
Zero		0	000 • • • • • • • • • • 00
Negative	Minimum	1	111 • • • • • • • • • • 11
	Maximum/ Undefined		000 • • • • • • • • • • 01

WI ← 15 bits →
DWI ← 31 bits →
QWI ← 63 bits →

Fig. 11. Binary Real (SR, LR) Formats

			Value	Sign	Exponent	Mantissa
			NaN	0	11 • • • • • 11	11 • • • • • 11 00 • • • • • 01
Positive	Numeric		+∞	0	11 • • • • • 11	00 • • • • • 00
		Normal		0	11 • • • • • 10 00 • • • • • 01	11 • • • • • 11 00 • • • • • 00
		Denormal		0	00 • • • • • 00	11 • • • • • 11 00 • • • • • 01
		+0		0	00 • • • • • 00	00 • • • • • 00
Negative		−0		1	00 • • • • • 00	00 • • • • • 00
		Denormal		1	00 • • • • • 00	11 • • • • • 11 00 • • • • • 01
		Normal		1	11 • • • • • 10 00 • • • • • 01	11 • • • • • 11 00 • • • • • 00
		−∞		1	11 • • • • • 11	00 • • • • • 00
			NaN	1	11 • • • • • 11	11 • • • • • 11 10 • • • • • 00* 00 • • • • • 01

*Indefinite

SR ← 8 bits → ← 23 bits →
LR ← 11 bits → ← 52 bits →

Fig. 12. Binary Real (XR) Formats

			Value	Sign	Exponent	Mantissa	
						Integer Bit	Fraction
			NaN	0	11 • • • • 11	1	11 • • • • 11 00 • • • • 01
Positive	Numeric		+∞	0	11 • • • • 11	1	00 • • • • 00
		Normal		0	11 • • • • 10 00 • • • • 01	1	11 • • • • 11 00 • • • • 00
		Unnormal		0	11 • • • • 10 00 • • • • 01	0	11 • • • • 11 00 • • • • 00
		Denormal		0	00 • • • • 00	0	11 • • • • 11 00 • • • • 01
		+0		0	00 • • • • 00	0	00 • • • • 00
Negative		−0		1	00 • • • • 00	0	00 • • • • 00
		Denormal		1	00 • • • • 00	0	11 • • • • 11 00 • • • • 01
		Unnormal		1	11 • • • • 10 00 • • • • 01	0	11 • • • • 11 00 • • • • 00
		Normal		1	11 • • • • 10 00 • • • • 01	1	11 • • • • 11 00 • • • • 00
		−∞		1	11 • • • • 11	1	00 • • • • 00
			NaN	1	11 • • • • 11	1	11 • • • • 11 10 • • • • 00* 00 • • • • 01

*Indefinite

← 15 bits → ← 64 bits →

Fig. 13. Packed Decimal Formats

	Value	Sign	—	MSD LSD
Positive	Maximum	0	0000000	1001 1001 • • • • 1001 1001
	Minimum			0000 0000 • • • • 0000 0001
	Zero	0	0000000	0000 0000 • • • • 0000 0000
Negative	Zero	1	0000000	0000 0000 • • • • 0000 0000
	Minimum	1	0000000	0000 0000 • • • • 0000 0001
	Maximum			1001 1001 • • • • 1001 1001
Undefined		1	1111111	1111 1111 • • • • 1111 1111

← 7 bits → ← 72 bits →

Unary instructions specify a single operand to be used as both the source and destination operand. Unary instructions implicitly specify the TOS as the source and replace the contents of TOS with the execution result. The contents of the TOSP field is unchanged by a unary type instruction.

Push type instructions always specify the TOS as the destination. The TOSP field is first decremented and the source operand is copied to the new TOS element.

Pop type instructions always specify the TOS as a source operand. The contents of the TOS data register is first transfered to the destination, the current TOS tag field set to empty and finally the TOSP field is incremented to point to the new TOS element. The operation of a normal data transfer is the same as a pop operation except that both the TOSP field and the TOS contents are unmodified.

Data Transfer Instructions

Data transfer instructions are used to load numeric data into the μPD72191 registers and convert between different numeric formats. Data transfer instructions include

- Move (MVXRF, MVXRPF)
- Move Constant (MVCF)
- Exchange (XCHF)
- Conversion (CVWIF, CVDWIF, CVQWIF, CVWIPF, CVDWIPF, CVQWIPF, CVSRF, CVLRF, CVSRPF, CVLRPF, CVPDF, CVPDPF)

Specifying TOS as the destination operand causes the TOSP field to be decremented and the source operand converted to the XR format prior to being copied to the new TOS.

Example MVXRF TOS, FR1

please see page 3-320

Specifying TOS as the source operand causes the source operand to be copied to the destination (in the destination format) and the TOSP field to be incremented. The old TOS tag field is then marked as empty.

Example MVXRPF FR2, FR0

please see page 3-320

The Move Constant (MVCF) instruction pushes one of eight frequently used constants (0, 1, π, $\pi/180$, $\log_2 10$, $\log_2 e$, $\log_{10} 2$, $\log_e 2$) on to the stack.

Example MVCF TOS, 1

Arithmetic Instructions

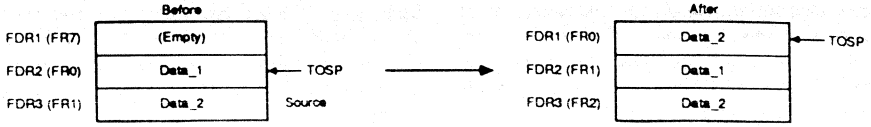
The μPD72191 contains a number of powerful arithmetic instructions for addition, subtraction, multiplication and division. These instructions include

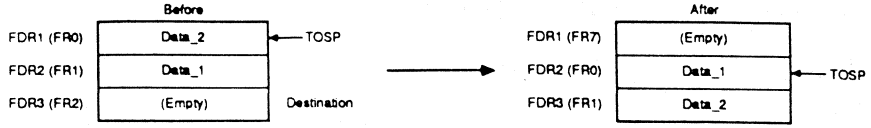
- Addition (ADBRF, ADBRPF, ADBIF)
- Subtraction (SBBRF, SBBRPF, SBBIF, SBBRRF, SBBRRPF, SBBIRF)
- Multiplication (MLBRF, MLBRPF, MLBIF)
- Division (DVBRF, DVBRPF, DVBIF, DVBRRF, DVBRRPF, DVBIRF)

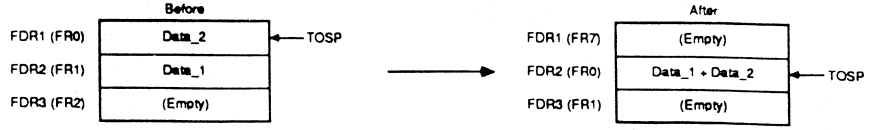
Each arithmetic instruction requires two operands. A normal type instruction will pop both operands and push the result on the stack.

Example ADBRF FR1, FR0

please see page 3-320


Before
FDR1 (FR7)
FDR2 (FR0)
FDR3 (FR1)
(Empty)
Data_1
Data_2
TOSP
Source
After
FDR1 (FR0)
FDR2 (FR1)
FDR3 (FR2)
Data_2
Data_1
Data_2
TOSP


Before
FDR1 (FR0)
FDR2 (FR1)
FDR3 (FR2)
Data_2
Data_1
(Empty)
TOSP
Destination
After
FDR1 (FR7)
FDR2 (FR0)
FDR3 (FR1)
(Empty)
Data_1
Data_2
TOSP


Before
FDR1 (FR0)
FDR2 (FR1)
FDR3 (FR2)
Data_2
Data_1
(Empty)
TOSP
After
FDR1 (FR7)
FDR2 (FR0)
FDR3 (FR1)
(Empty)
Data_1 + Data_2
(Empty)
TOSP

Subtraction and division can performed in reverse order if desired. The reverse form of the instruction will pop the second operand from the stack, perform the operation with the first operand and push the result back on the stack.

Example SBBRRF FR0, FR2

please see page 3-322

Two remainder instructions (REMF, MODF) are provided and differ by either rounding quotient (REMF) or truncating the quotient (MODF). When the difference between the dividend and the modulus exponents is 64 or greater, the partial remainder is stored in FR0. When these instructions are executed the condition codes are modified as follows:

C3	C2	C1	C0	Result
q1	0	q0	q2	remainder < modulus
-	1	-	-	remainder > modulus

Following the completion of a REMF or MODF instruction, the three least significant bits of the quotient are available in condition codes C3, C1 and C0.

Other arithmetic instructions include:

- Square Root (SQRF)
- Negation (NOTSF)
- Absolute Value (ABSF)
- Rounding (ROUNDIF)
- Extract (EXTEMF)
- Scaling (SCLF)

Comparison Instructions

Comparison instructions compare two operands and update the condition codes to reflect the ordering between the operands. Comparisons are performed between the TOS and a register or memory operand. A memory resident operand is first converted to the XR format before performing the comparison.

C3	C0	Operand relationship
0	0	TOS > source operand
0	1	TOS < source operand
1	0	TOS = source operand
1	1	Comparison nor valid

Example CPBRPTF

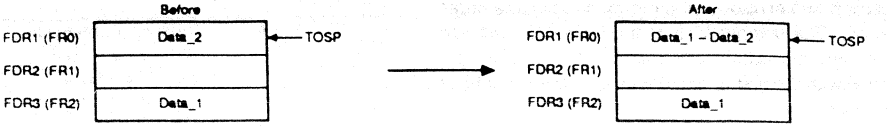
please see page 3-322

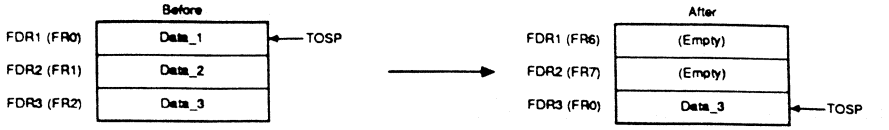
CPXRZF instruction tests the TOS contents against zer and sets the condition codes as follows:

C3	C2	C1	C0	Operand relationship
0	0	-	0	TOS > 0
0	0	-	1	TOS < 0
1	0	-	0	TOS = 0
1	1	-	1	Test not valid

The EXAMF instruction is used to examine the content and data type of the source operand and set the condition codes as follows:

C3	C2	C1	C0	Data Type
0	0	0	0	+UnN
0	0	0	1	+NaN
0	0	1	0	-UnN
0	0	1	1	-NaN
0	1	0	0	+NmN
0	1	0	1	+∞
0	1	1	0	-NmN
0	1	1	1	-∞
1	0	0	0	+0
1	0	0	1	Emp
1	0	1	0	-0
1	0	1	1	Emp
1	1	0	0	+DeN
1	1	0	1	Emp
1	1	1	0	-DeN
1	1	1	1	Emp


Before
FDR1 (FR0)
Data_2
TOSP
FDR2 (FR1)
FDR3 (FR2)
Data_1
After
FDR1 (FR0)
Data_1 – Data_2
TOSP
FDR2 (FR1)
FDR3 (FR2)
Data_1


Before
FDR1 (FR0)
Data_1
TOSP
FDR2 (FR1)
Data_2
FDR3 (FR2)
Data_3
After
FDR1 (FR6)
(Empty)
FDR2 (FR7)
(Empty)
FDR3 (FR0)
Data_3
TOSP

Transcendental Instructions

Fifteen separate transcendental instructions include a number of popular exponential, logarithmic, trigonometric and hyperbolic functions. A complete list of input arguments and results are provided at the start of the instruction set description.

Exponential instructions accept a wide range of input arguments and in bases 2, e or 10. The valid input argument ranges are:

XPTF	(10^X)	$-\infty < X < +\infty$
XPEF	(e^X)	$-\infty < X < +\infty$
XP2F	(2^X)	$-\infty < X < +\infty$
XP2M1F	$(2^X - 1)$	$0 \le X \le 0.5$

The XP2M1F instruction is used when the value of the input argument is small to increase the precision of the result.

Example XPEF

please see page 3-324

The μPD72191 allows logarithms to be computed directly in base 2, e, or 10. This eliminate the need for the multiplication required to change bases and allows more efficient use of the stack. Logarithmic instructions and their input argument ranges are:

LGTXF	$(\log_{10} X)$	$0 < X < +\infty$
LGEXF	$(\log_e X)$	$0 < X < +\infty$
YLG2XF	$(Y \log_2 X)$	$0 < X < +\infty, -\infty < Y < +\infty$
YLG2XP1F	$(Y \log_2 (X+1))$	$0 < \lvert X \rvert < (1 - (\sqrt{2}/2))$ $-\infty < Y < +\infty$

The YLG2XP1F instruction is used when the value of the input argument is close to one to increase the precision of the result.

Example YLG2XF

please see page 3-324

A complete set of trigonometric instructions allow fast, accurate computation over a wide range of input arguments:

SINXF	(sin X)	$-2\pi \le X \le +2\pi$
COSXF	(cos X)	$-2\pi \le X \le +2\pi$
TANXF	(tan X)	$-2\pi \le X \le +2\pi$
RTANXF	(tan X)	$0 < X < \pi/4$

The results of a tangent computation can be computed directly or be expressed as a ratio. The TANXF instruction also returns the quadrant in which the input argument lies as follows:

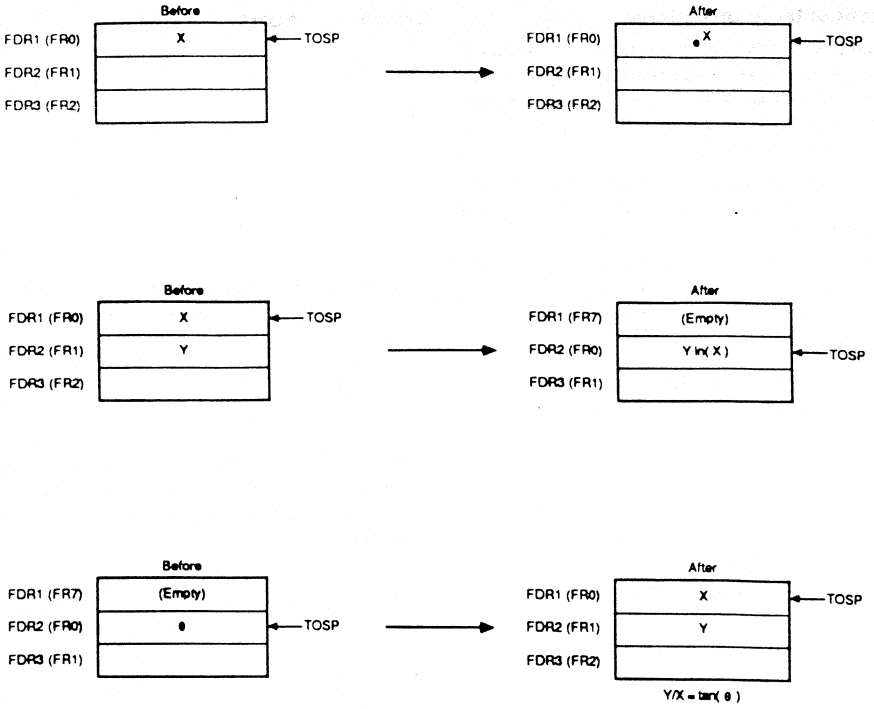
C3	C2	C1	C0	Operand value
0	0	0	0	$=0 \le \lvert X \rvert < \pi/2$
0	0	1	0	$\pi/2 \le \lvert X \rvert < \pi$
1	0	0	0	$\pi \le \lvert X \rvert < 3\pi/2$
1	0	1	0	$3\pi/2 \le \lvert X \rvert < 2\pi$
0	0	0	1	$\lvert X \rvert = 2\pi$
1	1	1	1	Other than above

Example RTANXF

please see page 3-324

Two inverse trigonometic instructions are available. The input argument ranges are:

ATANXF	$(\tan^{-1} X)$	$-\infty < X < +\infty$
ATANXYF	$(\tan^{-1} (Y/X))$	$0 < Y < X < +\infty$


Before
FDR1 (FR0)
FDR2 (FR1)
FDR3 (FR2)
X
TOSP
After
FDR1 (FR0)
FDR2 (FR1)
FDR3 (FR2)
X
TOSP
Before
FDR1 (FR0)
FDR2 (FR1)
FDR3 (FR2)
X
Y
TOSP
After
FDR1 (FR7)
FDR2 (FR0)
FDR3 (FR1)
(Empty)
Y in(X)
TOSP
Before
FDR1 (FR7)
FDR2 (FR0)
FDR3 (FR1)
(Empty)
θ
TOSP
After
FDR1 (FR0)
FDR2 (FR1)
FDR3 (FR2)
X
Y
TOSP
Y/X = tan(θ)

The input argument to the arctangent function can be supplied directly or be expressed as a ratio of two numbers. The ATANXF instruction also returns the range of the input argument as follows:

C3	C2	C1	C0	Operand value
1	1	0	1	$-\infty \le X < -1$
0	0	0	1	$-1 \le X \le -0$
0	0	0	0	$+0 \le X \le +1$
1	1	0	0	$+1 < X \le +\infty$
1	1	1	1	Other than above

Example ATANXYF

please see page 3-326

The hyperbolic instruction and its input argument range is:

TANHXF (tanh X) $-\infty < X < +\infty$

The hyperbolic tangent instruction can be used to compute other hyperbolic functions as follows:

$\sinh X = \tanh X / \sqrt{(1 - \tanh^2 X)}$

$\cosh X = 1 / \sqrt{(1 - \tanh^2 X)}$

Control Instructions

Control instructions are used to set operating modes, clear exception flags and perform initialization of the μPD72191. Control instructions can be executed while an operational instruction is in progress. Control instructions execute entirely within the Interface Unit while operational instructions execute within the Execution Unit. Control instructions do not generate any exceptions.

The Move (MVF) instruction is used to transfer the contents of the CMW, STW or the instruction execution environment to/from memory. Four different options (Figure 14) exist for transfering the internal state of the μPD72191:

AEVR	All μPD72191 internal registers
AEV	Same as AEVR but excluding the floating point data registers
EVR	Same as AEVR but only a 2-bit tag field is saved
EV	Same as EVR but excluding the floating point data registers

Other control instructions include

- Reset (RESETF)
- Interrupt Enable/Disable (DIF, EIF)
- Clear Exception Flags (CLREXF)
- Stack Pointer (INCSPF, DECSPF)
- Release Register (RELF, RELPF)
- No Operation (NOPF)

Figure 14. μPD72191 ***Environment***

please see page 3-326

Exceptions

As a result of instruction execution or an improper operand condition, one or more exceptions may occur Depending on the user programmable mask bits in the CMW, an exception can be handled automatically by the μPD72191 or via a user supplied exception handler.

Exceptions detected by the μPD72191 and the masked/unmasked actions taken are as follows:

Invalid Operation Exception (IE)

This exception occurs as a result of stack overflow, underflow or the use of an indeterminate form or NaN as an operand. If masked, the μPD72191 will generate an *Indefinite* NaN or propagate the exisiting NaN to the result of the calculation. This exception is detected prior to instruction execution.

Example:

MVXRF TOS, FR3 (FR3 is empty)

Masked Response TOS ← Undefined

Unmasked Response CPU Interrupt

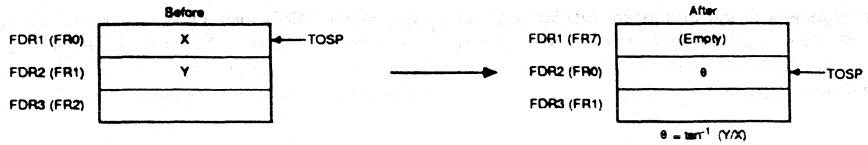
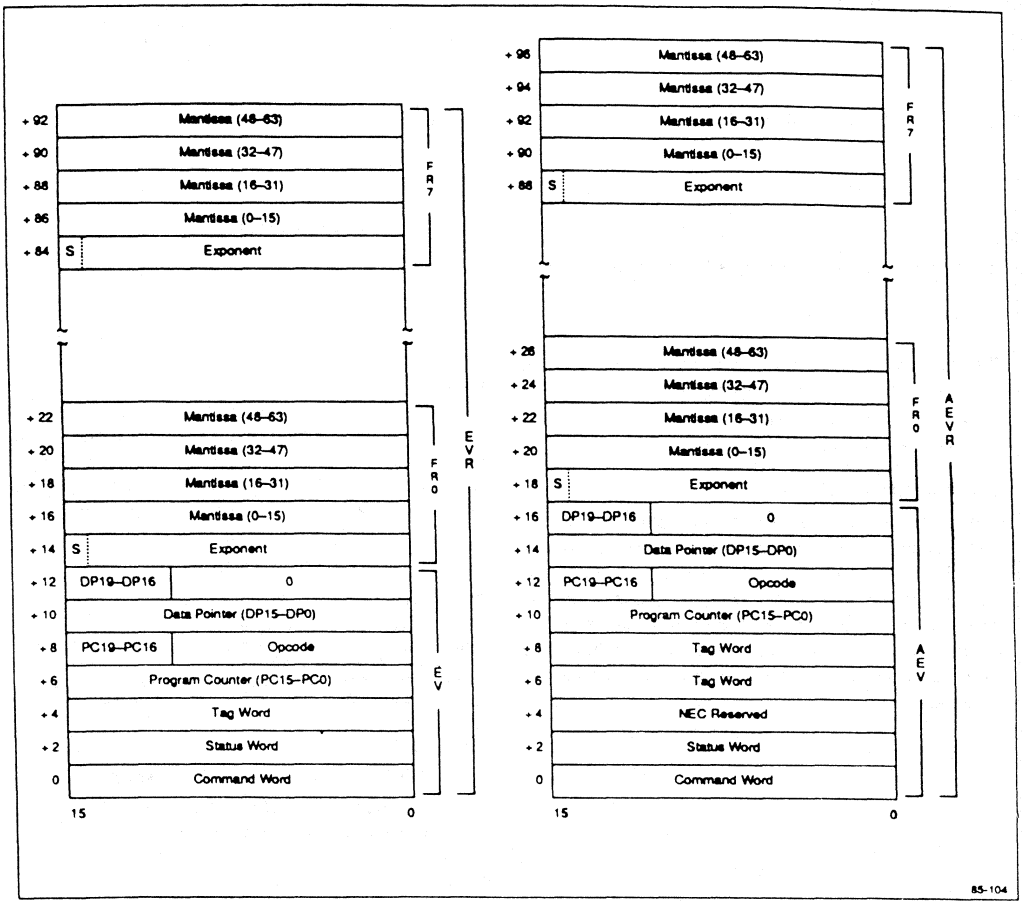


Fig. 14. μPD72191 Environment



Zero Divisor Exception (ZE)

This exception occurs when the divisor is zero and the dividend is non–zero, non–infinite number. If masked, the μPD72191 will return a signed ∞ with the Exclusive–OR of the operand signs as the result of the calculation. This exception is detected prior to instruction execution.

Example:

DVBRF FR0, mem(SR) (zero divisor)

Masked Response	FR0 ← Infinity
Unmasked Response	CPU Interrupt

Overflow Exception (OE)

The computed result is too large to fit in the destination format. If masked, the μPD72191 will generate an ∞ with the proper sign.

Example:

MLBRF FR5, FR0

Masked Response	FR5 ← Infinity
Unmasked Response	Exp ← Exp - 6000H Precison Exception

Underflow Exception (UE)

The computed result is non–zero yet is too small to fit in the destination format. If masked, the μPD72191 will adjust the exponent and generate an a denormal operand.

Example:

SBBRRF FR7, FR0

Masked Response	FR7 ← Denormal
Unmasked Response	Exp ← Exp + 6000H Precison Exception

Denormalized Operand Exception (DE)

This exception will occur if one or more operands or the result in a calculation is denormalized. If masked, normal processing will continue.

Example:

CPBRF FR0, FR1 (FR1 is denormal)

Masked Response	FR1 ← Unnormal
Unmasked Response	CPU Interrupt

Precision Exception (PE)

This exception occurs when the result of a calculation does not fit exactly into the destination and must be rounded using the RC field of the CMW. If masked, the PE flag is set and processing continues without interruption.

Example:

DVBRRF FR2, FR0

Masked Response	No response
Unmasked Response	CPU Interrupt

μPD72191 Instruction Set

Operation Types

Identifier	Description
mem	16-, 32-, 64- or 80-bit memory operand
md	Modifier field of an instruction
WI	Word Integer
DWI	Double Word Integer
QWI	Quad Word Integer
SR	Short Real
LR	Long Real
XR	Extended Real
PD	Packed Decimal

Memory Addressing Modes

	md		
mem	00	01	10
000	BW + IX	BW + IX + disp8	BW + IX + disp16
001	BW + IY	BW + IY + disp8	BW + IY + disp16
010	BP + IX	BP + IX + disp8	BP + IX + disp16
011	BP + IY	BP + IY + disp8	BP + IY + disp16
100	IX	IX + disp8	IX + disp16
101	IY	IY + disp8	IY + disp16
110	Direct	BP + disp8	BP + disp16
111	BW	BW + disp8	BW + disp16

Register Selection

reg	Register Selected
000	FR0 (TOS)
001	FR1
010	FR2
011	FR3
100	FR4
101	FR5
110	FR6
111	FR7

The table on the following pages describes the μPD72191 instruction set. Some instructions show a range of clock times, separated by a hyphen. The execution clocks of these instructions can depend on either the size or the value of the operand.

The "Clocks" column includes the following operations

- Instruction Decoding
- Effective Address Calculation
- Operand Fetch
- Instruction Execution
- POLL Instruction Execution

Clock timings assume the instruction has been prefetched and is present in the μPD72191 instruction queue. Otherwise, add four clocks for each byte of instruction (μPD70108/μPD70208 systems) or instruction word (μPD70116/μPD70216 systems) not present in the instruction queue.

Valid Arguments

Instruction	Input Argument	Result
SINXF, COSXF	$-2\pi \le X \le +2\pi$	$-1 \le Y \le +1$
TANXF	$-2\pi \le X \le +2\pi$	$-\infty \le Y \le +\infty$
RTANXF	$0 \le X \le \pi/4$	$0 \le Y/X \le 1$
ATANXF	$-\infty < X < +\infty$	$-\pi/2 < Y < \pi/2$
ATANXYF	$0 \le Y < X < +\infty$	$0 \le Y < \pi/4$
TANHXF	$-\infty < X < +\infty$	$-1 < Y < +1$
XPTF, XPEF, XP2F	$-\infty < X < +\infty$	$0 < Y < +\infty$
XP2M1F	$0 \le X < 1$	$0 \le Y < +1$
LGTXF, LGEXF	$0 < X < +\infty$	$-\infty < Y < +\infty$
YLG2XF	$0 < X < +\infty$ $-\infty < Y < +\infty$	$-\infty < Z < +\infty$
YLG2XP1F	$-1/2 < X < +1$ $-\infty < Y < +\infty$	$-\infty < Z < +\infty$

Mnemonic	Operands	Opcode	Bytes	Clocks	Operation
		Data Transfer Instructions			
CVWIF	TOS, mem	DF md00 0mem	2-4		TOS:XR ← (mem:WI), Push
	mem, FR0	DF md01 0mem	2-4		(mem:WI) ← FR0:XR (Note 1)
CVDWIF	TOS, mem	DB md00 0mem	2-4		TOS:XR ← (mem:DWI), Push
	mem, FR0	DB md01 0mem	2-4		(mem:DWI) ← FR0:XR (Note 1)
CVQWIF	TOS, mem	DF md10 1mem	2-4		TOS:XR ← (mem:QWI), Push
CVSRF	TOS, mem	D9 md00 0mem	2-4		TOS:XR ← (mem:SR), Push
	mem, FR0	D9 md01 0mem	2-4		(mem:SR) ← FR0:XR
CVLRF	TOS, mem	DD md00 0mem	2-4		TOS:XR ← (mem:LR), Push
	mem, FR0	DD md01 0mem	2-4		(mem:LR) ← FR0:XR
CVPDF	TOS, mem	DF md10 0mem	2-4		TOS:XR ← (mem:PD), Push
CVPDPF	mem, FR0	DF md11 0mem	2-4		(mem:PD) ← FR0:XR, Pop (Note 1)
CVWIPF	mem, FR0	DF md01 1mem	2-4		(mem:WI) ← FR0:XR, Pop (Note 1)
CVDWIPF	mem, FR0	DB md01 1mem	2-4		(mem:DWI) ← FR0:XR, Pop (Note 1)
CVQWIPF	mem, FR0	DF md11 1mem	2-4		(mem:QWI) ← FR0:XR, Pop (Note 1)
CVSRPF	mem, FR0	D9 md01 1mem	2-4		(mem:SR) ← FR0:XR, Pop
CVLRPF	mem, FR0	DD md01 1mem	2-4		(mem:LR) ← FR0:XR, Pop
MVXRF	TOS, mem	DB md10 1mem	2-4		TOS:XR ← (mem:XR), Push
	TOS, FRn	D9 1100 0reg	2		TOS:XR ← FRn:XR, Push
	FRn, FR0	DD 1101 0reg	2		FRn:XR ← FR0:XR
MVXRPF*	mem, FR0	DB md11 1mem	2-4		(mem:XR) ← FR0:XR, Pop
	FRn, FR0	DD 1101 1reg	2		FRn:XR ← FR0:XR, Pop
XCHF	FR0, FRn	D9 1100 1reg	2		FRn ↔ FR0
MVCF	TOS, 1	D9 1110 1000	2		TOS ← +1.0, Push
	TOS, LG2T	D9 1110 1001	2		TOS ← $\log_2 10$, Push
	TOS, LG2E	D9 1110 1010	2		TOS ← $\log_2 e$, Push
	TOS, PI	D9 1110 1011	2		TOS ← π, Push
	TOS, LGT2	D9 1110 1100	2		TOS ← $\log_{10} 2$, Push
	TOS, LGE2	D9 1110 1101	2		TOS ← $\log_e 2$, Push
	TOS, 0	D9 1110 1110	2		TOS ← +0.0, Push
	TOS, DTR	D9 1110 1111	2		TOS ← π/180, Push
		Arithmetic Instructions			
ADBRF	FR0, mem	D8 md00 0mem	2-4		FR0:XR ← FR0:XR + (mem:SR)
	FR0, mem	DC md00 0mem	2-4		FR0:XR ← FR0:XR + (mem:LR)
	FR0, FRn	D8 1100 0reg	2		FR0:XR ← FR0:XR + FRn:XR
	FRn, FR0	DC 1100 0reg	2		FRn:XR ← FRn:XR + FR0:XR
ADBRPF	FRn, FR0	DE 1100 0reg	2		FRn:XR ← FRn:XR + FR0:XR, Pop

Mnemonic	Operands	Opcode	Bytes	Clocks	Operation
		Arithmetic Instructions (cont)			
ADBIF	FR0, mem	DA md00 0mem	2-4		FR0:XR ← FR0:XR + (mem:DWI)
	FR0, mem	DE md00 0mem	2-4		FR0:XR ← FR0:XR + (mem:WI)
SBBRF	FR0, mem	D8 md10 0mem	2-4		FR0:XR ← FR0:XR - (mem:SR)
	FR0, mem	DC md10 0mem	2-4		FR0:XR ← FR0:XR - (mem:LR)
	FR0, FRn	D8 1110 0reg	2		FR0:XR ← FR0:XR - FRn:XR
	FRn, FR0	DC 1110 1reg	2		FRn:XR ← FRn:XR - FR0:XR
SBBRPF	FRn, FR0	DE 1110 1reg	2		FRn:XR ← FRn:XR - FR0:XR, Pop
SBBIF	FR0, mem	DA md10 0mem	2-4		FR0:XR ← FR0:XR - (mem:DWI)
	FR0, mem	DE md10 0mem	2-4		FR0:XR ← FR0:XR - (mem:WI)
SBBRRF	FR0, mem	D8 md10 1mem	2-4		FR0:XR ← (mem:SR) - FR0:XR
	FR0, mem	DC md10 1mem	2-4		FR0:XR ← (mem:LR) - FR0:XR
	FR0, FRn	D8 1110 1reg	2		FR0:XR ← FRn:XR - FR0:XR
	FRn, FR0	DC 1110 0reg	2		FRn:XR ← FR0:XR - FRn:XR
SBBRRPF	FRn, FR0	DE 1110 0reg	2		FRn:XR ← FR0:XR - FRn:XR, Pop
SBBIRF	FR0, mem	DA md10 1mem	2-4		FR0:XR ← (mem:DWI) - FR0:XR
	FR0, mem	DE md10 1reg	2-4		FR0:XR ← (mem:WI) - FR0:XR
MLBRF	FR0, mem	D8 md00 1mem	2-4		FR0:XR ← FR0:XR x (mem:SR)
	FR0, mem	DC md00 1mem	2-4		FR0:XR ← FR0:XR x (mem:LR)
	FR0, FRn	D8 1100 1reg	2		FR0:XR ← FR0:XR x FRn:XR
	FRn, FR0	DC 1100 1reg	2		FRn:XR ← FRn:XR x FR0:XR
MLBRPF	FRn, FR0	DE 1100 1reg	2		FRn:XR ← FRn:XR x FR0:XR, Pop
MLBIF	FR0, mem	DA md00 1mem	2-4		FR0:XR ← FR0:XR x (mem:DWI)
	FR0, mem	DE md00 1mem	2-4		FR0:XR ← FR0:XR x (mem:WI)
DVBRF	FR0, mem	D8 md11 0mem	2-4		FR0:XR ← FR0:XR ÷ (mem:SR)
	FR0, mem	DC md11 0mem	2-4		FR0:XR ← FR0:XR ÷ (mem:LR)
	FR0, FRn	D8 1111 0reg	2		FR0:XR ← FR0:XR ÷ FRn:XR
	FRn, FR0	DC 1111 1reg	2		FRn:XR ← FRn:XR ÷ FR0:XR
DVBRPF	FRn, FR0	DE 1111 1reg	2		FRn:XR ← FRn:XR ÷ FR0:XR, Pop
DVBIF	FR0, mem	DA md11 0mem	2-4		FR0:XR ← FR0:XR ÷ (mem:DWI)
	FR0, mem	DE md11 0mem	2-4		FR0:XR ← FR0:XR ÷ (mem:WI)
DVBRRF	FR0, mem	D8 md11 1mem	2-4		FR0:XR ← (mem:SR) ÷ FR0:XR
	FR0, mem	DC md11 1mem	2-4		FR0:XR ← (mem:LR) ÷ FR0:XR
	FR0, FRn	D8 1111 1reg	2		FR0:XR ← FRn:XR ÷ FR0:XR
	FRn, FR0	DC 1111 0reg	2		FRn:XR ← FR0:XR ÷ FRn:XR
DVBRRPF	FRn, FR0	DE 1111 0reg	2		FRn:XR ← FR0:XR ÷ FRn:XR, Pop
DVBIRF	FR0, mem	DA md11 1mem	2-4		FR0:XR ← (mem:DWI) ÷ FR0:XR
	FR0, mem	DE md11 1reg	2-4		FR0:XR ← (mem:WI) ÷ FR0:XR

Mnemonic	Operands	Opcode		Bytes	Clocks	Operation
			Arithmetic Instructions (cont)			
SQRF		D9	1111 1010	2		FR0 ← √FR0
SCLF		D9	1111 1101	2		FR0 ← FR0 x 2^{FR1}
REMF		D9	1111 1011	2		FR0 ← FR0 % FR1 (IEEE Standard)
MODF		D9	1111 1000	2		FR0 ← FR0 % FR1
ROUNDIF		D9	1111 1100	2		FR0 ← INT(FR0)
EXTMEF		D9	1111 0100	2		FR0 ← Sig(FR0), FR1 ← Exp(FR0)
ABSF		D9	1110 0001	2		FR0 ← |FR0|
NOTSF		D9	1110 0000	2		FR0 ← -FR0
			Transcendental Instructions			
XP2F		DB	1100 0000	2		FR0 ← 2^{FR0}
XP2M1F		D9	1111 0000	2		FR0 ← $2^{FR0} - 1$
XPTF		DB	1100 0001	2		FR0 ← 10^{FR0}
XPEF		DB	1100 0010	2		FR0 ← e^{FR0}
YLG2XF		D9	1111 0001	2		FR0 ← FR1 x $\log_2$ (FR0)
YLG2XP1F		D9	1111 1000	2		FR0 ← FR1 x $\log_2$ (FR0+1)
LGTXF		DB	1100 0100	2		FR0 ← $\log_{10}$(FR0)
LGEXF		DB	1100 0101	2		FR0 ← ln(FR0)
SINXF		DB	1100 1000	2		FR0 ← sin(FR0)
COSXF		DB	1100 1001	2		FR0 ← cos(FR0)
TANXF		DB	1100 1010	2		FR0 ← tan(FR0)
RTANXF		D9	1111 0010	2		FR1/FR0 ← tan(FR0)
ATANXF		DB	1100 1110	2		FR0 ← $\tan^{-1}$(FR0)
ATANXYF		D9	1111 0011	2		FR0 ← $\tan^{-1}$(FR1/FR0), Pop
TANHXF		DB	1101 0010	2		FR0 ← tanh(FR0)
			Comparison Instructions			
CPBRF	FR0, mem	D8	md01 0mem	2-4		FR0:XR - (mem:SR)
	FR0, mem	DC	md01 0mem	2-4		FR0:XR - (mem:LR)
	FR0, FRn	D8	1101 0reg	2		FR0:XR - FRn:XR
CPBRPF	FR0, mem	D8	md01 1mem	2-4		FR0:XR - (mem:SR), Pop
	FR0, mem	DC	md01 1mem	2-4		FR0:XR - (mem:LR), Pop
	FR0, FRn	D8	1101 1reg	2		FR0:XR - FRn:XR, Pop
CPBRF	FR0, FR1	DE	1101 1001	2		FR0:XR - FR1:XR, Pop x 2
CPBIF	FR0, mem	DA	md01 0mem	2-4		FR0:XR - (mem:DWI)
	FR0, mem	DE	md01 0mem	2-4		FR0:XR - (mem:WI)
CPBIPF	FR0, mem	DA	md01 1mem	2-4		FR0:XR - (mem:DWI), Pop
	FR0, mem	DE	md01 1mem	2-4		FR0:XR - (mem:WI), Pop
CPXRZF		D9	1110 0100	2		FR0:XR - 0.0
EXAMF		D9	1110 0101	2		Examine FR0

Mnemonic	Operands	Opcode	Bytes	Clocks	Operation
		Processor Control Instructions			
MVF	CMW, mem	D9 md10 1mem	2-4		Command Word ← (mem) (Note 2)
	mem, CMW	D9 md11 1mem	2-4		(mem) ← Command Word
	mem, STW	DD md11 1mem	2-4		(mem) ← Status Word
	AEV, mem	D9 md00 1mem	2-4		Command Word ← (mem) (Note 3)
	mem, AEV	DB md00 1mem	2-4		(mem) ← Command Word
	AEVR, mem	DD md00 1mem	2-4		Command Word ← (mem) (Note 3)
	mem, AEVR	DF md00 1mem	2-4		(mem) ← Command Word
	EVR, mem	DD md10 0mem	2-4		Command Word ← (mem) (Note 2)
	mem, EVR	DD md11 0mem	2-4		(mem) ← Command Word
	EV, mem	D9 md10 0mem	2-4		Command Word ← (mem) (Note 2)
	mem, EV	D9 md11 0mem	2-4		(mem) ← Command Word
	ACMW, mem	DD md10 1mem	2-4		ACMW ← (mem) (Note 3)
RESETF		DB 1110 0011	2		Reset
DIF		DB 1110 0001	2		Disable Interrupts
EIF		DB 1110 0000	2		Enable Interrupts
CLREXF		DB 1110 0010	2		Clear Exception Flags
INCSPF		D9 1111 0111	2		TOSP ← TOSP + 1
DECSPF		D9 1111 0110	2		TOSP ← TOSP - 1
RELF	FRn	DD 1100 0reg	2		Release Floating Point register FRn
RELPF	FRn	DF 1100 0reg	2		Release Floating Point register FRn and Pop
NOPF		D9 1110 0011	2		No Operation

Note 1 Instruction affected by the Integer Rounding Mode bit in the CMW register.

Note 2 For compatibility with other coprocessors, these instructions set the following CMW fields

RM ← 0
PW ← 00
IU ← 1

Note 3 These instructions are used to program the state of the RM, PW and IU fields in the CMW register to the desired value.

NEC

NMOS MICROPROCESSORS 4

Section 4 – NMOS Microprocessors

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μPD780
HIGH-PERFORMANCE CP/M®-COMPATIBLE NMOS 8-BIT MICROPROCESSOR

Description

The μPD780 is a microprocessor that utilizes a highly consistent architectural organization, a comprehensive instruction set that is a superset of the industry-standard 8080A instruction set, and third-generation technology, to provide a flexible, high-performance, efficient CPU easily adaptable to a very broad range of industrial and commercial applications.

All software developed on 8080A-based systems may be run on 780-based systems as a subset of the full 780 instruction set. In addition, the NEC μPD780 is fully pin-compatible and software-compatible with the Z80® microprocessor and is therefore perfectly suited for CP/M® designs. The NEC μPD780 provides system designers with powerful, wide-range logic capability that requires minimal additional circuitry to complete a microcomputer system.

The output signals of the μPD780 are fully decoded and signal timing is fully compatible with industry-standard memory and peripheral devices. Two faster versions of the basic μPD780 (2.5 MHz master clock rate) are offered by the μPD780-1 (4 MHz master clock rate) and the μPD780-2 (6 MHz master clock rate). Other than clock rates, all three versions are identical.

Features

- ☐ Powerful, wide-range logic capability requiring minimal support circuitry
- ☐ Fully Z80® -compatible
- ☐ Industry-standard 8080A software compatibility
- ☐ CP/M® -compatible
- ☐ Comprehensive, powerful instruction set featuring 158 instruction types
- ☐ Vectored, multilevel interrupt structure
- ☐ Highly consistent architectural structure featuring dual register set
- ☐ Foreground/background programming
- ☐ Automatic refreshing of external dynamic memory
- ☐ Signal timing compatible with industry-standard memory and peripheral devices
- ☐ TTL-compatible signals
- ☐ Single-phase +5 V clock and +5 V DC power supply

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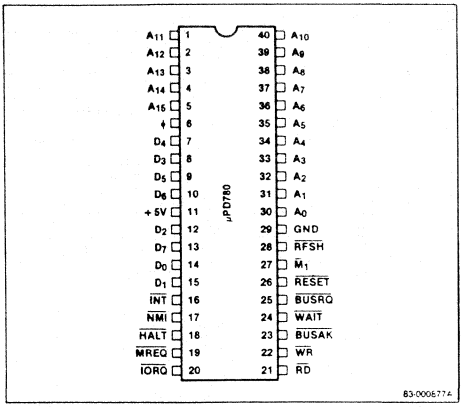
® CP/M is a registered trademark of Digital Research Corporation.

Pin Configuration



Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD780C	40-pin plastic DIP	2.5 MHz
μPD780C-1	40-pin plastic DIP	4 MHz
μPD780C-2	40-pin plastic DIP	6 MHz

Pin Identification

No.	Symbol	Function
1-5, 30-40	A_0-A_{15}	Three-state address bus (output)
6	ϕ	Clock input
7-10, 12-15	D_0-D_7	Three-state, I/O data bus
11	+5 V	Power supply
16	$\overline{INT}$	Interrupt request input
17	$\overline{NMI}$	Non-maskable interrupt input
18	$\overline{HALT}$	Halt state input
19	$\overline{MREQ}$	Memory request output
20	$\overline{IORQ}$	I/O request output
21	$\overline{RD}$	Read output
22	$\overline{WR}$	Write output
23	$\overline{BUSAK}$	Bus acknowledge output
24	$\overline{WAIT}$	Wait state input
25	$\overline{BUSRQ}$	Bus request input
26	$\overline{RESET}$	Reset input
27	$\overline{M_1}$	Machine cycle 1
28	$\overline{RFSH}$	Refresh output
29	GND	Ground

Pin Functions

A_0-A_{15} (Address Bus)

16-bit, three-state output address bus. During refresh operations, lines A_0-A_6 output the external memory address.

D_0-D_7 (Data Bus)

8-bit, three-state I/O data bus.

$\overline{NMI}$ (Non-Maskable Interrupt)

This active low input line is used for non-maskable interrupts. A non-maskable interrupt is always acknowledged at the end of the current instruction, regardless of whether the interrupt enable flip flop has been turned on, except when the $\overline{BUSRQ}$ signal is asserted. Because of the higher priority of the $\overline{BUSRQ}$ signal, it is acknowledged before the $\overline{NMI}$ signal. When $\overline{NMI}$ is acknowledged, program execution automatically restarts from location 0066H.

$\overline{INT}$ (Interrupt Request)

This active low input line is used for interrupt requests by external I/O devices. Interrupts are serviced upon completion of the current instruction if the interrupt enable flip flop has been turned on by the software. There are three interrupt response modes: the mode 0 response is equivalent to an 8080 interrupt response, mode 1 uses location 0038H as a restart address; and mode 2 is a simple vectoring to an interrupt service routine that can be located anywhere in memory.

$\overline{BUSRQ}$ (Bus Request)

This active low input signal is used to place the data bus, address bus, and all three-state bus control signals ($\overline{WR}$, $\overline{RD}$, $\overline{IORQ}$, and $\overline{MREQ}$) in a high-impedance state to allow a requesting device to assume bus control. The $\overline{BUSRQ}$ signal has a higher priority than the NMI signal and is always honored at the end of the current machine cycle.

Excessive DMA operations resulting in long periods in which $\overline{BUSRQ}$ is asserted can impair the CPU's ability to adequately refresh the dynamic RAMs. Also, $\overline{BUSRQ}$ does not have an internal pull-up resistor. For input signals to this pin in a wire-OR'ed configuration, an external pull-up resistor should be used.

$\overline{BUSAK}$ (Bus Acknowledge)

This active low output line is used to inform the device requesting bus control that the data bus, address bus, and all three-state bus controls ($\overline{WR}$, $\overline{RD}$, $\overline{IORQ}$, and $\overline{MREQ}$) are in a high-impedance state and the requesting device can now assume control.

$\overline{WR}$ (Write)

This three-state active low output is used to strobe data from the data bus to external memory or I/O devices. $\overline{WR}$ is asserted to indicate the data bus holds valid data. This line is three-stated during halt or reset conditions.

$\overline{IORQ}$ (I/O Request)

This three-state active low output is used to indicate the lower half of the address bus holds a valid address for an I/O read or write. During interrupt acknowledge cycles, $\overline{IORQ}$ and $\overline{M_1}$ are asserted together to indicate that a vector address can be sent to the data bus.

$\overline{RD}$ (Read)

This three-state active low output is used to strobe data from external memory or I/O devices onto the data bus. $\overline{RD}$ is asserted to indicate the CPU is requesting data from external memory or I/O devices. This line is three-stated during halt or reset conditions.

$\overline{MREQ}$ (Memory Request)

This three-state active low output is used to indicate that the address specified for the memory read or write is valid.

$\overline{M_1}$ (Machine Cycle 1)

This active low output is used to indicate that the current machine cycle is the opcode fetch phase of an instruction execution.

$\overline{HALT}$ (Halt State)

This active low input is used with the $\overline{HALT}$ instruction to initiate a halt state. When $\overline{HALT}$ is asserted, program execution stops and does not resume until an interrupt is generated. During the halt state, NOPs are executed in order to continue memory refresh operations.

$\overline{WAIT}$ (Wait State)

This active low input is used to indicate that the external memory or I/O devices addressed by the CPU are not ready to transfer data. When $\overline{WAIT}$ is asserted, the CPU is placed in a wait condition.

$\overline{RESET}$

This active low input signal is used to initialize the CPU. When $\overline{RESET}$ is asserted, the interrupt enable flip flop is reset, the program counter and the I and R registers are cleared, and interrupt response mode 0 is enabled. In a reset condition, the address and data busses are three-stated and all output control signals are inactive, after which program execution begins from address 0000.

The pulse width of $\overline{RESET}$ must be a minimum of 3 clock cycles in length to reinitialize the CPU and stabilize operation.

$\overline{RFSH}$ (Refresh)

This active low output is used in conjunction with the $\overline{MREQ}$ signal to initiate a refresh read of all external dynamic memory. $\overline{RFSH}$ and $\overline{MREQ}$ are both asserted when the least significant 7 bits of the address on the address bus hold a valid external dynamic memory address.

ϕ (Clock)

This line is an input for external clock sources.

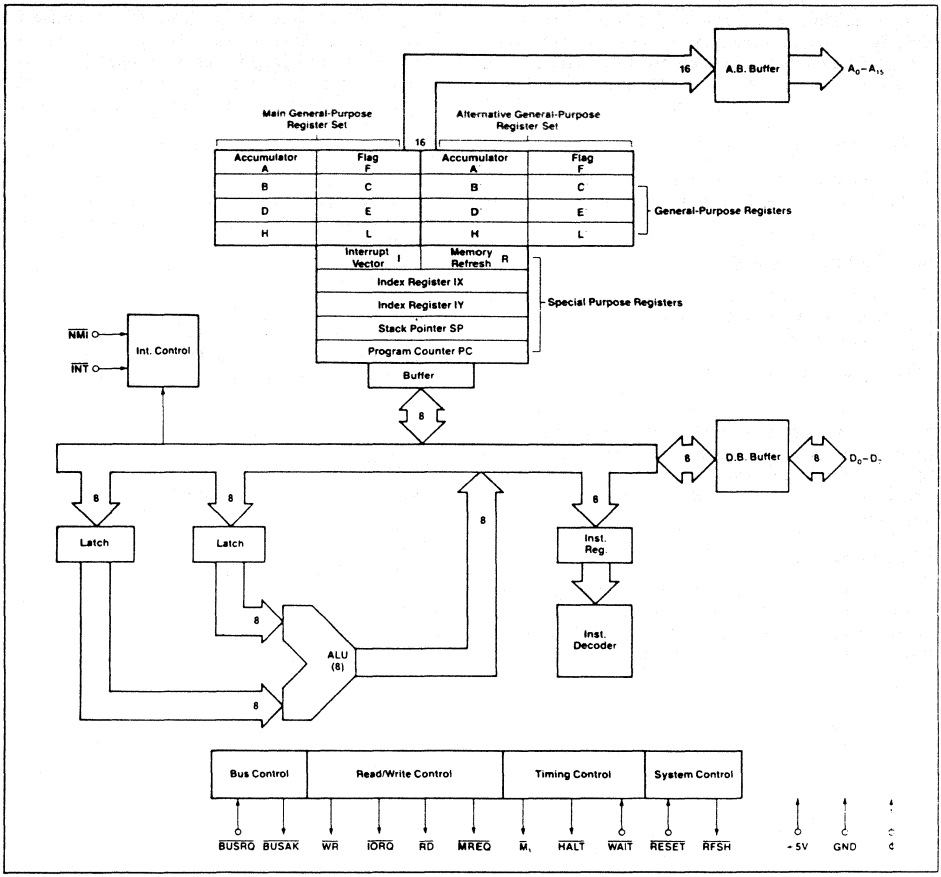
+5 V

Single +5 V power supply.

GND

Ground.

Block Diagram



Architecture

The architecture includes a dual set of six 8-bit general-purpose registers and two 8-bit accumulators and flag registers. A flexible vectored interrupt structure is supported by an 8-bit interrupt vector register that provides the most-significant 8 bits of a pointer to a table of vector addresses, while the requesting device generates the least-significant 8 bits of the pointer. Two 16-bit index registers enable the manipulation of tabular data as well as facilitating code relocation.

Multilevel interrupts as well as virtually unlimited subroutine nesting are supported by a 16-bit stack pointer and complimentary 16-bit program counter, enhancing the speed and efficiency of a wide variety of data-handling operations. Processing efficiency is additionally supported by a special memory refresh register that enables automatic refreshing of all external dynamic memory with minimal processor overhead.

The dual set of general-purpose registers may be used as individual 8-bit registers or paired as 16-bit registers. The dual register set (including a dual accumulator and flag register) not only allows more powerful addressing and data transfer operations, but also permits programming in foreground/background mode for vastly improved throughput.

Standard Test Conditions

The standard test conditions reference all voltages to ground (0 V) and follow the convention that positive current flows into the referenced pin. The listing of AC parameters is based on a load capacitance of 50 pF unless explicitly stated otherwise. For every 50 pF increase in load capacitance there is a 10 ns delay, up to a maximum increase of 200 pF for the data bus and 100 pF for the address bus and the bus control lines.

The operating temperature range is: 0°C to +70°C; $+4.75\ V \leq V_{CC} \leq +5.25\ V$.

Absolute Maximum Ratings

T_A = 25°C

Operating temperature	0°C to +70°C
Storage temperature	−65°C to +150°C
Voltage on any pin	−0.3 to +7 V (1)
Power dissipation	1.5 W

Note:

(1) With respect to ground.

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

T_A = 25°C

Parameter	Symbol	Limits Min	Max	Unit	Test Conditions
Clock capacitance	C_ϕ		35	pF	f_c = 1 MHz
Input capacitance	C_{IN}		5	pF	Unmeasured pins
Output capacitance	C_{OUT}		10	pF	returned to ground.

DC Characteristics

T_A = 0°C to +70°C; V_{CC} = +5 V ± 5% unless otherwise specified

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Clock input low voltage	V_{ILC}	−0.3		0.45	V	
Clock input high voltage	V_{IHC}	V_{CC} −0.6		V_{CC} +0.3	V	
Input low voltage	V_{IL}	−0.3		0.8	V	
Input high voltage	V_{IH}	2.0		V_{CC}	V	
Output low voltage	V_{OL}			0.4	V	I_{OL} = 1.8 mA
Output high voltage	V_{OH}	2.4			V	I_{OH} = −250 μA
Power supply Current μPD780	I_{CC}			150	mA	t_C = 400 ns
μPD780-1	I_{CC}		90	200	mA	t_C = 250 ns
Input leakage current	I_{LI}			10	μA	V_{IN} = 0 to V_{CC}
Three-state output leakage current in float	I_{LOH}			10	μA	V_{OUT} = 2.4 to V_{CC}
Three-state output leakage current in float	I_{LOL}			−10	μA	V_{OUT} = 0.4 V
Data bus leakage current in input mode	I_{LD}			±10	μA	$0 \leq V_{IN} \leq V_{CC}$

AC Characteristics

T_A = 0°C to +70°C; V_{CC} = +5 V ± 5%; unless otherwise specified

Parameter	Symbol	Limits μPD780 (2.5 MHz) Min	Max	μPD780-1(4 MHz) Min	Max	μPD780-2 (6 MHz) Min	Max	Unit	Test Conditions
Clock period	t_C	0.4	(1)	0.25	(1)	0.165	(1)	μs	
Clock pulse width, clock high	$t_{W(\phi H)}$	180	(2)	110	(2)	65	(2)	ns	
Clock pulse width, clock low	$t_{W(\phi L)}$	180	2000	110	2000	72	2000	ns	
Clock rise and fall time	t_{Rf}		30		30		20	ns	
Address output delay	$t_{D(AD)}$		145		110		90	ns	
Delay to float	$t_{F(AD)}$		110		90		80	ns	
Address stable prior to $\overline{MREQ}$ (Memory cycle)	t_{ACM}	(3)		(3)		(3)		ns	C_L = 50 pF
Address stable prior to $\overline{IORQ}$, $\overline{RD}$ or $\overline{WR}$ (I/O cycle)	t_{ACI}	(4)		(4)		(4)		ns	
Address stable from $\overline{RD}$ or $\overline{WR}$	t_{CA}	(5)		(5)		(5)		ns	
Address stable from $\overline{RD}$ or $\overline{WR}$ during Float	t_{CAF}	(6)		(6)		(6)		ns	
Data output delay	$t_{D(D)}$		230		150		130	ns	
Delay to float during write cycle	$t_{F(D)}$		90		90		80	ns	
Data setup time to rising edge of clock during M_1 cycle	$t_{S\phi(D)}$	50		35		30		ns	
Data setup time to falling edge of clock during M_2 to M_5 cycles	$t_{S\phi(D)}$	60		50		40		ns	C_L = 200 pF
Data stable prior to $\overline{WR}$ (Memory cycle)	t_{DCM}	(7)		(7)		(7)		ns	
Data stable prior to $\overline{WR}$ (I/O cycle)	t_{DCI}	(8)		(8)		(8)		ns	
Data stable from $\overline{WR}$	t_{CDF}	(9)		(9)		(9)		ns	
$\overline{BUSRQ}$ setup time to rising edge of clock	$t_{S(BQ)}$	80		50		50		ns	
$\overline{BUSAK}$ delay from rising edge of clock to $\overline{BUSAK}$ low	$t_{DL(BA)}$		120		100		90	ns	
$\overline{BUSAK}$ delay from falling edge of clock to $\overline{BUSAK}$ high	$t_{DH(BA)}$		110		100		90	ns	C_L = 50 pF
Delay to float ($\overline{MREQ}$, $\overline{IORQ}$, $\overline{RD}$ and $\overline{WR}$)	$t_{F(C)}$		100		80		70	ns	
$\overline{M_1}$ stable prior to $\overline{IORQ}$ (Interrupt ack.)	t_{MR}	(10)		(10)		(10)		ns	
Any hold time for setup time	t_H	0		0		0		ns	
$\overline{HALT}$ delay time from falling edge of clock	$t_{D(HT)}$		300		300		260	ns	C_L = 50 pF
$\overline{INT}$ setup time to rising edge of clock	$t_{S(IT)}$	80		80		70		ns	
$\overline{IORQ}$ delay from rising edge of clock to $\overline{IORQ}$ low	$t_{DL\phi(IR)}$		90		75		65	ns	
$\overline{IORQ}$ delay from falling edge of clock to $\overline{IORQ}$ low	$t_{DL\bar{\phi}(IR)}$		110		85		70	ns	
$\overline{IORQ}$ delay from rising edge of clock to $\overline{IORQ}$ high	$t_{DH\phi(IR)}$		100		85		70	ns	
$\overline{IORQ}$ delay from falling edge of clock to $\overline{IORQ}$ high	$t_{DH\bar{\phi}(IR)}$		110		85		70	ns	C_L = 50 pF
$\overline{M_1}$ delay from rising edge of clock to $\overline{M_1}$ low	$t_{DL(M_1)}$		130		100		80	ns	
$\overline{M_1}$ delay from rising edge of clock to $\overline{M_1}$ high	$t_{DH(M_1)}$		130		100		80	ns	
$\overline{MREQ}$ delay from falling edge of clock to $\overline{MREQ}$ low	$t_{DL\bar{\phi}(MR)}$		100		85		70	ns	
$\overline{MREQ}$ delay from rising edge of clock to $\overline{MREQ}$ high	$t_{DH\phi(MR)}$		100		85		70	ns	
$\overline{MREQ}$ delay from falling edge of clock to $\overline{MREQ}$ high	$t_{DH\bar{\phi}(MR)}$		100		85		70	ns	
Pulse width, $\overline{MREQ}$ low	$t_{W(MRL)}$	(11)		(11)		(11)		ns	
Pulse width, $\overline{MREQ}$ high	$t_{W(MRH)}$	(12)		(12)		(12)		ns	
Pulse width, $\overline{NMI}$ low	$t_{W(NML)}$	80		80		70		ns	
$\overline{RESET}$ setup time to rising edge of clock	$t_{S(RS)}$	90		60		60		ns	
$\overline{RD}$ delay from rising edge of clock to $\overline{RD}$ low	$t_{DL\phi(RD)}$		100		85		70	ns	
$\overline{RD}$ delay from falling edge of clock to $\overline{RD}$ low	$t_{DL\bar{\phi}(RD)}$		130		95		80	ns	
$\overline{RD}$ delay from rising edge of clock to $\overline{RD}$ high	$t_{DH\phi(RD)}$		100		85		70	ns	
$\overline{RD}$ delay from falling edge of clock to $\overline{RD}$ high	$t_{DH\bar{\phi}(RD)}$		110		85		70	ns	C_L = 30 pF

AC Characteristics (cont)

T_A = 0°C to +70°C; V_{CC} = +5 V ± 5%; unless otherwise specified

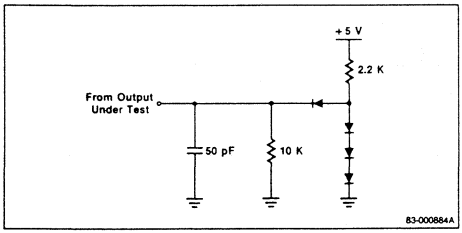
Parameter	Symbol	Limits μPD780 (2.5 MHz) Min	Max	μPD780-1(4 MHz) Min	Max	μPD780-2 (6 MHz) Min	Max	Unit	Test Conditions
$\overline{RFSH}$ delay from rising edge of clock to $\overline{RFSH}$ low	$t_{DL(RF)}$		180		130		110	ns	C_L = 30 pF
$\overline{RFSH}$ delay from rising edge of clock to $\overline{RFSH}$ high	$t_{DH(RF)}$		150		120		100	ns	
$\overline{WAIT}$ setup time to falling edge of clock	$t_{S(WT)}$	70		70		60		ns	
$\overline{WR}$ delay from rising edge of clock to $\overline{WR}$ low	$t_{DL\downarrow(WR)}$		80		65		60	ns	
$\overline{WR}$ delay from falling edge of clock $\overline{WR}$ low	$t_{DL\downarrow(WR)}$		90		80		70	ns	
$\overline{WR}$ delay from falling edge of clock to $\overline{WR}$ high	$t_{DH\downarrow(WR)}$		100		80		70	ns	
Pulse width to $\overline{WR}$ low	$t_{W(WRL)}$	(13)		(13)		(13)		ns	

Notes:

(1) $t_C = t_{W(\phi H)} + t_{W(\phi L)} + t_R + t_F$
(2) Though the structure of the 780 is static, 200μs is guaranteed maximum.
(3) $t_{ACM} = t_{W(\phi H)} + t_F - 65\ (75)^* - (50)^{**}$
(4) $t_{ACI} = t_C - 70\ (80)^* - (55)^{**}$
(5) $t_{CA} = t_{W(\phi L)} + t_R - 50\ (40)^* - (50)^{**}$
(6) $t_{CAF} = t_{W(\phi L)} + t_R - 45\ (60)^* - (40)^{**}$
(7) $t_{DCM} = t_C - 170\ (210)^* - (140)^{**}$
(8) $t_{DCI} = t_{W(\phi L)} + t_R - 170\ (210)^* - (140)^{**}$
(9) $t_{CDF} = t_{W(\phi L)} + t_R - 70\ (80)^* - (55)^{**}$
(10) $t_{MR} = 2t_C + t_{W(\phi H)} + t_F - 65\ (80)^* - (50)^{**}$
(11) $t_{W(MRL)} = t_C - 30\ (40)^* - (30)^{**}$
(12) $t_{W(MRH)} = t_{W(\phi H)} + t_F - 20\ (30)^* - (20)^{**}$
(13) $t_{W(WR)} = t_C - 30\ (40)^* - (30)^{**}$

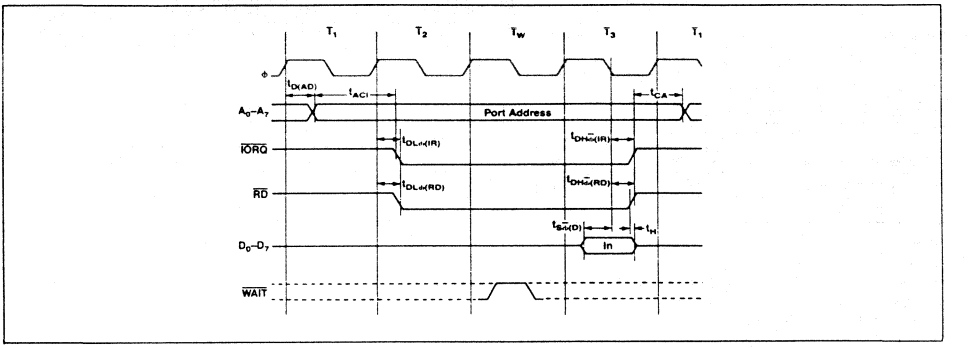
* These values apply to the μPD780.
** These values apply to the μPD780-2.

Load Circuit for Output

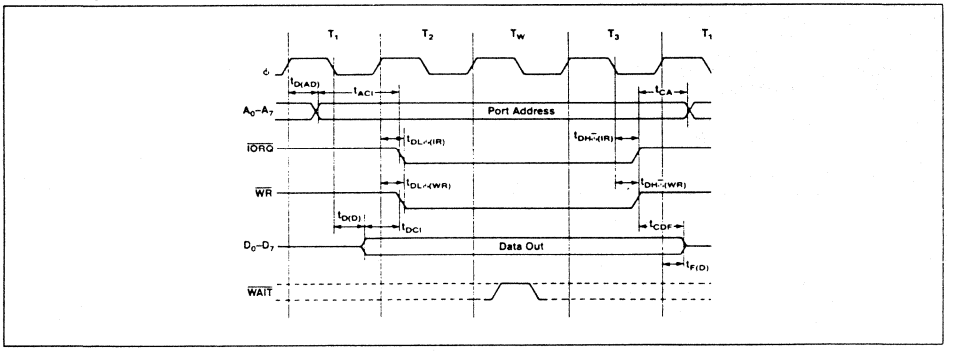


Timing Waveforms

Input Cycle

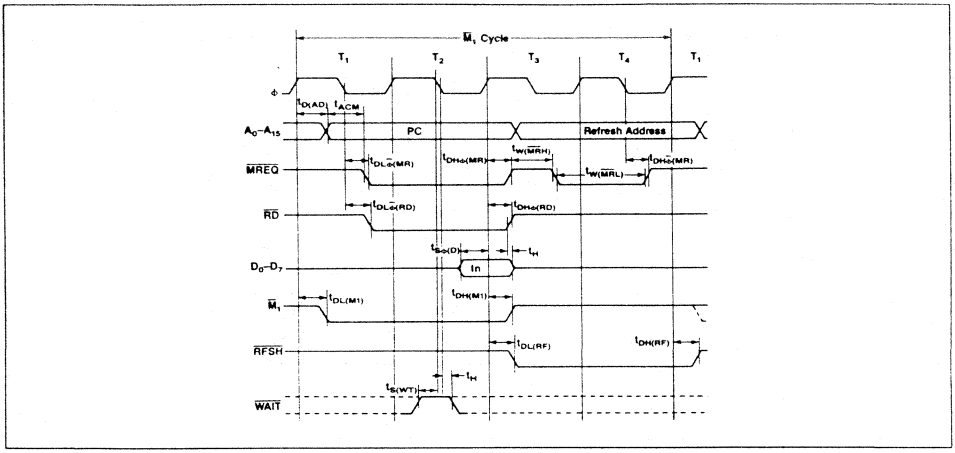


Output Cycle

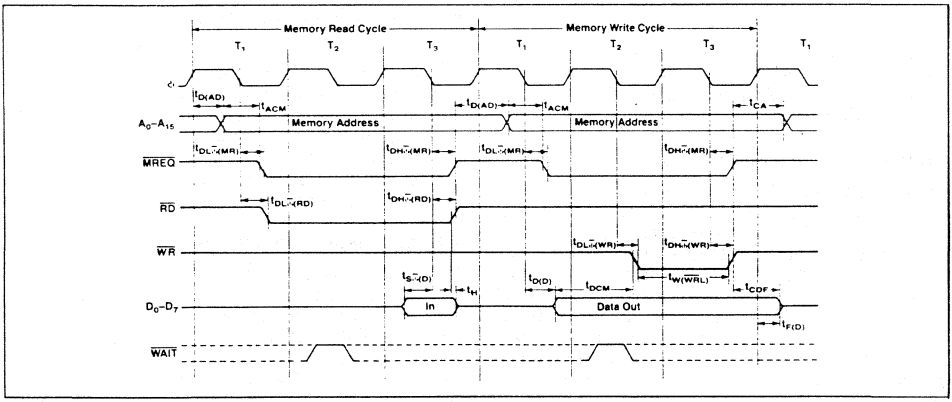


Timing Waveforms (cont)

M_1 Cycle

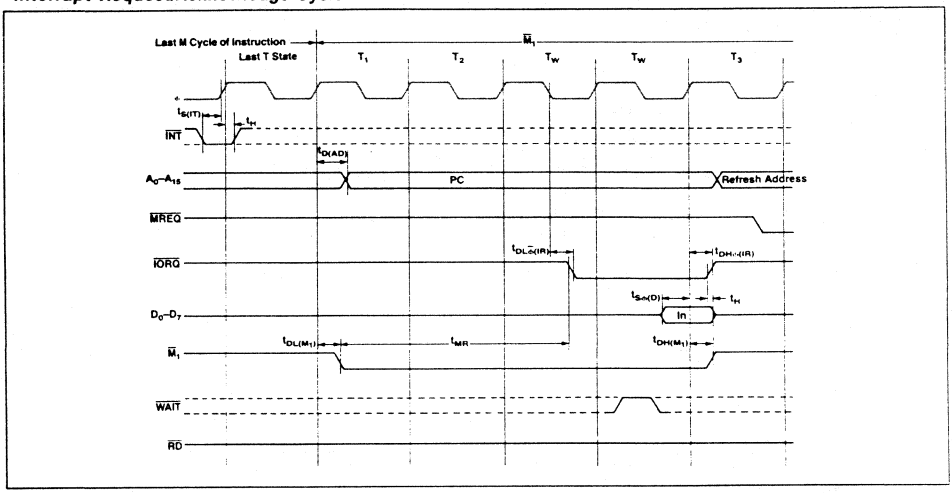


Memory Read/Write Cycles



Timing Waveforms (cont)

Interrupt Request/Acknowledge Cycle



Input and Output Cycles

In I/O operations, a single wait state (T_W) is automatically included to provide adequate time for an I/O port to decode the address from the port address lines and initiate a wait condition if needed.

Opcode Fetch Instruction Cycle

At the beginning of the cycle, the contents of the program counter are placed on the address bus. After approximately one-half cycle, $\overline{MREQ}$ is asserted and its falling edge can be used directly by the external memory as a chip enable signal. The data from the external memory can be gated onto the data bus when $\overline{RD}$ is asserted. The CPU reads the data at the rising edge of T_3. During T_3 and T_4, external dynamic memory is refreshed while the instruction is decoded and executed. The assertion of $\overline{RFSH}$ indicates that the external dynamic memory requires a refresh read.

Memory Read or Write Cycles

In read and write operations, the $\overline{MREQ}$ and $\overline{RD}$ signals function the same as they do in opcode fetch operations. In a write operation $\overline{MREQ}$ is asserted and can be used directly by external memory as a chip enable signal when information on the address bus is stable. The $\overline{WR}$ signal is used as a write strobe to almost any type of semiconductor memory, and is asserted when data on the data bus is stable.

Interrupt Request/Acknowledge Cycle

The interrupt signal is sampled at the rising edge of the final clock pulse at the end of an instruction. When an interrupt is accepted, an M_1 cycle is begun. Instead of $\overline{MREQ}$, $\overline{IORQ}$ is asserted during this cycle to indicate that an 8-bit vector address can be placed on the data bus by the interrupting device. This cycle includes the automatic addition of two wait states to facilitate the implementation of a daisy-chain priority interrupt protocol.

Instruction Set

The instruction set of the μPD780 consists of 158 types of instructions divided into 16 categories as follows:

- 8-bit load operations
- register exchanges
- memory block searches
- 16-bit arithmetic operations
- rotate and shift operations
- jump operations
- restart operations
- miscellaneous operations
- 16-bit load operations
- memory block transfers
- 8-bit arithmetic and logic operations
- bit set, reset, and test operations
- I/O operations
- call operations
- return operations
- general-purpose accumulator and flag operations

This comprehensive instruction set is made more powerful by the array of addressing modes implemented by the architecture, as follows:

- bit addressing
- register-indirect addressing
- immediate addressing
- extended addressing
- implied addressing
- register addressing
- relative addressing
- immediate-extended addressing
- indexed addressing
- modified page zero addressing

Instruction Set Symbol Definitions

Symbol	Description
•	Flag not affected
0	Flag set
X	Flag
↕	Flag affected according to result of operation
V	Overflow set
P	Parity set
IFF	Interrupt flip-flop set
C	Carry/Link
Z	Zero
P/V	Parity/Overflow
S	Sign
N	Add/Subtract
H	Half Carry

Instruction Set

Mnemonic	Operation	Description	Operation Code 7	6	5	4	3	2	1	0	No. of Clocks	No. of Bytes	Flags C	Z	P/V	S	N	H
ADC HL, ss	HL ← HL + ss + CY	Add with carry reg. pair ss to HL	1	1	1	0	1	1	0	1 (A)	15	1	↕	↕	V	↕	0	X
			0	1	s	s	1	0	1	0								
ADC A, r	A ← A + r + CY	Add with carry Reg. r to ACC	1	0	0	0	1	r	r	r (B)	4	1	↕	↕	V	↕	0	↕
ADC A, n	A ← A + n + CY	Add with carrry value n to ACC	1	1	0	0	1	1	1	0	7	2	↕	↕	V	↕	0	↕
			n	n	n	n	n	n	n	n								
ADC A, (HL)	A ← A + (HL) + CY	Add with carry loc. (HL) to ACC	1	0	0	0	1	1	1	0	7	1	↕	↕	V	↕	0	↕
ADC A, (IX + d)	A ← A + (IX + d) + CY	Add with carry loc. (IX + d) to ACC	1	1	0	1	1	1	0	1	19	3	↕	↕	V	↕	0	↕
			1	0	0	0	1	1	1	0								
			d	d	d	d	d	d	d	d								
ADC A, (IY + d)	A ← A + (IY + d) + CY	Add with carry loc. (IY + d) to ACC	1	1	1	1	1	1	0	1	19	3	↕	↕	V	↕	0	↕
			1	0	0	0	1	1	1	0								
			d	d	d	d	d	d	d	d								
ADD A, n	A ← A + n	Add value n to ACC	1	1	0	0	0	1	1	0	7	2	↕	↕	V	↕	0	↕
			n	n	n	n	n	n	n	n								
ADD A, r	A ← A + r	Add Reg. r to ACC	1	0	0	0	0	r	r	r (B)	4	1	↕	↕	V	↕	0	↕
ADD A, (HL)	A ← A + (HL)	Add location (HL) to ACC	1	0	0	0	0	1	1	0	7	1	↕	↕	V	↕	0	↕
ADD A, (IX + d)	A ← A + (IX + d)	Add location (IX + d) to ACC	1	1	0	1	1	1	0	1	19	3	↕	↕	V	↕	0	↕
			1	0	0	0	0	1	1	0								
			d	d	d	d	d	d	d	d								
ADD A, (IY + d)	A ← A + (IY + d)	Add location (IY + d) to ACC	1	1	1	1	1	1	0	1	19	3	↕	↕	V	↕	0	↕
			1	0	0	0	0	1	1	0								
			d	d	d	d	d	d	d	d								
ADD HL, ss	HL ← HL + ss	Add Reg. pair ss to HL	0	0	s	s	1	0	0	1 (A)	11	1	↕	•	•	•	0	X
ADD IX, pp	IX ← IX + pp	Add Reg. pair pp to IX	1	1	0	1	1	1	0	1 (C)	15	2	↕	•	•	•	0	X
			0	0	p	p	1	0	0	1								
ADD IY, rr	IY ← IY + rr	Add Reg. pair rr to IY	1	1	1	1	1	1	0	1 (D)	15	2	↕	•	•	•	0	X
			0	0	r	r	1	0	0	1								
AND r	A ← A ∧ r	Logical 'AND' of Reg. r ∧ ACC	1	0	1	0	0	r	r	r (B)	4	1	0	↕	P	↕	0	↕
AND n	A ← A ∧ n	Logical 'AND' of value n ∧ ACC	1	1	1	0	0	1	1	0	7	2	0	↕	P	↕	0	↕
			n	n	n	n	n	n	n	n								
AND (HL)	A ← A ∧ (HL)	Logical 'AND' of loc. (HL) ∧ ACC	1	0	1	0	0	1	1	0	7	1	0	↕	P	↕	0	↕
AND (IX + d)	A ← A ∧ (IX + d)	Logical 'AND' of loc. (IX + d) ∧ ACC	1	1	0	1	1	1	0	1	19	3	0	↕	P	↕	0	↕
			1	0	1	0	0	1	1	0								
			d	d	d	d	d	d	d	d								
AND (IY + d)	A ← A ∧ (IY + d)	Logical 'AND' of loc. (IY + d) ∧ ACC	1	1	1	1	1	1	0	1	19	3	0	↕	P	↕	0	↕
			1	0	1	0	0	1	1	0								
			d	d	d	d	d	d	d	d								

Instruction Set (cont)

Mnemonic	Operation	Description	Operation Code 7 6 5 4 3 2 1 0	No. of Clocks	No. of Bytes	Flags C	Z	P/V	S	N	H
CPIR	A – (HL) HL ← HL + 1 BC ← BC – 1 until A = (HL) or BC = 0	Compare location (HL) and ACC, increment HL, decrement BC Repeat until BC = C	1 1 1 0 1 1 0 1 1 0 1 1 0 0 0 1	21 if BC = 0 and A≠(HL) 16 if BC = 0 or A = (HL)	2	•	‡(2)	‡(1)	‡	1	‡
CPL	A← Ā	Complement ACC (1's comp.)	0 0 1 0 1 1 1 1	4	1	•	•	•	•	1	1
DAA		Decimal adjust ACC	0 0 1 0 0 1 1 1	4	1	‡	‡	P	‡	•	‡
DEC r	r ← r – 1	Decrement Reg. r	0 0 r r r 1 0 1 (B)	4	1	•	‡	V	‡	1	‡
DEC (HL)	(HL) ← (HL) – 1	Decrement loc. (HL)	0 0 1 1 0 1 0 1	11	1	•	‡	V	‡	1	‡
DEC (IX + d)	(IX + d) ← (IX + d) – 1	Decrement loc. (IX + d)	1 1 0 1 1 1 0 1 0 0 1 1 0 1 0 1 d d d d d d d d	23	3	•	‡	V	‡	1	‡
DEC (IY + d)	(IY + d) ← (IY + d) –1	Decrement loc. (IY + d)	1 1 1 1 1 1 0 1 0 0 1 1 0 1 0 1 d d d d d d d d	23	3	•	‡	V	‡	1	‡
DEC IX	IX ← IX – 1	Decrement IX	1 1 0 1 1 1 0 1 0 0 1 0 1 0 1 1	10	2	•	•	•	•	•	•
DEC IY	IY ← IY – 1	Decrement IY	1 1 1 1 1 1 0 1 0 0 1 0 1 0 1 1	10	2	•	•	•	•	•	•
DEC ss	ss ← ss – 1	Decrement Reg. pair ss	0 0 s s 1 0 1 1 (A)	6	1	•	•	•	•	•	•
DI	IFF ← 0	Disable interrupts	1 1 1 1 0 0 1 1	4	1	•	•	•	•	•	•
DJNZ, e	B ← B – 1 if B = 0 continue if B ≠ 0, PC ← PC + e	Decrement B and jump relative if B = 0	0 0 0 1 0 0 0 0 ← e-2 →	8	2	•	•	•	•	•	•
EI	IFF ← 1	Enable interrupts	1 1 1 1 1 0 1 1	4	1	•	•	•	•	•	•
EX (SP), HL	H ↔ (SP + 1), L ↔ (SP)	Exchange the location (SP) and HL	1 1 1 0 0 0 1 1	19	1	•	•	•	•	•	•
EX (SP), IX	IX_H ↔ (SP + 1) IX_L ↔ (SP)	Exchange the location (SP) and IX	1 1 0 1 1 1 0 1 1 1 1 0 0 0 1 1	23	2	•	•	•	•	•	•
EX (SP), IY	IY_H ↔ (SP + 1) IY_L ↔ (SP)	Exchange the location (SP) and IY	1 1 1 1 1 1 0 1 1 1 1 0 0 0 1 1	23	2	•	•	•	•	•	•
EX AF, AF'	AF ↔ AF'	Exchange the contents of AF, AF'	0 0 0 0 1 0 0 0	4	1	•	•	•	•	•	•
EX DE, HL	DE ↔ HL	Exchange the contents of DE and HL	1 1 1 0 1 0 1 1	4	1	•	•	•	•	•	•
EXX	BC ↔ BC' DE ↔ DE', HL ↔ HL'	Exchange the contents of BC, DE, HL with contents of BC', DE', HL', respectively	1 1 0 1 1 0 0 1	4	1	•	•	•	•	•	•
HALT	Processor Halted	HALT (wait for interrupt or reset)	0 1 1 1 0 1 1 0	4	1	•	•	•	•	•	•

Instruction Set (cont)

Mnemonic	Operation	Description	Operation Code 7 6 5 4 3 2 1 0	No. of Clocks	No. of Bytes	Flags C	Z	P/V	S	N	H
BIT b, (HL)	$Z \leftarrow (\overline{HL})_b$	Test BIT b of location (HL)	1 1 0 0 1 0 1 1 (E) 0 1 b b b 1 1 0	12	2	•	‡	X	X	0	1
BIT b, (IX + d)	$Z \leftarrow (\overline{IX + d})_b$	Test BIT b at location (IX + d)	1 1 0 1 1 1 0 1 (E) 1 1 0 0 1 0 1 1 d d d d d d d d 0 1 b b b 1 1 0	20	4	•	‡	X	X	0	1
BIT b, (IY + d)	$Z \leftarrow (\overline{IY + d})_b$	Test BIT b at location (IY + d)	1 1 1 1 1 1 0 1 (E) 1 1 0 0 1 0 1 1 d d d d d d d d 0 1 b b b 1 1 0	20	4	•	‡	X	X	0	1
BIT b, r	$Z \leftarrow \bar{r}_b$	Test BIT of Reg. r	1 1 0 0 1 0 1 1 0 1 b b b r r r (B) (E)	8	2	•	‡	X	X	0	1
CALL cc, nn	If condition cc false continues, else same as CALL nn	Call subroutine at location nn if condition cc is true	1 1 ← cc → 1 0 0 (H) n n n n n n n n n n n n n n n n	10	3	•	•	•	•	•	•
CALL nn	(SP − 1) ← PC_H (SP − 2) ← PC_L PC ← nn	Unconditional call subroutine at location nn	1 1 0 0 1 1 0 1 n n n n n n n n n n n n n n n n	17	3	•	•	•	•	•	•
CCF	CY ← CY	Complement carry flag	0 0 1 1 1 1 1 1	4	1	‡	•	•	•	0	X
CP r	A − r	Compare Reg. r with ACC	1 0 1 1 1 r r r (B)	4	1	‡	‡	V	‡	1	‡
CP n	A − n	Compare value n with ACC	1 1 1 1 1 1 1 0 n n n n n n n n	7	2	‡	‡	V	‡	1	‡
CP (HL)	A − (HL)	Compare loc. (HL) with ACC	1 0 1 1 1 1 1 0	7	1	‡	‡	V	‡	1	‡
CP (IX + d)	A − (IX + d)	Compare loc. (IX + d) with ACC	1 1 0 1 1 1 0 1 1 0 1 1 1 1 1 0 d d d d d d d d 1 1 1 1 1 1 1 0 1	19	4	‡	‡	V	‡	1	‡
CP (IY + d)		Compare loc. (IY + d) with ACC	1 0 1 1 1 1 1 0 d d d d d d d d	19	2	‡	‡	V	‡	1	‡
CPD	A − (HL) HL ← HL − 1 BC ← BC − 1	Compare location (HL) and ACC, decrement HL and BC	1 1 1 0 1 1 0 1 1 0 1 0 1 0 0 1	16	2	•	‡(2)	‡(1)	‡	1	‡
CPDR	A − (HL) HL ← HL − 1 BC ← BC − 1 until A = (HL) or BC = 0	Compare location (HL) and ACC, decrement HL and BC, repeat until BC = 0	1 1 1 0 1 1 0 1 1 0 1 1 1 0 0 1	21 if BC = 0 and A ≠ (HL) 16 if BC = 0 or A = (HL)	2	•	‡(2)	‡(1)	‡	1	‡
CPI	A − (HL) HL ← HL + 1, BC ← BC − 1	Compare location (HL) and ACC, increment HL and decrement BC	1 1 1 0 1 1 0 1 1 0 1 0 0 0 0 1	16	2	•	‡(2)	‡(1)	‡	1	‡

Instruction Set (cont)

Mnemonic	Operation	Description	Operation Code 7 6 5 4 3 2 1 0	No. of Clocks	No. of Bytes	Flags C	Z	P/V	S	N	H
IM 0		Set interrupt mode 0	1 1 1 0 1 1 0 1 0 1 0 0 0 1 1 0	8	2	•	•	•	•	•	•
IM 1		Set interrupt mode 1	1 1 1 0 1 1 0 1 0 1 0 1 0 1 1 0	8	2	•	•	•	•	•	•
IM 2		Set interrupt mode 2	1 1 1 0 1 1 0 1 0 1 0 1 1 1 1 0	8	2	•	•	•	•	•	•
IN A, (n)	A ← (n)	Load ACC with input from device n	1 1 0 1 1 0 1 1 n n n n n n n n	11	2	•	•	•	•	•	•
IN r, (C)	r ← (C)	Load Reg. r with input from device (C)	1 1 1 0 1 1 0 1 (1) 0 1 r r r 0 0 0	12	2	•	‡	P	‡	0	‡
INC (HL)	(HL) ← (HL) + 1	Increment location (HL)	0 0 1 1 0 1 0 0	11	1	•	‡	V	‡	0	‡
INC IX	IX ← IX + 1	Increment IX	1 1 0 1 1 1 0 1 0 0 1 0 0 0 1 1	10	2	•	•	•	•	•	•
INC (IX + d)	(IX + d) ← (IX + d) + 1	Increment location (IX + d)	1 1 0 1 1 1 0 1 0 0 1 1 0 1 0 0 d d d d d d d d	23	3	•	‡	V	‡	0	‡
INC IY	IY ← IY + 1	Increment IY	1 1 1 1 1 1 0 1 0 0 1 0 0 0 1 1	10	2	•	•	•	•	•	•
INC (IY + d)	(IY + d) ← (IY + d) + 1	Increment location (IY + d)	1 1 1 1 1 1 0 1 0 0 1 1 0 1 0 0 d d d d d d d d	23	3	•	‡	V	‡	0	‡
INC r	r ← r + 1	Increment Reg. r	0 0 r r r 1 0 0 (B)	4	1	•	‡	V	‡	0	‡
INC ss	ss ← ss + 1	Increment Reg. pair ss	0 0 s s 0 0 1 1 (A)	6	1	•	•	•	•	•	•
IND	(HL) ← (C) B ← B′ − 1, HL ← HL − 1	Load location (HL) with input from port (C), decrement HL and B	1 1 1 0 1 1 0 1 1 0 1 0 1 0 1 0	16	2	•	‡(3)	X	X	1	X
INDR	(HL) ← (C) B ← B − 1 HL ← HL − 1 until B = 0	Load location (HL) with input from port (C), decrement HL and decrement B, repeat until B = 0	1 1 1 0 1 1 0 1 1 0 1 1 1 0 1 0	21	2	•	1	X	X	1	X
INI	(HL) ← (C) B ← B − 1, HL ← HL + 1	Load location (HL) with input from port (C), and increment HL and decrement B	1 1 1 0 1 1 0 1 1 0 1 0 0 0 1 0	16	2	•	‡(3)	X	X	1	X
INIR	(HL) ← (C) B ← B − 1 HL ← HL + 1 until B = 0	Load location (HL) with input from port (C), increment HL and decrement B, repeat until B = 0	1 1 1 0 1 1 0 1 1 0 1 1 0 0 1 0	21	2	•	1	X	X	1	X
JP (HL)	PC ← HL	Unconditional jump to (HL)	1 1 1 0 1 0 0 1	4	1	•	•	•	•	•	•
JP (IX)	PC ← IX	Unconditional jump to (IX)	1 1 0 1 1 1 0 1 1 1 1 0 1 0 0 1	8	2	•	•	•	•	•	•
JP (IY)	PC ← IY	Unconditional jump to (IY)	1 1 1 1 1 1 0 1 1 1 1 0 1 0 0 1	8	2	•	•	•	•	•	•

Instruction Set (cont)

Mnemonic	Operation	Description	Operation Code 7 6 5 4 3 2 1 0	No. of Clocks	No. of Bytes	Flags C	Z	P/V	S	N	H
JP cc, nn	If cc true PC ← nn else continue	Jump to location nn if continue cc	1 1 ← cc → 0 1 0 (H) n n n n n n n n n n n n n n n n	10	3	•	•	•	•	•	•
JP nn	PC ← nn	Unconditional jump to location nn	1 1 0 0 0 0 1 1 n n n n n n n n n n n n n n n n	10	3	•	•	•	•	•	•
JR C, e	If C = 0 continue If C = 1 PC ← PC + e	Jump relative to PC + e, if carry = 1	0 0 1 1 1 0 0 0 ← e-2 →	7 if condition met, 12 if not	2	•	•	•	•	•	•
JR e	PC ← PC + e	Unconditional jump relative to PC + e	0 0 0 1 1 0 0 0 ← e-2 →	12	2	•	•	•	•	•	•
JR NC, e	If C = 1 continue If C = 0 PC ← PC + e	Jump relative to PC + e if carry = 0	0 0 1 1 0 0 0 0 ← e-2 →	7	2	•	•	•	•	•	•
JR NZ, e	If Z = 1 continue	Jump relative to PC + e if non-zero (Z = 0)	0 0 1 0 0 0 0 0 ← e-2 →	7	2	•	•	•	•	•	•
JR Z, e	if Z = 0 continue	Jump relative to PC + e if zero (Z = 1)	0 0 1 0 1 0 0 0 ← e-2 →	7	2	•	•	•	•	•	•
LD A, (BC)	A ← (BC)	Load ACC with location (BC)	0 0 0 0 1 0 1 0	7	1	•	•	•	•	•	•
LD A, (DE)	A ← (DE)	Load ACC with location (DE)	0 0 0 1 1 0 1 0	7	1	•	•	•	•	•	•
LD A, I	A ← I	Load ACC with I	1 1 1 0 1 1 0 1 0 1 0 1 0 1 1 1	9	2	•	‡	IFF	‡	0	0
LD A, (nn)	A ← (nn)	Load ACC with location nn	0 0 1 1 1 0 1 0 n n n n n n n n n n n n n n n n	13	3	•	•	•	•	•	•
LD A, R	A ← R	Load ACC with Reg. R	1 1 1 0 1 1 0 1 0 1 0 1 1 1 1 1	9	2	•	‡	IFF	‡	0	0
LD (BC), A	(BC) ← A	Load location (BC) with ACC	0 0 0 0 0 0 1 0	7	1	•	•	•	•	•	•
LD (DE), A	(DE) ← A	Load location (DE) with ACC	0 0 0 1 0 0 1 0	7	1	•	•	•	•	•	•
LD (HL), n	(HL) ← n	Load location (HL) with value n	0 0 1 1 0 1 1 0 n n n n n n n n	10	2	•	•	•	•	•	•
LD ss, nn	ss ← nn	Load Reg. pair ss with value nn	0 0 s s 0 0 0 1 (A) n n n n n n n n n n n n n n n n	20	4	•	•	•	•	•	•
LD HL, (nn)	H ← (nn + 1)	Load HL with location (nn)	0 0 1 0 1 0 1 0 n n n n n n n n n n n n n n n n	16	3	•	•	•	•	•	•
LD (HL), r	(HL) ← r	Load location (HL) with Reg. r	0 1 1 1 0 r r r (B)	7	1	•	•	•	•	•	•
LD I, A	I ← A	Load I with ACC	1 1 1 0 1 1 0 1 0 1 0 0 0 1 1 1	9	2	•	•	•	•	•	•

Instruction Set (cont)

Mnemonic	Operation	Description	Operation Code 7	6	5	4	3	2	1	0	No. of Clocks	No. of Bytes	Flags C	Z	P/V	S	N	H
LD IX, nn	IX ← nn	Load IX with value nn	1	1	0	1	1	1	0	1	19	4	•	•	•	•	•	•
			0	0	1	0	0	0	0	1								
			n	n	n	n	n	n	n	n								
			n	n	n	n	n	n	n	n								
LD IX, (nn)	IX_H ← (nn + 1) IX_L ← (nn)	Load IX with location (nn)	1	1	0	1	1	1	0	1	20	4	•	•	•	•	•	•
			0	0	1	0	1	0	1	0								
			n	n	n	n	n	n	n	n								
			n	n	n	n	n	n	n	n								
LD (IX + d), n	(IX + d) ← n	Load location (IX + d) with value n	1	1	0	1	1	1	0	1	19	4	•	•	•	•	•	•
			0	0	1	1	0	1	1	0								
			d	d	d	d	d	d	d	d								
			n	n	n	n	n	n	n	n								
LD (IX + d), r	(IX + d) ← r	Load location (IX + d) with Reg. r	1	1	0	1	1	1	0	1 (B)	19	3	•	•	•	•	•	•
			0	1	1	1	0	r	r	r								
			d	d	d	d	d	d	d	d								
LD IY, nn	IY ← nn	Load IY with value nn	1	1	1	1	1	1	0	1	14	4	•	•	•	•	•	•
			0	0	1	0	0	0	0	1								
			n	n	n	n	n	n	n	n								
			n	n	n	n	n	n	n	n								
LD IY, (nn)	IY_H ← (nn + 1) IY_L ← (nn)	Load IY with location (nn)	1	1	1	1	1	1	0	1	20	4	•	•	•	•	•	•
			0	0	1	0	1	0	1	0								
			n	n	n	n	n	n	n	n								
			n	n	n	n	n	n	n	n								
LD ss, (nn)	ss_H ← (nn + 1) ss_L ← (nn)	Load Reg. pair dd with location (nn)	1	1	1	0	1	1	0	1 (A)	20	4	•	•	•	•	•	•
			0	1	s	s	1	0	1	1								
			n	n	n	n	n	n	n	n								
			n	n	n	n	n	n	n	n								
LD (IY + d), n	(IY + d) ← n	Load (IY + d) with value n	1	1	1	1	1	1	0	1	19	4	•	•	•	•	•	•
			0	0	1	1	0	1	1	0								
			d	d	d	d	d	d	d	d								
			n	n	n	n	n	n	n	n								
LD (IY + d), r	(IY + d) ← r	Load location (IY + d) with Reg. r	1	1	1	1	1	1	0	1 (B)	19	3	•	•	•	•	•	•
			0	1	1	1	0	r	r	r								
			d	d	d	d	d	d	d	d								
LD (nn), A	(nn) ← A	Load location (nn) with ACC	0	0	1	1	0	0	1	0	13	3	•	•	•	•	•	•
			n	n	n	n	n	n	n	n								
			n	n	n	n	n	n	n	n								
LD (nn), ss	(nn + 1) ← ss_H (nn) ← ss_L	Load location (nn) with Reg. pair dd	1	1	1	0	1	1	0	1 (A)	20	4	•	•	•	•	•	•
			0	1	s	s	0	0	1	1								
			n	n	n	n	n	n	n	n								
			n	n	n	n	n	n	n	n								

Instruction Set (cont)

Mnemonic	Operation	Description	Operation Code 7	6	5	4	3	2	1	0	No. of Clocks	No. of Bytes	Flags C	Z	P/V	S	N	H
LD (nn), HL	(nn + 1) ← H (nn) ← L	Load location (nn) with HL	0	0	1	0	0	0	1	0	16	3	•	•	•	•	•	•
			n	n	n	n	n	n	n	n								
			n	n	n	n	n	n	n	n								
LD (nn), IX	(nn + i) ← IX_H (nn) ← IX_L	Load location (nn) with IX	1	1	0	1	1	1	0	1	20	4	•	•	•	•	•	•
			0	0	1	0	0	0	1	0								
			n	n	n	n	n	n	n	n								
			n	n	n	n	n	n	n	n								
LD(nn), IY	(nn +1) ← IY_H (nn) ← IY_L	Load location (nn) with IY	1	1	1	1	1	1	0	1	20	4	•	•	•	•	•	•
			0	0	1	0	0	0	1	0								
			n	n	n	n	n	n	n	n								
			n	n	n	n	n	n	n	n								
LD R, A	R ← A	Load R with ACC	1	1	1	0	1	1	0	1	9	2	•	•	•	•	•	•
			0	1	0	0	1	1	1	1								
LD r, (HL)	r ← (HL)	Load Reg. r with location (HL)	0	1	r	r	r	1	1	0 (B)	7	1	•	•	•	•	•	•
LD r, (IX + d)	r ← (IX + d)	Load Reg. r with location (IX + d)	1	1	0	1	1	1	0	1 (B)	19	3	•	•	•	•	•	•
			0	1	r	r	r	1	1	0								
			d	d	d	d	d	d	d	d								
LD r, (IY +d)	r ← (IY +d)	Load Reg. r with location (IY + d)	1	1	1	1	1	1	0	1 (B)	19	3	•	•	•	•	•	•
			0	1	r	r	r	1	1	0								
			d	d	d	d	d	d	d	d								
LD r, n	r ←n	Load Reg. r with value n	0	0	r	r	r	1	1	0 (B)	7	2	•	•	•	•	•	•
			n	n	n	n	n	n	n	n								
LD, r, r'	r ← r'	Load Reg. r with Reg. r'	0	1	r	r	r	r'	r'	r' (F)	4	1	•	•	•	•	•	•
LD SP, HL	SP ← HL	Load SP with HL	1	1	1	1	1	0	0	1	6	1	•	•	•	•	•	•
LD SP, IX	SP ← IX	Load SP with IX	1	1	0	1	1	1	0	1	10	2	•	•	•	•	•	•
			1	1	1	1	1	0	0	1								
LD SP, IY	SP ← IY	Load SP with IY	1	1	1	1	1	1	0	1	10	2	•	•	•	•	•	•
			1	1	1	1	1	0	0	1								
LDD	(DE) ← (HL) DE ← DE − 1 HL ← HL − 1, BC ← BC − 1	Load location (DE) with location (HL), decrement DE, HL and BC	1	1	1	0	1	1	0	1	16	2	•	•	‡	•	0	0
			1	0	1	0	1	0	0	0								
LDDR	(DE) ← (HL) DE ← DE − 1 HL ← HL − 1, BC ← BC − 1 until BC = 0	Load location (DE) with location (HL)	1	1	1	0	1	1	0	1	21	2	•	•	0	•	0	0
			1	0	1	1	1	0	0	0								

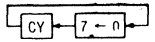
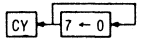
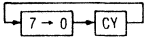
Instruction Set (cont)

Mnemonic	Operation	Description	Operation Code 7 6 5 4 3 2 1 0	No. of Clocks	No. of Bytes	Flags C	Z	P/V	S	N	H
LDI	(DE) ← (HL) DE ← DE + 1 HL ← HL + 1 BC ← BC − 1	Load location (DE) with location (HL), increment DE, HL; decrement BC	1 1 1 0 1 1 0 1 1 0 1 0 0 0 0 0	16	2	•	•	‡(T)	•	0	0
LDIR	(DE) ← (HL) DE ← DE + 1 HL ← HL + 1 BC ← BC − 1 until BC = 0	Load location (DE) with location (HL); increment DE, HL, decrement BC and repeat until BC = 0	1 1 1 0 1 1 0 1 1 0 1 1 0 0 0 0	21 if BC ≠ 0 16 if BC = 0	2	•	•	0	•	0	0
NEG	A ← 0 − A	Negate ACC (2's complement)	1 1 1 0 1 1 0 1 0 1 0 0 0 1 0 0	8	2	‡	‡	V	‡	1	‡
NOP		No operation	0 0 0 0 0 0 0 0	4	1	•	•	•	•	•	•
OR r	A ← AV r	Logical 'OR' of Reg. r and ACC	1 0 1 1 0 r r r (B)	4	1	0	‡	P	‡	0	‡
OR n	A ← AV n	Logical 'OR' of value n and ACC	1 1 1 1 0 1 1 0 n n n n n n n n	7	2	•	‡	P	‡	0	‡
OR (HL)	A ← AV (HL)	Logical 'OR' of loc. (HL) and ACC	1 0 1 1 0 1 1 0	7	1	•	‡	P	‡	0	‡
OR (IX + d)	A ← (IX + d)	Logical 'OR' of loc. (IX + d) ∧ ACC	1 1 0 1 1 1 0 1 1 0 1 1 0 1 1 0 d d d d d d d d	19	3	•	‡	P	‡	0	‡
OR (IY +d)	A ← AV (IY + d)	Logical 'OR' of loc. (IY + d) ∧ ACC	1 1 1 1 1 1 0 1 1 0 1 1 0 1 1 0 d d d d d d d d	19	3	•	‡	P	‡	0	‡
OTDR	(C) ← (HL) B ← B − 1 HL ← HL − 1 until B = 0	Load output port (C) with contents of location (HL), decrement HL and B, repeat until B = 0	1 1 1 0 1 1 0 1 1 0 1 1 1 0 1 1	21 if B ≠ 0 16 if B = C	2	•	1	X	X	1	X
OTIR	(C) ← (HL) B ← B − 1 HI ← HL + 1 until B = 0	Load output port (C) with location (HL), increment HL, decrement B, repeat until B = 0	1 1 1 0 1 1 0 1	21 if B ≠ 0 16 if B = C	2	•	1	X	X	1	X
OUT (C), r	(C) ← r	Load output port (C) with Reg. r	1 1 1 0 1 1 0 1 (B) 0 1 r r r 0 0 1	12	2	•	•	•	•	•	•
OUT (n), A	(n) ← A	Load output port (n) with ACC	1 1 0 1 0 0 1 1 n n n n n n n n	11	2	•	•	•	•	•	•
OUTD	(C) ← (HL) B ← B − 1, HL ← HL − 1	Load output port (C) with location (HL), increment HL and decrement B	1 1 1 0 1 1 0 1 1 0 1 0 1 0 1 1	16	2	•	‡(3)	X	X	1	X
OUTI	(C) ← (HL) B ← B − 1, HL ← HL + 1	Load output port (C) with location (HL), increment HL and decrement B	1 1 1 0 1 1 0 1 1 0 1 0 0 0 1 1	16	2	•	‡(3)	X	X	1	X

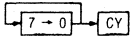
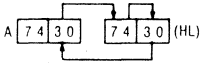
Instruction Set (cont)

Mnemonic	Operation	Description	Operation Code 7 6 5 4 3 2 1 0	No. of Clocks	No. of Bytes	Flags C	Z	P/V	S	N	H
POP IX	$IX_H \leftarrow (SP + 1)$ $IX_L \leftarrow (SP)$	Load IX with top of stack	1 1 0 1 1 1 0 1 1 1 1 0 0 0 0 1	14	2	•	•	•	•	•	•
POP IY	$IY_H \leftarrow (SP + 1)$ $IY_L \leftarrow (SP)$	Load IY with top of stack	1 1 1 1 1 1 0 1 1 1 1 0 0 0 0 1	14	2	•	•	•	•	•	•
POP qq	$qq_H \leftarrow (SP + 1)$ $qq_L \leftarrow (SP)$	Load Reg. pair qq with top of stack	1 1 q q 0 0 0 1 (G)	10	1	•	•	•	•	•	•
PUSH IX	$(SP - 2) \leftarrow IX_L$ $(SP - 1) \leftarrow IX_H$	Load IX onto stack	1 1 0 1 1 1 0 1 1 1 1 0 0 1 0 1	15	2	•	•	•	•	•	•
PUSH IY	$(SP - 2) \leftarrow IY_L$ $(SP - 1) \leftarrow IY_H$	Load IY onto stack	1 1 1 1 1 1 0 1 1 1 1 0 0 1 0 1	15	2	•	•	•	•	•	•
PUSH qq	$(SP - 2) \leftarrow qq_L$ $(SP - 1) \leftarrow qq_H$	Load Reg. pair qq onto stack	1 1 q q 0 1 0 1 (G)	11	1	•	•	•	•	•	•
RES b,r	$S_b \leftarrow 0$	Reset Bit b of Reg. r	1 1 0 0 1 0 1 1 (B) 1 0 b b b r r r (E)	8	2	•	•	•	•	•	•
RES b, (HL)	$S_b \leftarrow 0$, (HL)	Reset Bit b of loc. (HL)	1 1 0 0 1 0 1 1 1 0 b b b 1 1 0	15	2	•	•	•	•	•	•
RES b, (IX + d)	$S_b \leftarrow 0$ (IX + d)	Reset Bit b of loc. (IX + d)	1 1 0 1 1 1 0 1 1 1 0 0 1 0 1 1 d d d d d d d d 1 0 b b b 1 10	23	4	•	•	•	•	•	•
RES b, (IY + d)	$S_b \leftarrow 0$, (IY + d)	Reset Bit b of loc. (IY + d)	1 1 1 1 1 1 0 1 1 1 0 0 1 0 1 1 d d d d d d d d 1 0 b b b 1 1 0	23	4	•	•	•	•	•	•
RET	$PC_L \leftarrow (SP)$ $PC_H \leftarrow (SP + 1)$	Return from subroutine	1 1 0 0 1 0 0 1	10	1	•	•	•	•	•	•
RET cc	If condition cc is false cont. else $(PC_L \leftarrow (SP)$ $PC_H \leftarrow (SP + 1)$	Return from subroutine if condition cc is true	1 1 ← cc → 0 0 0 (H)	5 if CC false 11 if CC true	1	•	•	•	•	•	•
RETI		Return from interrupt	1 1 1 0 1 1 0 1 0 1 0 0 1 1 0 1	14	2	•	•	•	•	•	•
RETN		Return from non-maskable interrupt	1 1 1 0 1 1 0 1 0 1 0 0 0 1 0 1	14	2	•	•	•	•	•	•
RL r		Rotate left through carry Reg. r	1 1 0 0 1 0 1 1 (R) 0 0 0 1 0 r r r	2	2	‡	‡	P	‡	0	0
RL (HL)		Rotate left through carry loc. (HL)	1 1 0 0 1 0 1 1 0 0 0 1 0 1 1 0	4	2	‡	‡	P	‡	0	0

Instruction Set (cont)

Mnemonic	Operation	Description	Operation Code 7	6	5	4	3	2	1	0	No. of Clocks	No. of Bytes	Flags C	Z	P/V	S	N	H
RL (IX + d)	 m r, (HL)	Rotate left through carry loc. (IX + d)	1	1	0	1	1	1	0	1	6	4	‡	‡	P	‡	0	0
			1	1	0	0	1	0	1	1								
			d	d	d	d	d	d	d	d								
			0	0	0	1	0	1	1	0								
RL (IY + d)	(IX + d), (IY + d), A	Rotate left through carry loc. (IY + d)	1	1	1	1	1	1	0	1	6	4	‡	‡	P	‡	0	0
			1	1	0	0	1	0	1	1								
			d	d	d	d	d	d	d	d								
			0	0	0	1	0	1	1	0								
RLA		Rotate left ACC through carry	0	0	0	1	0	1	1	1	4	1	‡	•	•	•	0	0
RLC (HL)		Rotate location (HL) left circular	1	1	0	0	1	0	1	1	15	2	‡	‡	P	‡	0	0
			0	0	0	0	0	1	1	0								
RLC (IX + d)		Rotate location (IX + d) left circular	1	1	0	1	1	1	0	1	23	4	‡	‡	P	‡	0	0
			1	1	0	0	1	0	1	1								
			d	d	d	d	d	d	d	d								
			0	0	0	0	0	1	1	0								
RLC (IY + d)	 m = r, (HL), (IX + d), (IY + d), A	Rotate location (IY + d) left circular	1	1	1	1	1	1	0	1	23	4	‡	‡	P	‡	0	0
			1	1	0	0	1	0	1	1								
			d	d	d	d	d	d	d	d								
			0	0	0	0	0	1	1	0								
RLC r		Rotate Reg. r left circular	1	1	0	0	1	0	1	1 (B)	8	2	‡	‡	P	‡	0	0
			0	0	0	0	0	r	r	r								
RLCA		Rotate left circular ACC	0	0	0	0	0	1	1	1	4	1	‡	•	•	•	0	0
RLD	A 7 4 3 0 7 4 3 0 (HL)	Rotate digit left and right between ACC and location (HL)	1	1	1	0	1	1	0	1	18	2	•	‡	P	‡	0	0
			0	1	1	0	1	1	1	1								
RR r		Rotate right through carry Reg. r	1	1	0	0	1	0	1	1 (B)	2	2	‡	‡	P	‡	0	0
			0	0	0	1	1	r	r	r								
RR (HL)		Rotate right through carry loc. (HL)	1	1	0	0	1	0	1	1	4	2	‡	‡	P	‡	0	0
			0	0	0	1	1	1	1	0								
RR (IX + d)		Rotate right through carry loc. (IX + d)	1	1	0	1	1	1	0	1	6	4	‡	‡	P	‡	0	0
			1	1	0	0	1	0	1	1								
			d	d	d	d	d	d	d	d								
			0	0	0	1	1	1	1	0								
RR (IY + d)	 m = r, (HL), (IX + d), (IY + d), A	Rotate right through carry loc. (IY + d)	1	1	1	1	1	1	0	1	6	4	‡	‡	P	‡	0	0
			1	1	0	0	1	0	1	1								
			d	d	d	d	d	d	d	d								
			0	0	0	1	1	1	1	0								
RRA		Rotate right ACC through carry	0	0	0	1	1	1	1	1	4	1	‡	•	•	•	0	0
RRC r		Rotate Reg. r right circular	1	1	0	0	1	0	1	1 (R)	2	2	‡	‡	P	‡	0	0
			0	0	0	0	1	r	r	r								

Instruction Set (cont)

Mnemonic	Operation	Description	Operation Code 7 6 5 4 3 2 1 0	No. of Clocks	No. of Bytes	Flags C	Z	P/V	S	N	H
RRC (HL)		Rotate loc. (HL) right circular	1 1 0 0 1 0 1 1 0 0 0 0 1 1 1 0	4	2	‡	‡	P	‡	0	0
RRC (IX + d)		Rotate loc (IX + d) right circular	1 1 0 1 1 1 0 1 1 1 0 0 1 0 1 1 d d d d d d d d 0 0 0 0 1 1 1 0	6	4	‡	‡	P	‡	0	0
RRC (IY + d)	m = r, (HL), (IX + d), (IY + d), A	Rotate loc. (IY + d) right circular	1 1 1 1 1 1 0 1 1 1 0 0 1 0 1 1 d d d d d d d d 0 0 0 0 1 1 1 0	6	4	‡	‡	P	‡	0	0
RRCA		Rotate right circular ACC	0 0 0 0 1 1 1 1	4	1	‡	•	•	•	0	0
RRD		Rotate digit right and then left between ACC and location (HL)	1 1 1 0 1 1 0 1 0 1 1 0 0 1 1 1	18	2	•	‡	P	‡	0	0
RST_t	(SP − 1) ← PC_H (SP − 2) ← PC_L PC_H ← 0, PC_L ← T	Restart to location T	1 1 t t t 1 1 1	11	1	•	•	•	•	•	•
SBC A, r	A ← A − r CY	Subtract Reg. r from ACC w/carry	1 0 0 1 1 r r r (B)	4	1	‡	‡	V	‡	1	‡
SBC A, n	A ← A − n − CY	Subtract value n from ACC with carry	1 1 0 1 1 1 1 0 n n n n n n n n	7	2	‡	‡	V	‡	1	‡
SBC A, (HL)	A ← A − (HL) − CY	Sub. loc. (HL) from ACC w/carry	1 0 0 1 1 1 1 0	7	1	‡	‡	V	‡	1	‡
SBC A, (IX + d)	A ← A − (IX + d) − CY	Subtract loc. (IX + d) from ACC with carry	1 1 0 1 1 1 0 1 1 0 0 1 1 1 1 0 d d d d d d d d	19	3	‡	‡	V	‡	1	‡
SBC A, (IY + d)	A ← A − (IY + d) − CY	Subtract loc. (IY + d) from ACC with carry	1 1 1 1 1 1 0 1 1 0 0 1 1 1 1 0 d d d d d d d d	19	3	‡	‡	V	‡	1	‡
SBC HL, ss	HL ← HL − ss − CY	Subtract Reg. pair ss from HL with carry	1 1 1 0 1 1 0 1 (A) 0 1 s s 0 0 1 0	15	2	‡	‡	V	‡	1	X
SCF	CY ← 1	Set carry flag (C = 1)	0 0 1 1 0 1 1 1	4	1	1	•	•	•	0	0
SET b, (HL)	$(HL)_b$ ← 1	Set Bit b of location (HL)	1 1 0 0 1 0 1 1 (E) 1 1 b b b 1 1 0	15	2	•	•	•	•	•	•
SET b, (IX + d)	$(IX + d)_b$ ← 1	Set Bit b of location (IX + d)	1 1 0 1 1 1 0 1 (E) 1 1 0 0 1 0 1 1 d d d d d d d d 1 1 b b b 1 1 0	23	4	•	•	•	•	•	•

Instruction Set (cont)

Mnemonic	Operation	Description	Operation Code 7 6 5 4 3 2 1 0	No. of Clocks	No. of Bytes	Flags C	Z	P/V	S	N	H
SET b, (IY + d)	$(IY + d)_b \leftarrow 1$	Set Bit b of location (IY + d)	1 1 1 1 1 1 0 1 (E) 1 1 0 0 1 0 1 1 d d d d d d d d 1 1 b b b 1 1 0	23	4	•	•	•	•	•	•
SET b, r	$r_b \leftarrow 1$	Set Bit b of Reg. r	1 1 0 0 1 0 1 1 (B) 1 1 b b b r r r	8	2	•	•	•	•	•	•
SLA r		Shift Reg. r left arithmetic	1 1 0 0 1 0 1 1 (B) 0 0 1 0 0 r r r	8	2	↕	↕	P	↕	0	0
SLA (HL)	CY ← 7 ← 0 ← 0	Shift loc. (HL) left arithmetic	1 1 0 0 1 0 1 1 0 0 1 0 0 1 1 0	15	2	↕	↕	P	↕	0	0
SLA (IX + d)	m = r, (HL), (IX + d), (IY + d)	Shift loc. (IX + d) left arithmetic	1 1 0 1 1 1 0 1 1 1 0 0 1 0 1 1 d d d d d d d d 0 0 1 0 0 1 1 0	23	4	↕	↕	P	↕	0	0
SLA (IY + d)		Shift loc. (IY + d) left arithmetic	1 1 1 1 1 1 0 1 1 1 0 0 1 0 1 1 d d d d d d d d 0 0 1 0 0 1 1 0	23	4	↕	↕	P	↕	0	0
SRA r		Shift Reg. r right arithmetic	1 1 0 0 1 0 1 1 (B) 0 0 1 0 1 r r r	8	2	↕	↕	P	↕	0	0
SRA (HL)	7 → 0 → CY	Shift loc. (HL) right arithmetic	1 1 0 0 1 0 1 1 0 0 1 0 1 1 1 0	15	2	↕	↕	P	↕	0	0
SRA (IX + d)	m = r, (HL), (IX + d), (IY + d)	Shift loc. (IX + d) right arithmetic	1 1 0 1 1 1 0 1 1 1 0 0 1 0 1 1 d d d d d d d d 0 0 1 0 1 1 1 0	23	4	↕	↕	P	↕	0	0
SRA (IY + d)		Shift loc. (IY + d) right arithmetic	1 1 1 1 1 1 0 1 1 1 0 0 1 0 1 1 d d d d d d d d 0 0 1 0 1 1 1 0	23	4	↕	↕	P	↕	0	0
SRL r		Shift Reg. r right logical	1 1 0 0 1 0 1 1 (B) 0 0 1 1 1 r r r	8	2	↕	↕	P	↕	0	0
SRL (HL)	0 → 7 → 0 → CY	Shift loc. (HL) right logical	1 1 0 0 1 0 1 1 0 0 1 1 1 1 1 0	15	2	↕	↕	P	↕	0	0
SRL (IX + d)	m = r, (HL), (IX + d), (IY + d)	Shift loc. (IX + d) right logical	1 1 0 1 1 1 0 1 1 1 0 0 1 0 1 1 d d d d d d d d 0 0 1 1 1 1 1 0	23	4	↕	↕	P	↕	0	0

Instruction Set (cont)

Mnemonic	Operation	Description	Operation Code 7	6	5	4	3	2	1	0	No. of Clocks	No. of Bytes	Flags C	Z	P/V	S	N	H
SRL (IY + d)		Shift loc. (IY + d) right logical	1	1	1	1	1	1	0	1	23	4	‡	‡	P	‡	0	0
			1	1	0	0	1	0	1	1								
			d	d	d	d	d	d	d	d								
			0	0	1	1	1	1	1	0								
SUB r	A ← A − r	Subtract Reg. r from ACC	1	0	0	1	0	r	r	r (B)	4	1	‡	‡	V	‡	1	‡
SUB n	A ← A − n	Subtract value n from ACC	1	1	0	1	0	1	1	0	7	2	‡	‡	V	‡	1	‡
			n	n	n	n	n	n	n	n								
SUB (HL)	A ← A − (HL)	Subtract loc. (HL) from ACC	1	0	0	1	0	1	1	0	7	1	‡	‡	V	‡	1	‡
SUB (IX + d)	A ← A − (IX + d)	Subtract loc. (IX + d) from ACC	1	1	0	1	1	1	0	1	19	3	‡	‡	V	‡	1	‡
			1	0	0	1	0	1	1	0								
			d	d	d	d	d	d	d	d								
SUB (IY + d)	A ← A − (IY + d)	Subtract loc. (IY + d) from ACC	1	1	1	1	1	1	0	1	19	3	‡	‡	V	‡	1	‡
			1	0	0	1	0	1	1	0								
			d	d	d	d	d	d	d	d								
XOR r	A ← A ∀ r	Exclusive 'OR' Reg. r and ACC	1	0	1	0	1	r	r	r (B)	4	1	‡	‡	P	‡	1	‡
XOR n	A ← A ∀ n	Exclusive 'OR' value n and ACC	1	1	1	0	1	1	1	0	7	2	‡	‡	P	‡	1	‡
			n	n	n	n	n	n	n	n								
XOR (HL)	A ← A ∀ (HL)	Exclusive 'OR' loc. (HL) and ACC	1	0	1	0	1	1	1	0	7	1	‡	‡	P	‡	1	‡
XOR (IX + d)	A ← A ∀ (IX + d)	Exclusive 'OR' loc. (IX + d) and ACC	1	1	0	1	1	1	0	1	19	3	‡	‡	P	‡	1	‡
			1	0	1	0	1	1	1	0								
			d	d	d	d	d	d	d	d								
XOR (IY + d)	A ← A ∀ (IY + d)	Exclusive 'OR' loc. (IY + d) and ACC	1	1	1	1	1	1	0	1	19	3	‡	‡	P	‡	1	‡
			1	0	1	0	1	1	1	0								
			d	d	d	d	d	d	d	d								

Note:

(1) P/V flag is 0 if B = 0, else P/V = 1
(2) Z = 1 if A = (HL), else Z = 0
(3) If B = 0, Z flag set, else reset

A		B		C		D		E		F		G		H			I	
Reg ss		Reg r		Reg pp		Reg rr		Bit b		Reg r, r'		Reg qq		CC	Condition	Relevant Flag	Reg r	
BC	00	A	111	BC	00	BC	00	0	000	A	111	BC	00	000	NZ	Non zero	Z	B 000
DE	01	B	000	DE	01	DE	01	1	001	B	000	DE	01	001	Z	Zero	Z	C 001
HL	10	C	001	IX	10	IY	10	2	010	C	001	HL	10	010	NC	Non carry	C	D 010
SP	11	D	010	SP	11	SP	11	3	011	D	010	AF	11	011	C	Carry	C	E 011
		E	011					4	100	E	011			100	PO	Parity odd	P/V	H 100
		H	100					5	101	H	100			101	PE	Parity even	P/V	L 101
		L	101					6	110	L	101			110	P	Sign positive	S	F 110
								7	111					111	M	Sign negative	S	A 111

Description

The μPD8085A-2, μPD8085AH, and μPD8085AH-2 8-bit, single-chip microprocessors are 100 percent software compatible with the industry standard 8080A. They have the ability of increasing system performance of the 8080A by operating at a higher speed. Using the μPD8085A in conjunction with its family of ICs allows the designer complete flexibility with minimum chip count. The H (HMOS) versions have lower power consumptions than the non-H versions.

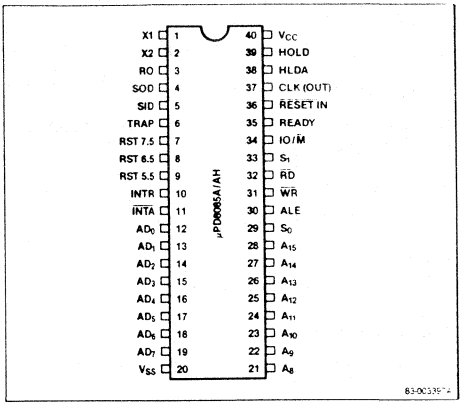
Features

- ☐ Single power supply, +5 V, ±10%
- ☐ Internal clock generation and system control
- ☐ Internal serial in/out port
- ☐ Fully TTL-compatible
- ☐ Internal four-level interrupt structure
- ☐ Multiplexed address/data bus for increased system performance
- ☐ Complete family of components for design flexibility
- ☐ Software compatible with industry standard 8080A
- ☐ Higher throughput
  - —μPD8085A-2 — 5 MHz
  - —μPD8085AH — 3 MHz
  - —μPD8085AH-2 — 5 MHz

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD8085AC-2	40-pin plastic DIP	5 MHz
μPD8085AHC	40-pin plastic DIP	3 MHz
μPD8085AHC-2	40-pin plastic DIP	5 MHz

Pin Configuration



Pin Identification

No.	Symbol	Function
1, 2	X1, X2	Crystal in
3	RO	Reset out
4	SOD	Serial out data
5	SID	Serial in data
6	TRAP	Trap interrupt input
7	RST 7.5	Restart interrupts
8	RST 6.5	Restart interrupts
9	RST 5.5	Restart interrupts
10	INTR	Interrupt request in
11	$\overline{INTA}$	Interrupt acknowledge
12–19	AD_0–AD_7	Low address / data bus
20	V_{SS}	Ground
21–28	A_8–A_{15}	High address bus
29, 33	S_0, S_1	Status outputs
30	ALE	Address latch enable out
31, 32	$\overline{WR}$, $\overline{RD}$	Write / read strobes out
34	IO / $\overline{M}$	I / O or memory indicator
35	READY	Ready input
36	$\overline{RESET\ IN}$	Reset input
37	CLK	Clock out
38, 39	HLDA, HOLD	Hold acknowledge out and hold input request
40	V_{CC}	+5 V supply

Pin Functions

Crystal In

Crystal, RC, or external clock input.

Reset Out

Acknowledges that the processor is being reset to be used as a system reset.

Serial Out Data

1-bit data out by the SIM instruction.

Serial In Data

1-bit data into ACC bit 7 by the RIM instruction.

Trap Interrupt Input

Highest priority nonmaskable restart interrupt.

Restart Interrupts

Priority restart interrupt inputs, of which 7.5 is the highest and 5.5 the lowest priority.

Interrupt Request In

A general interrupt input which stops the PC from incrementing, generates $\overline{INTA}$, and samples the data bus for a restart or call instruction.

Interrupt Acknowledge

An output which indicates that the processor has responded to INTR.

Low Address/Data Bus

Multiplexed low address and data bus.

Ground

Ground Reference.

High Address Bus

Nonmultiplexed high 8 bits of the address bus.

Status Outputs

Outputs which indicate data bus status: Halt, Write, Read, Fetch.

Address Latch Enable Out

A signal which indicates that the lower 8 bits of address are valid on the AD lines.

Write/Read Strobes Out

Signals out which are used as write and read strobes for memory and I/O devices.

I/O or Memory Indicator

A signal out which indicates whether $\overline{RD}$ or $\overline{WR}$ strobes are for I/O or memory devices.

Ready Input

An input which is used to increase the data and address bus access times (can be used for slow memory).

Reset Input

An input which is used to start the processor activity at address 0, resetting IE and HLDA flip-flops.

Clock Out

System clock output.

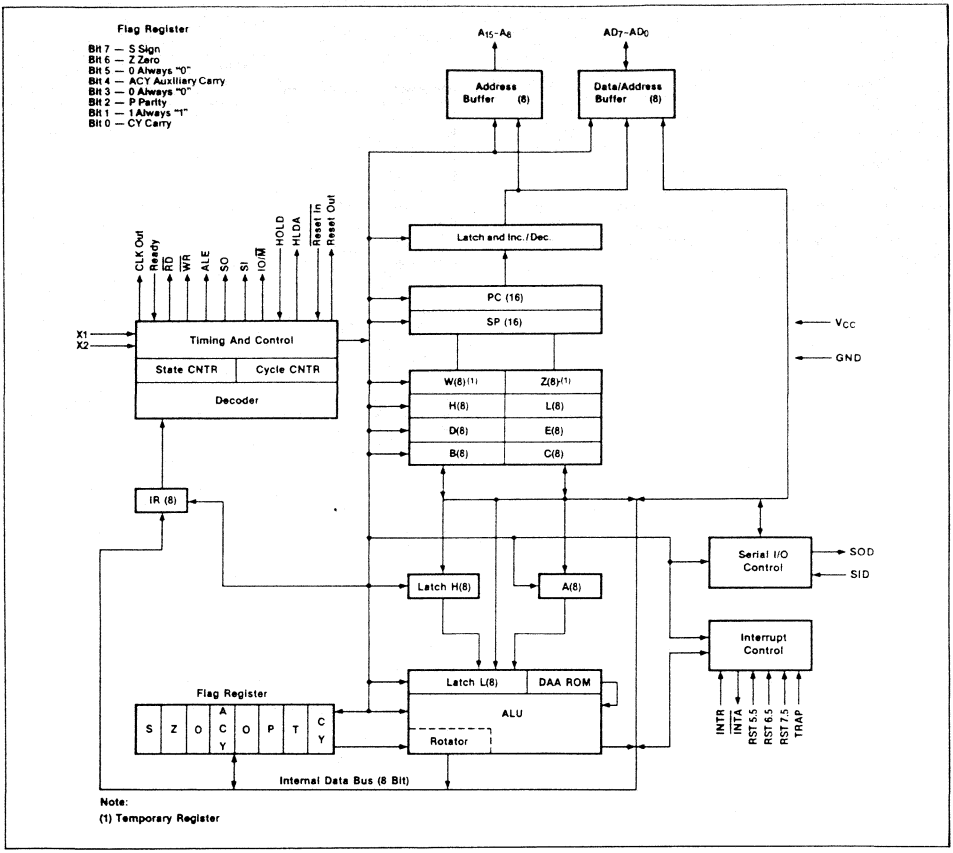
Hold Acknowledge Out and Hold Input Request

Used to request and indicate that the processor should relinquish the bus for DMA activity. When hold is acknowledged, $\overline{RD}$, $\overline{WR}$, IO/$\overline{M}$, address and data buses are all three-stated.

+5 V Supply

Power supply input.

Block Diagram



Absolute Maximum Ratings

μPD8085A-2: $T_A = 25°C$; $V_{CC} = +5V \pm 5\%$

Power supply voltage, V_{DD}	−0.5 V to +7 V
Input voltage, V_I	−0.5 V to +7 V
Output voltage, V_O	−0.5 V to +7 V
Operating temperature, T_{OPT}	0°C to +70°C
Storage temperature, T_{STG}	−65°C to +150°C
Power dissipation, P_D	1.5 W

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

μPD8085AH, μPD8085AH-2: $T_A = 0°C$ to +70°C, $V_{CC} = +5V \pm 10\%$, $V_{SS} = GND$

μPD8085A-2: $T_A = 0°C$ to +70°C, $V_{CC} = +5V \pm 5\%$, $V_{SS} = GND$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage low	V_{IL}	$V_{SS}-0.5$		$V_{SS}+0.8$	V	
Input voltage high	V_{IH}	2.0		$V_{CC}+0.5$	V	
Output voltage low	V_{OL}			+0.45	V	$I_{OL} = 2.0$ mA, $I_{OH} = -400\,\mu A$ (Notes 1 & 2)
Output voltage high	V_{OH}	2.4			V	$I_{OH} = -400\,\mu A$, $I_{OL} = 2$ mA (Notes 1 & 2)
Input leakage current	I_{LI}			±10(1)	μA	$0V \leq V_{IN} \leq V_{CC}$
Output leakage current	I_{LO}			±10(1)	μA	$0.45V \leq V_{OUT} \leq V_{CC}$
Input level low, reset	V_{ILR}	−0.5		+0.8	V	
Input level high, reset	V_{IHR}	2.4		$V_{CC}+0.5$	V	
Hysteresis, reset	V_{HY}	0.25			V	
X1, X2 input voltage high	V_{IHX}	4.0		$V_{CC}+0.5$	V	
Power supply current (V_{CC}) μPD8085A-2	$I_{CC}(AV)$			170	mA	t_{CY} min
μPD8085AH, μPD8085AH-2				135	mA	t_{CY} min. (Note 3)

Note:

(1) Minus (−) designates current flow out of the device.

(2) On all outputs.

(3) Maximum unit test.

AC Characteristics

μPD8085A-2: $T_A = 0°C$ to $+70°C$, $V_{CC} = 5\ V \pm 5\%$
μPD8085AH, μPD8085AH-2: $T_A = 0°C$ to $+70°C$, $V_{CC} = 5\ V \pm 10\%$

Parameter	Symbol	Limits μPD8085AH Min	Limits μPD8085AH Max	Limits μPD8085AH-2, μPD8085A-2 Min	Limits μPD8085AH-2, μPD8085A-2 Max	Unit	Test Conditions
CLK cycle period	t_{CYC}	320	2000	200	2000	ns	
CLK low time	t_1	80		40		ns	
CLK high time	t_2	120		70		ns	
CLK rise time	t_r		30		30	ns	
CLK fall time	t_f		30		30	ns	
X1 rising to CLK rising	t_{XKR}	30	120	30	100	ns	
X1 rising to CLK falling	t_{XKF}	30	150	30	110	ns	
A_8–A_{15} valid to leading edge of CONTROL	t_{AC}	270		115		ns	(Note 1)
A_0–A_7 valid to leading edge of CONTROL	t_{ACL}	240		115		ns	
A_0–A_{15} valid to data input	t_{AD}		575		350	ns	
Address float after leading edge of $\overline{RD}$ ($\overline{INTA}$)	t_{AFR}		0		0	ns	
A_8–A_{15} valid before trailing edge of ALE	t_{AL}	115		50		ns	(Note 1)
A_0–A_7 valid before trailing edge of ALE	t_{ALL}	90		50		ns	
READY valid from address valid	t_{ARY}		220		100	ns	
A_8–A_{15} valid after CONTROL	t_{CA}	120		60		ns	
Width of control low ($\overline{RD}$, $\overline{WR}$, $\overline{INTA}$)	t_{CC}	400		230		ns	
Trailing edge of CONTROL to leading edge of ALE	t_{CL}	50		25		ns	
Data valid to trailing edge of $\overline{WR}$	t_{DW}	420		230		ns	
HLDA to bus enable	t_{HABE}		210		150	ns	
Bus float after HLDA	t_{HABF}		210		150	ns	
HLDA valid to trailing edge of CLK	t_{HACK}	110		40		ns	
HOLD hold time	t_{HDH}	0		0		ns	
HOLD setup time to trailing edge of CLK	t_{HDS}	170		120		ns	
INTR hold time	t_{INH}	0		0		ns	
INTR, RST, TRAP setup time to trailing edge of CLK	t_{INS}	160		150		ns	
Address hold time after ALE	t_{LA}	100		50		ns	
Trailing edge of ALE to leading edge of CONTROL	t_{LC}	130		60		ns	
ALE low time during CLK high	t_{LCK}	100		50		ns	
ALE to valid data input during read	t_{LDR}		460		270	ns	
ALE to valid data during write	t_{LDW}		200		120	ns	
ALE pulse width	t_{LL}	140		80		ns	
ALE to READY stable	t_{LRY}		110		30	ns	

AC Characteristics (cont)

μPD8085A-2: $T_A = 0°C$ to $+70°C$, $V_{CC} = 5\,V \pm 5\%$
μPD8085AH, μPD8085AH-2: $T_A = 0°C$ to $+70°C$, $V_{CC} = 5\,V \pm 10\%$

Parameter	Symbol	Limits μPD8085AH Min	Limits μPD8085AH Max	Limits μPD8085AH-2, μPD8085A-2 Min	Limits μPD8085AH-2, μPD8085A-2 Max	Unit	Test Conditions
Trailing edge of $\overline{RD}$ to re-enabling of address	t_{RAE}	150		90		ns	
$\overline{RD}$ (or $\overline{INTA}$) to valid data	t_{RD}		300		150	ns	
Trailing edge of CONTROL to leading edge of next CONTROL	t_{RV}	400		220		ns	
Data hold time after $\overline{RD}$ ($\overline{INTA}$)	t_{RDH}	0		0		ns	(Note 7)
READY hold time	t_{RYH}	0		0		ns	
READY setup time to leading edge of CLK	t_{RYS}	110		100		ns	
Leading edge data valid after trailing edge of $\overline{WR}$	t_{WD}	100		60		ns	
Leading edge of $\overline{WR}$ to data valid	t_{WDL}		40		20	ns	

Note:

(1) A_8-A_{15} address specs apply to IO/$\overline{M}$. S_0 and S_1 except A_8-A_{15} are undefined during T_4-T_6 of OF cycle whereas IO/$\overline{M}$, S_0 and S_1 are stable.

(2) Test conditions: $t_{CYC} = 320$ ns (8085AH)/200 ns (8085A-2) $C_L = 150$ pF

(3) For all output timing except where $C_L = 150$ pF use the following correction factors:
25 pF, $C_L = 150$ pF: -0.10 ns/pF
150 pF, $C_L = 300$ pF: $+0.3$ ns/pF

(4) Output timings are measured with purely capacitive load.

(5) All timings are measured as the following:
Output voltage: $V_L = 0.8\,V$, $V_H = 2.0\,V$
Input voltage: 1.5 V; t_r, $t_f = 20$ ns

(6) To calculate timing specifications at other values of t_{CYC} use Bus Timing Specifications.

(7) Data hold time is guaranteed under all loading conditions.

Bus Timing Specifications

t_{CYC} as a Dependent

Symbol	Timing Formula μPD8085AH	Timing Formula μPD8085A-2, μPD8085AH-2	Min/Max
t_{AL}	$(1/2)\,t_{CY} - 45$	$(1/2)\,t_{CY} - 50$	Min
t_{LA}	$(1/2)\,t_{CY} - 60$	$(1/2)\,t_{CY} - 50$	Min
t_{LL}	$(1/2)\,t_{CY} - 20$	$(1/2)\,t_{CY} - 20$	Min
t_{LCK}	$(1/2)\,t_{CY} - 60$	$(1/2)\,t_{CY} - 50$	Min
t_{LC}	$(1/2)\,t_{CY} - 30$	$(1/2)\,t_{CY} - 40$	Min
t_{AD}	$(5/2+N)\,t_{CY} - 225$	$(5/2+N)\,t_{CY} - 150$	Max
t_{RD}	$(3/2+N)\,t_{CY} - 180$	$(3/2+N)\,t_{CY} - 150$	Max
t_{RAE}	$(1/2)\,t_{CY} - 10$	$(1/2)\,t_{CY} - 10$	Min
t_{CA}	$(1/2)\,t_{CY} - 40$	$(1/2)\,t_{CY} - 40$	Min
t_{DW}	$(3/2+N)\,t_{CY} - 60$	$(3/2+N)\,t_{CY} - 70$	Min
t_{WD}	$(1/2)\,t_{CY} - 60$	$(1/2)\,t_{CY} - 40$	Min

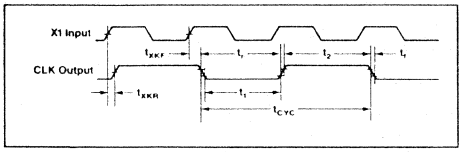
Symbol	Timing Formula μPD8085AH	Timing Formula μPD8085A-2, μPD8085AH-2	Min/Max
t_{CC}	$(3/2+N)\,t_{CY} - 80$	$(3/2+N)\,t_{CY} - 70$	Min
t_{CL}	$(1/2)\,t_{CY} - 110$	$(1/2)\,t_{CY} - 75$	Min
t_{ARY}	$(3/2)\,t_{CY} - 260$	$(3/2)\,t_{CY} - 200$	Max
t_{HACK}	$(1/2)\,t_{CY} - 50$	$(1/2)\,t_{CY} - 60$	Min
t_{HABF}	$(1/2)\,t_{CY} + 50$	$(1/2)\,t_{CY} - 50$	Max
t_{HABE}	$(1/2)\,t_{CY} + 50$	$(1/2)\,t_{CY} - 50$	Max
t_{AC}	$(2/2)\,t_{CY} - 50$	$(2/2)\,t_{CY} - 85$	Min
t_1	$(1/2)\,t_{CY} - 80$	$(1/2)\,t_{CY} - 60$	Min
t_2	$(1/2)\,t_{CY} - 40$	$(1/2)\,t_{CY} - 30$	Min
t_{RV}	$(3/2)\,t_{CY} - 80$	$(3/2)\,t_{CY} - 80$	Min
t_{LDR}	$(4/2+N)\,t_{CY} - 180$	$(4/2+N)\,t_{CY} - 130$	Max

Note:

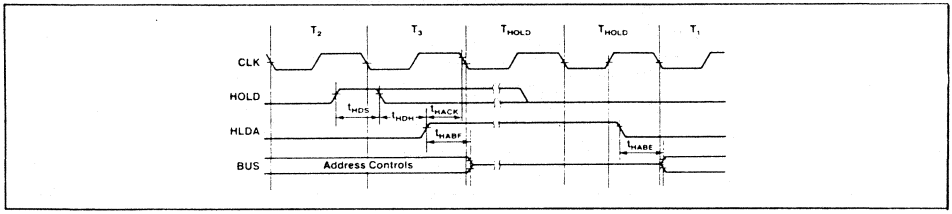
(1) N = Number of WAIT state

Timing Waveforms

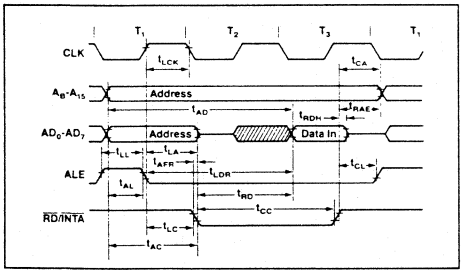
Clock Timing Waveform



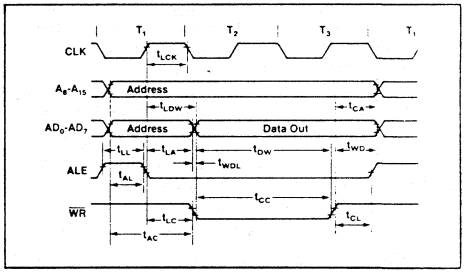
Hold Timing



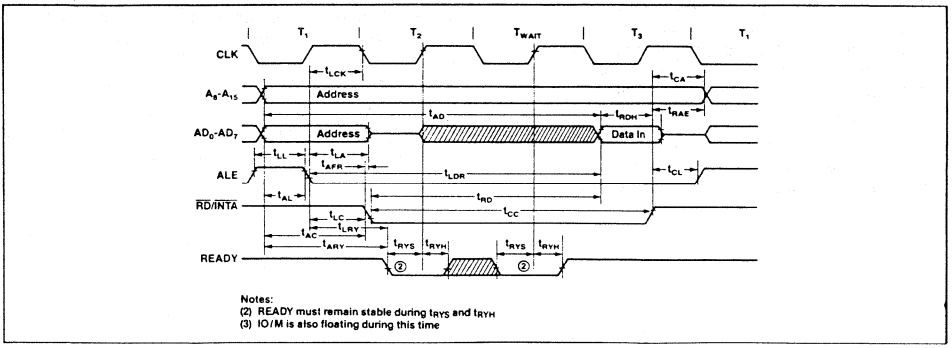
8085AH Bus Timing Read Operation



Write Operation



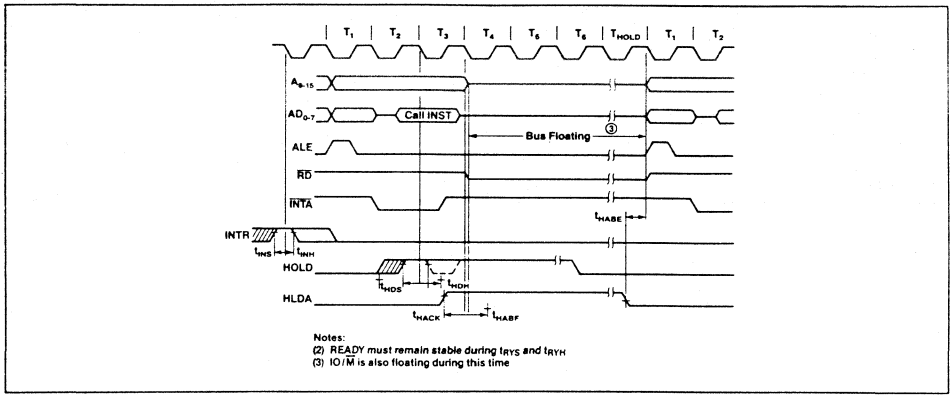
Read Operation with Wait Cycle (same Ready Timing Applies to Write Operation)



Notes:
(2) READY must remain stable during t_{RYS} and t_{RYH}
(3) IO/M is also floating during this time

Timing Waveforms (cont)

Interrupt and Hold Timing



Functional Description

The μPD8085A contains six 8-bit data registers, an 8-bit accumulator, four testable flag bits, and an 8-bit parallel binary arithmetic unit. The μPD8085A also provides decimal arithmetic capability and it includes 16-bit arithmetic and immediate operators which greatly simplify memory address calculations, and high speed arithmetic operations.

The μPD8085A has a stack architecture wherein any portion of the external memory can be used as a last in/first out (LIFO) stack to store/retrieve the contents of the accumulator, the flags, or any of the data registers.

The μPD8085A also contains a 16-bit stack pointer to control the addressing of this external stack. One of the major advantages of the stack is that multiple level interrupts can easily be handled since complete system status can be saved when an interrupt occurs and then restored after the interrupt is complete. Another major advantage is that almost unlimited subroutine nesting is possible.

The μPD8085A was designed with speed and simplicity of the overall system in mind. The multiplexed address/data bus increases available pins for advanced functions in the processor and peripheral chips while providing increased system speed and less critical timing functions. All signals to and from the μPD8085A are fully TTL-compatible.

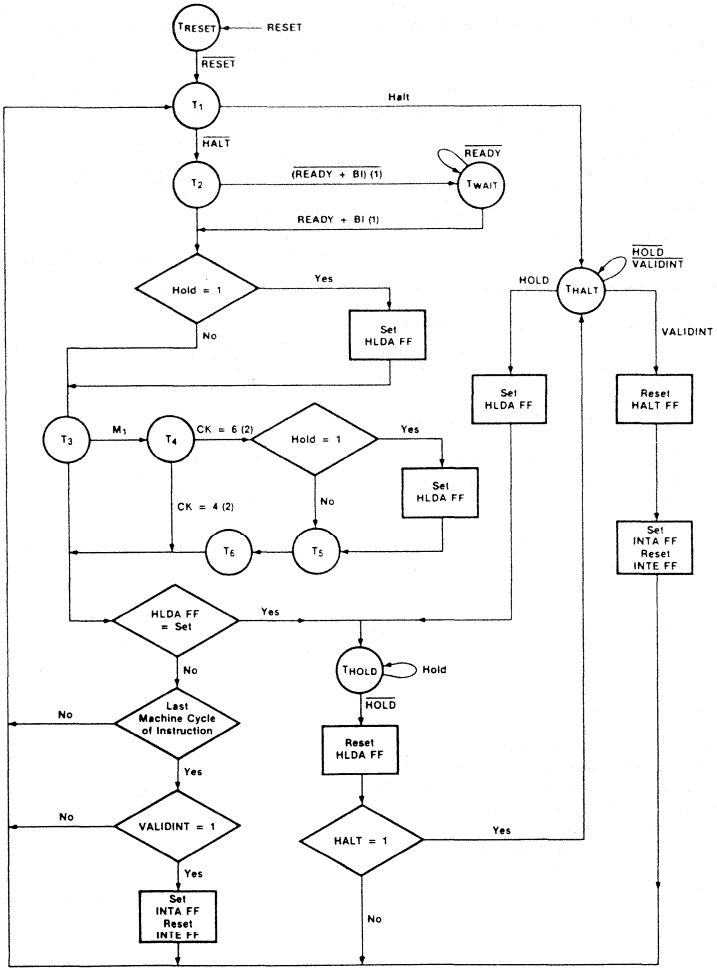
The internal interrupt structure of the μPD8085A features 4 levels of prioritized interrupt with three levels internally maskable.

Communication on both the address lines and the data lines can be interlocked by using the HOLD input. When the hold acknowledge (HLDA) signal is issued by the processor, its operation is suspended and the address, data and control lines are forced to be in the FLOATING state. This permits other devices, such as direct memory access channels (DMA), to be connected to the address and data buses.

The μPD8085A features internal clock generation with status outputs available for advanced read/write timing and memory/IO instruction indications. The clock may be crystal controlled, RC controlled, or driven by an external signal.

On-chip serial in/out port is available and controlled by the newly added RIM and SIM instructions.

Processor State Transition Diagram



Notes:
1. BI indicates that the bus is idle during this machine cycle.
2. CK indicates the number of clock cycles in this machine cycle.

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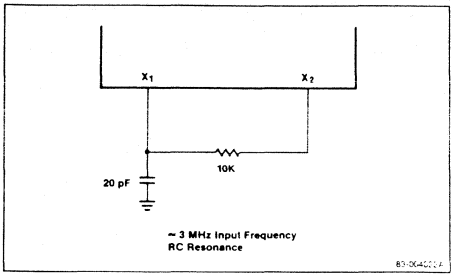
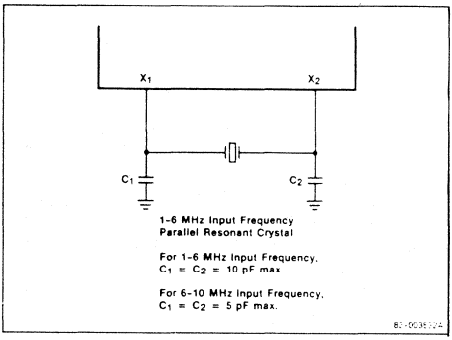
Clock Inputs

As stated, the timing for the μPD8085A may be generated in one of two ways: crystal, or external clock. Recommendations for these methods are shown below. Note the input frequency must be twice the internal operating frequency.

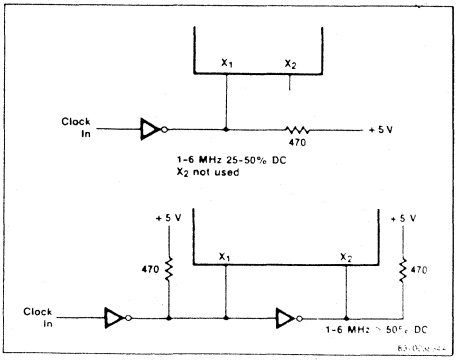
RC



Crystal



External



Status Outputs

The status outputs are valid during ALE time and have the following meaning:

	S_1	S_0
Halt	0	0
Write	0	1
Read	1	0
Fetch	1	1

These pins may be decoded to portray the processor's data bus status.

Interrupts

The μPD8085A has five interrupt pins available to the user. INTR is operationally the same as the 8080 interrupt request, three (3) internally maskable restart interrupts: RESTART 5.5, 6.5, and 7.5, and TRAP, a non-maskable restart.

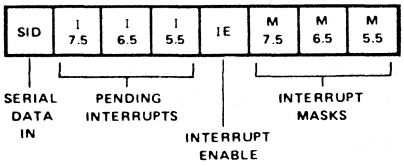
Priority	Interrupt	Restart Address
Highest	TRAP	24_{16}
↑	RST 7.5	$3C_{16}$
↑	RST 6.5	34_{16}
↑	RST 5.5	$2C_{16}$
Lowest	INTR	

INTR, RST 5.5 and RST 6.5 are all level sensing inputs while RST 7.5 is set on a rising-edge. TRAP, the highest priority interrupt, is non-maskable and is set on the rising-edge or positive level. It must make a low-to-high transition and remain high to be seen, but it will not be generated again until it makes another low-to-high transition.

Serial I/O

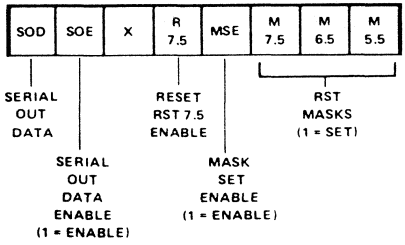
Serial input and output is accomplished with two new instructions not included in the 8080: RIM and SIM. These instructions serve several purposes: serial I/O, and reading or setting the interrupt mask.

The RIM (Read Interrupt Mask) instruction is used for reading the interrupt mask and for reading serial data. After execution of the RIM instruction the ACC content is as follows:



Note:
(1) After the TRAP interrupt, the RIM instruction must be executed to preserve the status of IE.

The SIM (Set Interrupt Mask) instruction is used to program the interrupt mask and to output serial data. Presetting the ACC for the SIM instruction has the following meaning:



Instruction Set

The instruction set includes arithmetic and logical operators with direct, register, indirect, and immediate addressing modes.

Move, load, and store instruction groups provide the ability to move either 8 or 16 bits of data between memory, the six working registers and the accumulator using direct, register, indirect, and immediate addressing modes.

The ability to branch to different portions of the program is provided with direct, conditional, or computed jumps. Also, the ability to call and return from subroutines is provided both conditionally and unconditionally. The RESTART (or single byte call instruction) is useful for interrupt vector operation.

Conditional jumps, calls and returns execute based on the state of the four testable flags (sign, zero, parity and carry). The state of each flag is determined by the result of the last instruction executed that affected flags. (See Instruction Set Table)

The sign flag is set (high) if bit 7 of the result is a "1"; otherwise it is reset (low). The zero flag is set if the result is "0"; otherwise it is reset. The parity flag is set if the modulo 2 sum of the bits of the result is "0" (even parity); otherwise (odd parity) it is reset. The carry flag is set if the last instruction resulted in a carry or a borrow out of the most significant bit (bit 7) of the result; otherwise it is reset.

In addition to the four testable flags, the μPD8085A has another flag (ACY) that is not directly testable. It is used for multiple precision arithmetic operations with the DAA instruction. The auxiliary carry flag is set if the last instruction resulted in a carry or a borrow from bit 3 into bit 4; otherwise it is reset.

Double precision operators such as stack manipulation and double add instructions extend both the arithmetic and interrupt handling capability of the μPD8085A. The ability to increment and decrement memory, the six general registers, and the accumulator are provided as well as extended increment and decrement instructions to operate on the register pairs and stack pointer. Further capability is provided by the ability to rotate the accumulator left or right through or around the carry bit.

Input and output may be accomplished using memory addresses as I/O ports or the directly addressed I/O provided for in the μPD8085A instruction set.

Two instructions, RIM and SIM, are used for reading and setting the internal interrupt mask as well as input and output to the serial I/O port.

The special instruction group completes the μPD8085A instruction set: NOP, HALT stop processor execution; DAA provides decimal arithmetic capability; STC sets the carry flag; CMC complements it; CMA complements the contents of the accumulator; and XCHG exchanges the contents of two 16-bit register pairs directly.

Data and Instruction Formats

Data in the μPD8085A is stored as 8-bit binary integers. All data/instruction transfers to the system data bus are in the following format:

Instructions are one, two, or three bytes long. Multiple byte instructions must be stored in successive locations of program memory. The address of the first byte is used as the address of the instruction.

One Byte Instructions

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	OP CODE

Typical Instructions

Register to register, memory referance, arithmetic or logical, rotate, return, push, pop, enable, or diable interrupt instructions

Two Byte Instructions

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	OP CODE
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	OPERAND

Immediate mode or I/O instructions

Three Byte Instructions

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	OP CODE
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	LOW ADDRESS OR OPERAND 1
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	HIGH ADDRESS OR OPERAND 2

Jump, call or direct load and store instructions

Instruction Cycle Times

One to five machine cycles (M_1-M_5) are required to execute an instruction. Each machine cycle involves the transfer of an instruction or data byte into the processor or a transfer of a data byte out of the processor (the sole exception being the double add instruction). The first one, two or three machine cycles obtain the instruction from the memory or an interrupting I/O controller. The remaining cycles are used to execute the instruction. Each machine cycle requires from three to five clock times (T1-T5).

Machine cycles and clock states used for each type of instruction are shown below.

Instruction Type	Machine Cycles Executed Min/Max	Clock Status Min/Max
ALU R	1	4
CMC	1	4
CMA	1	4
DAA	1	4
DCR R	1	4
DI	1	4
EI	1	4
INR R	1	4
MOV R, R	1	4
NOP	1	4
ROTATE	1	4
RIM	1	4
SIM	1	4
STC	1	4
XCHG	1	4
HLT	1	5
DCX	1	6
INX	1	6
PCHL	1	6
RET COND.	1/3	6/12
SPHL	1	6
ALU I	2	7
ALU M	2	7
JNC	2/3	7/10
LDAX	2	7
MVI	2	7
MOV M, R	2	7
MOV R, M	2	7
STAX	2	7
CALL COND.	2/5	9/18
DAD	3	10
DCR M	3	10
IN	3	10
INR M	3	10
JMP	3	10
LOAD PAIR	3	10
MVI M	3	10
OUT	3	10
POP	3	10
RET	3	10
PUSH	3	12
RST	3	12
LDA	4	13
STA	4	13
LHLD	5	16
SHLD	5	16
XTHL	5	16
CALL	5	18

Instruction Set

Mnemonic(1)	Description	Operation Code(2)								Cycles(3)	Flags(4)			
		D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0		Sign	Zero	Parity	Carry
Move														
MOV d, s	Move register to register	0	1	d	d	d	s	s	s	4				
MOV M, s	Move register to memory	0	1	1	1	0	s	s	s	7				
MOV d, M	Move memory to register	0	1	d	d	d	1	1	0	7				
MVI d, D8	Move immediate to register	0	0	d	d	d	1	1	0	7				
MVI M, D8	Move immediate to memory	0	0	1	1	0	1	1	0	10				
Increment / Decrement														
INR d	Increment register	0	0	d	d	d	1	0	0	4	•	•	•	
DCR d	Decrement register	0	0	d	d	d	1	0	1	4	•	•	•	
INR M	Increment memory	0	0	1	1	0	1	0	0	10	•	•	•	
DCR M	Decrement memory	0	0	1	1	0	1	0	1	10	•	•	•	
ALU — Register to Accumulator														
ADD s	Add register to A	1	0	0	0	0	s	s	s	4	•	•	•	•
ADC s	Add register to A with carry	1	0	0	0	1	s	s	s	4	•	•	•	•
SUB s	Subtract register from A	1	0	0	1	0	s	s	s	4	•	•	•	•
SUBB s	Subtract register from A with borrow	1	0	0	1	1	s	s	s	4	•	•	•	•
ANA s	AND register with A	1	0	1	0	0	s	s	s	4	•	•	•	0
XRA s	Exclusive OR register with A	1	0	1	0	1	s	s	s	4	•	•	•	0
ORA s	OR register with A	1	0	1	1	0	s	s	s	4	•	•	•	0
CMP s	Compare register with A	1	0	1	1	1	s	s	s	4	•	•	•	•
ALU — Memory to Accumulator														
ADD M	Add memory to A	1	0	0	0	0	1	1	0	7	•	•	•	•
ADC M	Add memory to A with carry	1	0	0	0	1	1	1	0	7	•	•	•	•
SUB M	Subtract memory from A	1	0	0	1	0	1	1	0	7	•	•	•	•
SBB M	Subtract memory from A with borrow	1	0	0	1	1	1	1	0	7	•	•	•	•
ANA M	AND memory with A	1	0	1	0	0	1	1	0	7	•	•	•	0
XRA M	Exclusive OR memory with A	1	0	1	0	1	1	1	0	7	•	•	•	0
ORA M	OR memory with A	1	0	1	1	0	1	1	0	7	•	•	•	0
CMP M	Compare memory with A	1	0	1	1	1	1	1	0	7	•	•	•	•
ALU — Immediate to Accumulator														
ADI D8	Add immediate to A	1	1	0	0	0	1	1	0	7	•	•	•	•
ACI D8	Add immediate to A with carry	1	1	0	0	1	1	1	0	7	•	•	•	•

Instruction Set (cont)

Mnemonic(1)	Description	Operation Code(2) D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Cycles(3)	Flags(4) Sign	Zero	Parity	Carry
ALU — Immediate to Accumulator (cont)														
SUI D8	Subtract immediate from A	1	1	0	1	0	1	1	0	7	•	•	•	•
SBI D8	Subtract immediate from A with borrow	1	1	0	1	1	1	1	0	7	•	•	•	•
ANI D8	AND immediate with A	1	1	1	0	0	1	1	0	7	•	•	•	0
XRI D8	Exclusive OR immediate with A	1	1	1	0	1	1	1	0	7	•	•	•	0
ORI D8	OR immediate with A	1	1	1	1	0	1	1	0	7	•	•	•	0
CPI D8	Compare immediate with A	1	1	1	1	1	1	1	0	7	•	•	•	•
ALU — Rotate														
RLC	Rotate A left, MSB to carry (8-bit)	0	0	0	0	0	1	1	1	4				•
RRC	Rotate A right, LSB to carry (8-bit)	0	0	0	0	1	1	1	1	4				•
RAL	Rotate A left through carry (9-bit)	0	0	0	1	0	1	1	1	4				•
RAR	Rotate A right through carry (9-bit)	0	0	0	1	1	1	1	1	4				•
Jump														
JMP ADDR	Jump unconditional	1	1	0	0	0	0	1	1	10				
JNZ ADDR	Jump on not zero	1	1	0	0	0	0	1	0	7 / 10				
JZ ADDR	Jump on zero	1	1	0	0	1	0	1	0	7 / 10				
JNC ADDR	Jump on no carry	1	1	0	1	0	0	1	0	7 / 10				
JC ADDR	Jump on carry	1	1	0	1	1	0	1	0	7 / 10				
JPO ADDR	Jump on parity odd	1	1	1	0	0	0	1	0	7 / 10				
JPE ADDR	Jump on parity even	1	1	1	0	1	0	1	0	7 / 10				
JP ADDR	Jump on positive	1	1	1	1	0	0	1	0	7 / 10				
JM ADDR	Jump on minus	1	1	1	1	1	0	1	0	7 / 10				
Call														
CALL ADDR	Call unconditional	1	1	0	0	1	1	0	1	18				
CNZ ADDR	Call on not zero	1	1	0	0	0	1	0	0	9 / 18				
CZ ADDR	Call on zero	1	1	0	0	1	1	0	0	9 / 18				
CNC ADDR	Call on no carry	1	1	0	1	0	1	0	0	9 / 18				
CC ADDR	Call on carry	1	1	0	1	1	1	0	0	9 / 18				
CPO ADDR	CAll on parity odd	1	1	1	0	0	1	0	0	9 / 18				
CPE ADDR	Call on parity even	1	1	1	0	1	1	0	0	9 / 18				
CP ADDR	Call on positive	1	1	1	1	0	1	0	0	9 / 18				
CM ADDR	Call on minus	1	1	1	1	1	1	0	0	9 / 18				

Instruction Set (cont)

Mnemonic(1)	Description	Operation Code(2) D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Cycles(3)	Flags(4) Sign	Zero	Parity	Carry
Call (cont)														
Return														
RET	Return	1	1	0	0	1	0	0	1	10				
RNZ	Return on not zero	1	1	0	0	0	0	0	0	6 / 12				
RZ	Return on zero	1	1	0	0	1	0	0	0	6 / 12				
RNC	Return on no carry	1	1	0	1	0	0	0	0	6 / 12				
RC	Return on carry	1	1	0	1	1	0	0	0	6 / 12				
RPO	Return on parity odd	1	1	1	0	0	0	0	0	6 / 12				
RPE	Return on parity even	1	1	1	0	1	0	0	0	6 / 12				
RP	Return on positive	1	1	1	1	0	0	0	0	6 / 12				
RM	Return on minus	1	1	1	1	1	0	0	0	6 / 12				
Load Register Pair														
LXI B, D16	Load immediate register pair BC	0	0	0	0	0	0	0	1	10				
LXI D, D16	Load immediate register pair DE	0	0	0	1	0	0	0	1	10				
LXI H, D16	Load immediate register pair HL	0	0	1	0	0	0	0	1	10				
LXI SP, D16	Load immediate stack pointer	0	0	1	1	0	0	0	1	10				
Push														
PUSH B	Push register pair BC on stack	1	1	0	0	0	1	0	1	12				
PUSH D	Push register pair DE on stack	1	1	0	1	0	1	0	1	12				
PUSH H	Push register pair HL on stack	1	1	1	0	0	1	0	1	12				
PUSH PSW	Push A and flags on stack	1	1	1	1	0	1	0	1	12				
Pop														
POP B	Pop register pair BC off stack	1	1	0	0	0	0	0	1	10				
POP D	Pop register pair DE off stack	1	1	0	1	0	0	0	1	10				
POP H	Pop register pair HL off stack	1	1	1	0	0	0	0	1	10				
POP PSW	Pop A and flags off stack	1	1	1	1	0	0	0	1	10	•	•	•	•
Double Add														
DAD R	Add BC to HL	0	0	0	0	1	0	0	1	10				•
DAD D	Add DE to HL	0	0	0	1	1	0	0	1	10				•
DAD H	Add HI to HL	0	0	1	0	1	0	0	1	10				•
DAD SP	Add stack pointer to HL	0	0	1	1	1	0	0	1	10				•

Instruction Set (cont)

Mnemonic(1)	Description	Operation Code(2)								Cycles(3)	Flags(4)			
		D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0		Sign	Zero	Parity	Carry
Increment Register Pair														
INX B	Increment BC	0	0	0	0	0	0	1	1	6				
INX D	Increment DE	0	0	0	1	0	0	1	1	6				
INX H	Increment HL	0	0	1	0	0	0	1	1	6				
INX SP	Increment stack pointer	0	0	1	1	0	0	1	1	6				
Decrement Register Pair														
DCX B	Decrement BC	0	0	0	0	1	0	1	1	6				
DCX D	Decrement DE	0	0	0	1	1	0	1	1	6				
DCX H	Decrement HL	0	0	1	0	1	0	1	1	6				
DCX SP	Decrement stack pointer	0	0	1	1	1	0	1	1	6				
Register Indirect														
STAX B	Store A at ADDR in BC	0	0	0	0	0	0	1	0	7				
STAX D	Store A at ADDR in DE	0	0	0	1	0	0	1	0	7				
LDAX B	Load A at ADDR in BC	0	0	0	0	1	0	1	0	7				
LDAX D	Load A at ADDR in DE	0	0	0	1	1	0	1	0	7				
Direct														
STA ADDR	Store A direct	0	0	1	1	0	0	1	0	13				
LDA ADDR	Load A direct	0	0	1	1	1	0	1	0	13				
SHLD ADDR	Store HL direct	0	0	1	0	0	0	1	0	16				
LHLD ADDR	Load HL direct	0	0	1	0	1	0	1	0	16				
Move Register Pair														
XCHG	Exchange DE and HL register pairs	1	1	1	0	1	0	1	1	4				
XTHL	Exchange top of stack and HL	1	1	1	0	0	0	1	1	16				
SPHL	HL to stack pointer	1	1	1	1	1	0	0	1	6				
PCHL	HL to program counter	1	1	1	0	1	0	0	1	6				
Input / Output														
IN A	Input	1	1	0	1	1	0	1	1	10				
OUT A	Output	1	1	0	1	0	0	1	1	10				
EI	Enable interrupts	1	1	1	1	1	0	1	1	4				
DI	Disable interrupts	1	1	1	1	0	0	1	1	4				
RIM	Read interrupt mask	0	0	1	0	0	0	0	0	4				
SIM	Set interrupt mask	0	0	1	1	0	0	0	0	4				
RST A	Restart	1	1	A	A	A	1	1	1	12				

Instruction Set (cont)

Mnemonic(1)	Description	Operation Code(2) D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Cycles(3)	Flags(4) Sign	Zero	Parity	Carry
Miscellaneous														
CMA	Complement A	0	0	1	0	1	1	1	1	4				
STC	Set carry	0	0	1	1	0	1	1	1	4				
CMC	Complement carry	0	0	1	1	1	1	1	1	4				1/Cy
DAA	Decimal adjust A	0	0	1	0	0	1	1	1	4	•	•	•	•
NOP	No operation	0	0	0	0	0	0	0	0	4				
HLT	Halt	0	1	1	1	0	1	1	0	5				

Note:

(1) Operand symbols used
A = 8-bit address or expression
s = source register
d = destination register
PSW = Processor status word
SP = Stack pointer
D8 = 8-bit data quantity, expression, or constant, always B_2 of instruction
D16 = 16-bit data quantity, expression, or constant, always B_3B_2 of instruction
ADDR = 16-bit memory address expression

(2) ddd or sss = 000-B, 001-C, 010-D, 011-E, 100-H, 101-L, 110-Memory, 111-A

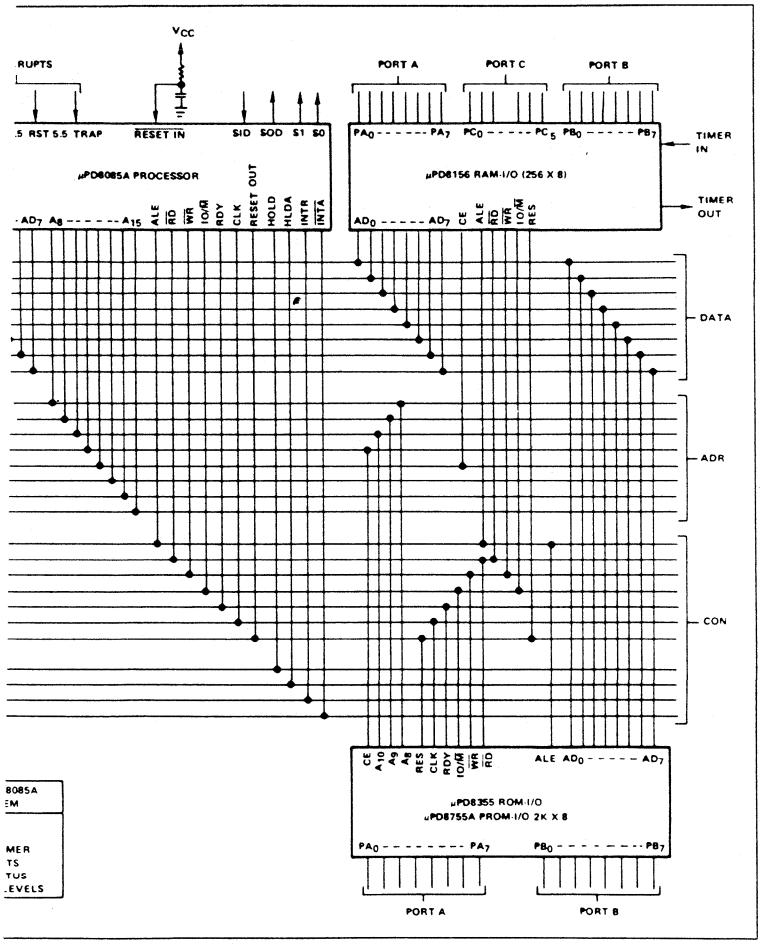
(3) Two possible cycle times (7/10) indicate instruction cycles dependent on condition flags.

(4) • = flag affected
= flag not affected
0 = flag reset
1 = flag set

inimum System

stem consisting of a processor, n be built with only 3 40-pin packs. This system is shown below with its address, data, control buses and I/O ports.

ystem



Description

The μPD8086 is a 16-bit microprocessor that has both 8-bit and 16-bit attributes. It has a 16-bit wide physical path to memory for high performance. Its architecture allows higher throughput than the 5 MHz μPD8085A-2.

The maximum operating frequency of the μPD8086 is 5 MHz. The μPD8086-2 is an 8-MHz version.

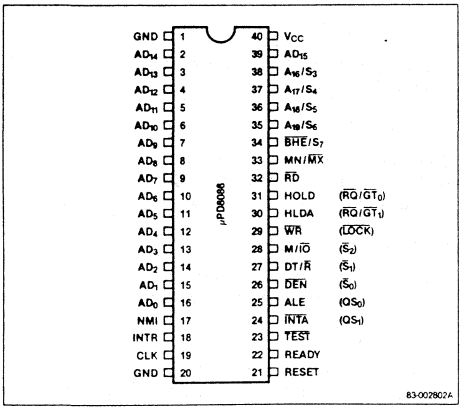
Features

- ☐ Can directly address 1 megabyte of memory
- ☐ Fourteen 16-bit registers with symmetrical operations
- ☐ Bit, byte, word, and block operations
- ☐ 8- and 16-bit signed and unsigned binary or decimal arithmetic operations
- ☐ Multiply and divide instructions
- ☐ 24 operand addressing modes
- ☐ Assembly language compatible with the μPD8080/8085
- ☐ Complete family of components for design flexibility

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD8086D	40-pin ceramic DIP	5 MHz
μPD8086D	40-pin cerdip	5 MHz
μPD8086D-2	40-pin cerdip	8 MHz

Pin Configuration



Pin Identification

No.	Symbol	Function
1, 20	GND	Ground
2–16, 39	AD_0–AD_{15}	Address / data bus
17	NMI	Non-maskable interrupt
18	INTR	Interrupt request
19	CLK	Clock
21	RESET	Reset
22	READY	Ready
23	$\overline{TEST}$	Test
24	$\overline{INTA}$	Interrupt acknowledge
25	ALE	Address latch enable
26	$\overline{DEN}$	Data enable
27	$DT/\overline{R}$	Data transmit / receive
28	$M/\overline{IO}$	Memory / IO status
29	$\overline{WR}$	Write
30	HLDA	Hold acknowledge
31	HOLD	Hold
32	$\overline{RD}$	Read
33	$MN/\overline{MX}$	Minimum / maximum
34	$\overline{BHE}/S_7$	Bus / high enable
35–38	A_{16}–A_{19}	Most significant address bits
26–28, 34–38	S_0–S_7	Status outputs
24, 25	QS_1, QS_0	Queue status
29	$\overline{LOCK}$	Lock
30, 31	$\overline{RQ}/\overline{GT}_0$ $\overline{RQ}/\overline{GT}_1$	Request / grant
40	V_{CC}	Power supply

Pin Functions

Ground

Ground.

Address/Data Bus

Multiplexed address (T1) and data (T2, T3, TW, T4) bus. 8-bit peripherals tied to the lower 8 bits use A_0 to condition chip select functions. These lines are three-state during interrupt acknowledge and hold states.

Non-Maskable Interrupt

This is an edge-triggered input causing a type 2 interrupt. A look-up table is used by the processor for vectoring information.

Interrupt Request

A level-triggered input sampled on the last clock cycle of each instruction. Vectoring is via an interrupt look-up table. INTR can mask in software by resetting the interrupt enable bit.

Clock

The clock input is a 1/3 duty cycle input basic timing for the processor and bus controller.

Reset

This active high signal must be high for 4 clock cycles. When it returns low, the processor restarts execution.

Ready

An acknowledgement from memory or I/O that data will be transferred. Synchronization is done by the μPD8284 clock generator.

Test

This input is examined by the WAIT instruction, and if low, execution continues. Otherwise the processor waits in an idle state. Synchronized by the processor on the leading edge of CLK.

Interrupt Acknowledge

This is a read strobe for reading vectoring information. During T2, T3, and TW of each interrupt acknowledge cycle it is low.

Address Latch Enable

This is used in conjunction with the μPD8282/8283 latches to latch the address, during T1 of any bus cycle.

Data Enable

This is the output enable for the μPD8282/8287 transceivers. It is active low during each memory and I/O access and $\overline{INTA}$ cycles.

Data Transmit/Receive

Used to control the direction of data flow through the transceivers.

Memory/IO Status

This is used to separate memory access from I/O access.

Write

Depending on the state of the M/$\overline{IO}$ line, the processor is either writing to I/O or memory.

Hold Acknowledge

A response to the HOLD input, causing the processor to three-state the local bus. The bus becomes active one cycle after HOLD goes low again.

Hold

When another device requests the local bus, driving HOLD high will cause the μPD8086 to issue a HLDA.

Read

Depending on the state of the M/$\overline{IO}$ line, the processor is reading from either memory or I/O.

Minimum/Maximum

This input is to tell the processor which mode it is to be used in. This effects some of the pin descriptions.

Bus/High Enable

This is used in conjunction with the most significant half of the data bus. Peripheral devices on this half of the bus use $\overline{BHE}$ to condition chip select functions.

Most Significant Address Bits

These are the four most significant address bits for memory operations. Low during I/O operations.

Status Outputs

These are the status outputs from the processor. They are used by the μPD8288 to generate bus control signals.

Queue Status

Used to track the internal μPD8086 instruction queue.

Lock

This output is set by the LOCK instruction to prevent other system bus masters from gaining control.

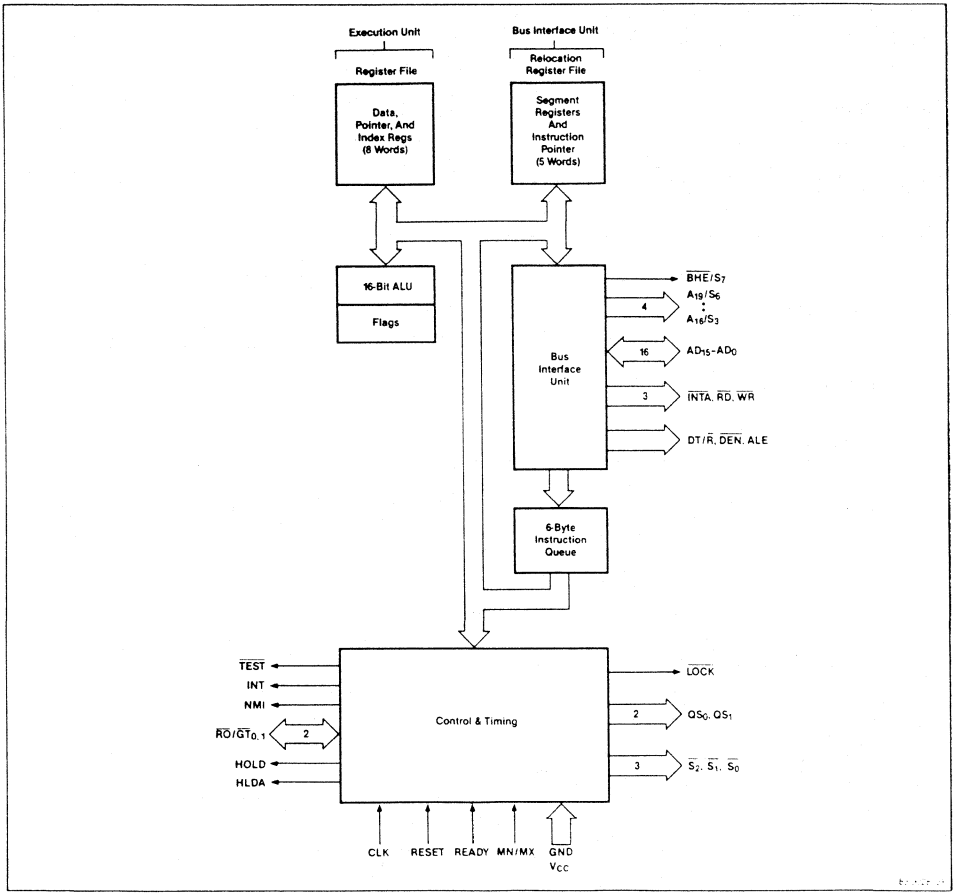
Request/Grant

Other local bus masters can force the processor to rebase the local bus at the end of the current bus cycle.

V_{CC}

This is the +5 V power supply.

Block Diagram



Absolute Maximum Ratings

$T_A = 25°C$

Power supply voltage, V_{CC}	−1.0 V to +7 V
Operating temperature, T_{OPT}	0°C to +70°C
Storage temperature, T_{STG}	−65°C to +150°C
Power dissipation, P_D	2.5 W

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

$f_c = 1.0$ MHz

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input capacitance	C_I			15	pF	(Note 1)
I/O capacitance	C_{IO}			15	pF	(Note 2)

Note:
(1) All input pins except AD_0-AD_{15} and $\overline{RQ}/\overline{GT}$.
(2) Only input pins AD_0-AD_{15} and $\overline{RQ}/\overline{GT}$.

DC Characteristics

$T_A = 0°C$ to $+70°C$, $V_{CC} = +5\,V \pm 10\%$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage low	V_{IL}	−0.5		+0.8	V	
Input voltage high	V_{IH}	2		$V_{CC}+0.5$	V	
Output voltage low	V_{OL}			+0.45	V	$I_{OL} = 2.5$ mA
Output voltage high	V_{OH}	2.4			V	$I_{OH} = -400\,\mu A$
Input clock voltage low	V_{CL}	−0.5		+0.6	V	
Output clock voltage high	V_{CH}	3.9		$V_{CC}+1.0$	V	
Input leakage current	I_{LI}			±10	μA	$0\,V < V_{IN} < V_{CC}$
Output leakage current	I_{LO}			±10	μA	$0.45\,V \leq V_{OUT} \leq V_{CC}$
Power supply current	I_{CC}					
μPD8086/				340	mA	$T_A = 25°C$
μPD8086-2				350	mA	$T_A = 25°C$

AC Characteristics

Minimum Complexity System

μPD8086: $T_A = 0°C$ to $+70°C$, $V_{CC} = 5\,V \pm 10\%$

Parameter	Symbol	Limits μPD8086 Min	μPD8086 Max	μPD8086-2 Min	μPD8086-2 Max	Unit	Test Conditions
CLK cycle period	t_{CLCL}	200	500	125	500	ns	
CLK low time	t_{CLCH}	$(2/3\,t_{CLCL})-15$		$(2/3\,t_{CLCL})-15$		ns	
CLK high time	t_{CHCL}	$(1/3\,t_{CLCL})+2$		$(1/3\,t_{CLCL})+2$		ns	
CLK rise time	t_{CH1CH2}		10		10	ns	From 1.0 V to 3.5 V
CLK fall time	t_{CL2CL1}		10		10	ns	From 3.5 V to 1.0 V
Data in setup time	t_{DVCL}	30		20		ns	
Data in hold time	t_{CLDX}	10		10		ns	
READY setup time into μPD8284	t_{R1VCL}	35		35		ns	(Notes 1 & 2)
READY hold time into μPD8284	t_{CLR1X}	0		0		ns	(Notes 1 & 2)
READY setup time into μPD8086	t_{RYHCH}	$(2/3\,t_{CLCL})-15$		$(2/3\,t_{CLCL})-15$		ns	
READY hold time into μPD8086	t_{CHRYX}	30		20		ns	
READY inactive to CLK	t_{RYLCL}	−8		−8		ns	(Note 3)
HOLD setup time	t_{HVCH}	35		20		ns	
INTR, NMI, $\overline{TEST}$ setup time	t_{INVCH}	30		15		ns	(Note 2)
Input rise time	t_{ILIH}		20		20	ns	From 0.8 V to 2.0 V
Input fall time	t_{IHIL}		12		12	ns	From 2.0 V to 0.8 V

AC Characteristics (cont)

Timing Responses

μPD8086: $T_A = 0°C$ to $+70°C$, $V_{CC} = 5\,V \pm 10\%$

Parameter	Symbol	Limits μPD8086 Min	Limits μPD8086 Max	Limits μPD8086-2 Min	Limits μPD8086-2 Max	Unit	Test Conditions
Address valid delay	t_{CLAV}	10	110	10	60	ns	(Note 4)
Address hold time	t_{CLAX}	10		10		ns	(Note 4)
Address float delay	t_{CLAZ}	t_{CLAX}	80	t_{CLAX}	50	ns	(Note 4)
ALE width	t_{LHLL}	$t_{CLCH} - 20$		$t_{CLCH} - 10$		ns	(Note 4)
ALE active delay	t_{CLLH}		80		50	ns	(Note 4)
ALE inactive delay	t_{CHLL}		85		55	ns	(Note 4)
Address hold time to ALE inactive	t_{LLAX}	$t_{CHCL} - 10$		$t_{CHCL} - 10$		ns	(Note 4)
Data valid delay	t_{CLDV}	10	110	10	60	ns	(Note 4)
Data hold time	t_{CHDX}	10		10		ns	(Note 4)
Data hold time after WR	t_{WHDX}	$t_{CLCH} - 30$		$t_{CLCH} - 30$		ns	(Note 4)
Control active delay 1	t_{CVCTV}	10	110	10	70	ns	(Note 4)
Control active delay 2	t_{CHCTV}	10	110	10	60	ns	(Note 4)
Control active delay	t_{CVCTX}	10	110	10	70	ns	(Note 4)
Address float to READ active	t_{AZRL}	0		0		ns	(Note 4)
$\overline{RD}$ active delay	t_{CLRL}	10	165	10	80	ns	(Note 4)
$\overline{RD}$ inactive delay	t_{CLRH}	10	150	10	80	ns	(Note 4)
$\overline{RD}$ inactive to next address active	t_{RHAV}	$t_{CLCL} - 45$		$t_{CLCL} - 40$		ns	(Note 4)
HLDA valid delay	t_{CLHAV}	10	160	10	100	ns	(Note 4)
$\overline{RD}$ width	t_{RLRH}	$2t_{CLCL} - 75$		$2t_{CLCL} - 50$		ns	(Note 4)
$\overline{WR}$ width	t_{WLWH}	$2t_{CLCL} - 60$		$2t_{CLCL} - 40$		ns	(Note 4)
Address valid to ALE low	t_{AVAL}	$t_{CLCH} - 60$		$t_{CLCH} - 40$		ns	(Note 4)
Output rise time	t_{OLOH}		20		20	ns	From 0.8 V to 2.0 V
Output fall time	t_{OHOL}		12		12	ns	From 2.0 V to 0.8 V

Note:

(1) Signal at μPD8284 shown for reference only.

(2) Setup requirement for asynchronous signal only to guarantee recognition at next CLK.

(3) Applies only to T2 state. (8 ns into T3)

(4) $C_L = 20$–100 pF for all μPD8086 outputs (in addition to μPD8086 self-load).

AC Characteristics (cont)

Maximum Mode System with μPB8288 Bus Controller

μPD8086: $T_A = 0°C$ to $+70°C$, $V_{CC} = 5\ V \pm 10\%$

Parameter	Symbol	Limits μPD8086 Min	Limits μPD8086 Max	Limits μPD8086-2 Min	Limits μPD8086-2 Max	Unit	Test Conditions
CLK cycle period	t_{CLCL}	200	500	125	500	ns	
CLK low time	t_{CLCH}	$(2/3\ t_{CLCL}) - 15$		$(2/3\ t_{CLCL}) - 15$		ns	
CLK high time	t_{CHCL}	$(1/3\ t_{CLCL}) + 2$		$(1/3\ t_{CLCL}) + 2$		ns	
CLK rise time	t_{CH1CH2}		10		10	ns	From 1.0 V to 3.5 V
CLK fall time	t_{CL2CL1}		10		10	ns	From 3.5 V to 1.0 V
Data in setup time	t_{DVCL}	30		20		ns	
Data in hold time	t_{CLDX}	10		10		ns	
READY setup time into μPD8284	t_{R1VCL}	35		35		ns	(Notes 1 & 2)
READY hold time into μPD8284	t_{CLR1X}	0		0		ns	(Notes 1 & 2)
READY setup time into μPD8086	t_{RYHCH}	$(2/3\ t_{CLCL}) - 15$		$(2/3\ t_{CLCL}) - 15$		ns	
READY hold time into μPD8086	t_{CHRYX}	30		20		ns	
READY inactive to CLK	t_{RYLCL}	−8		−8		ns	(Note 5)
INTR, NMI, $\overline{TEST}$ setup time	t_{INVCH}	30		15		ns	(Note 2)
$\overline{RQ}$ / $\overline{GT}$ setup time	t_{GVCH}	30		15		ns	
$\overline{RQ}$ hold time into μPD8086	t_{CHGX}	40		30		ns	
Input rise time	t_{ILIH}		20		20	ns	From 0.8 V to 2.0 V
Input fall time	t_{IHIL}		12		12	ns	From 2.0 V to 0.8 V

AC Characteristics (cont)

Timing Responses

μPD8086: $T_A = 0°C$ to $+70°C$, $V_{CC} = 5\,V \pm 10\%$

Parameter	Symbol	Limits μPD8086 Min	Limits μPD8086 Max	Limits μPD8086-2 Min	Limits μPD8086-2 Max	Unit	Test Conditions
Command active delay	t_{CLML}	10	35	10	35	ns	(Notes 1 & 4)
Command inactive delay	t_{CLMH}	10	35	10	35	ns	(Notes 1 & 4)
READY active to status passive	t_{RYHSH}		110		65	ns	(Notes 3 & 4)
Status active delay	t_{CHSV}	10	110	10	60	ns	(Note 4)
Status inactive delay	t_{CLSH}	10	130	10	70	ns	(Note 4)
Address valid delay	t_{CLAV}	10	110	10	60	ns	(Note 4)
Address hold time	t_{CLAX}	10		10		ns	(Note 4)
Address float delay	t_{CLAZ}	t_{CLAX}	80	t_{CLAX}	50	ns	(Note 4)
Status valid to ALE high	t_{SVLH}		15		15	ns	(Notes 1 & 4)
Status valid to MCE high	t_{SVMCH}		15		15	ns	(Notes 1 & 4)
CLK low to ALE valid	t_{CLLH}		15		15	ns	(Notes 1 & 4)
CLK low to MCE high	t_{CLMCH}		15		15	ns	(Notes 1 & 4)
ALE inactive delay	t_{CHLL}		15		15	ns	(Notes 1 & 4)
MCE inactive delay	t_{CLMCL}		15		15	ns	(Notes 1 & 4)
Data valid delay	t_{CLDV}	10	110	10	60	ns	(Note 4)
Data hold time	t_{CHDX}	10		10		ns	(Note 4)
Control active delay	t_{CVNV}	5	45	5	45	ns	(Notes 1 & 4)
Control inactive delay	t_{CVNX}	10	45	10	45	ns	(Notes 1 & 4)
Address float to READ active	t_{AZRL}	0		0		ns	(Note 4)
$\overline{RD}$ active delay	t_{CLRL}	10	165	10	100	ns	(Note 4)
$\overline{RD}$ inactive delay	t_{CLRH}	10	150	10	80	ns	(Note 4)
$\overline{RD}$ inactive to next address active	t_{RHAV}	$t_{CLCL} - 45$		$t_{CLCL} - 40$		ns	(Note 4)
Direction control active delay	t_{CHDTL}		50		50	ns	(Notes 1 & 4)
Direction control inactive delay	t_{CHDTH}		30		30	ns	(Notes 1 & 4)
$\overline{GT}$ active delay	t_{CLGL}	0	85	0	50	ns	(Note 4)
$\overline{GT}$ inactive delay	t_{CLGH}	0	85	0	50	ns	(Note 4)
$\overline{RD}$ width	t_{RLRH}	$2t_{CLCL} - 50$		$2t_{CLCL} - 50$		ns	(Note 4)
Output rise time	t_{OLOH}		20		20	ns	From 0.8 V to 2.0 V
Output fall time	t_{OHOL}		12		12	ns	From 2.0 V to 0.8 V

Note:

(1) Signal at μPB8284 or μPB8288 shown for reference only.

(2) Setup requirement for asynchronous signal only to guarantee recognition at next CLK.

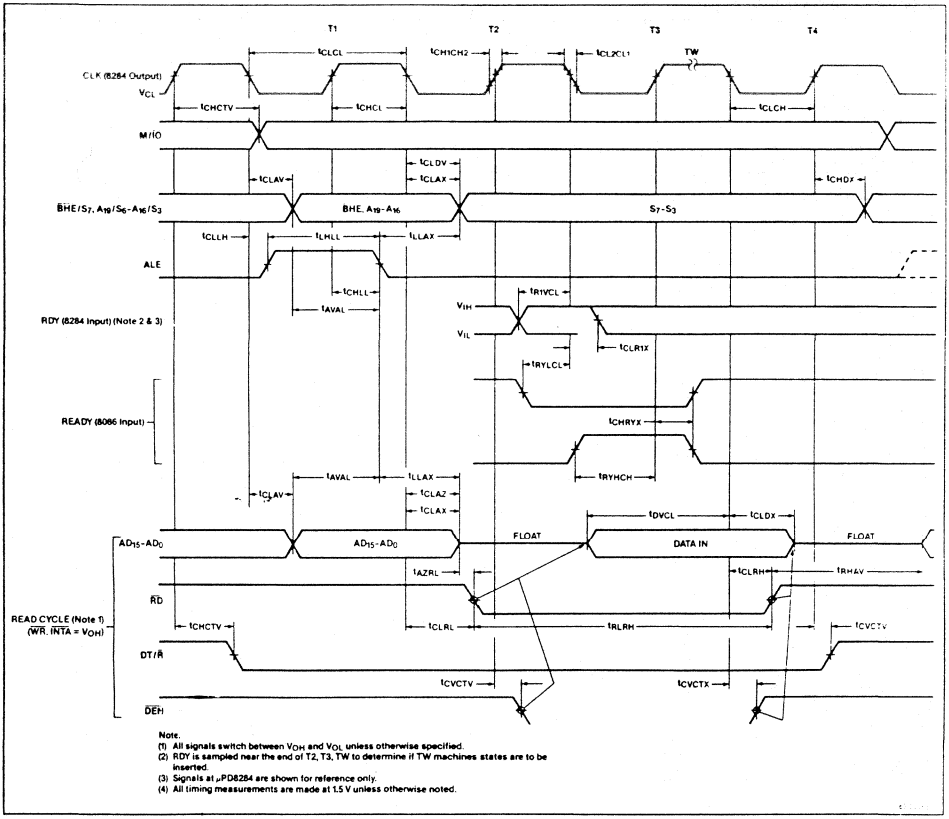
(3) Applies only to T3 and wait states.

(4) $C_L = 20$-100 pF for all μPD8086 outputs (in addition to μPD8086 self-load).

(5) Applies only to T2 state. (8 ns into T3).

AC Timing Waveforms

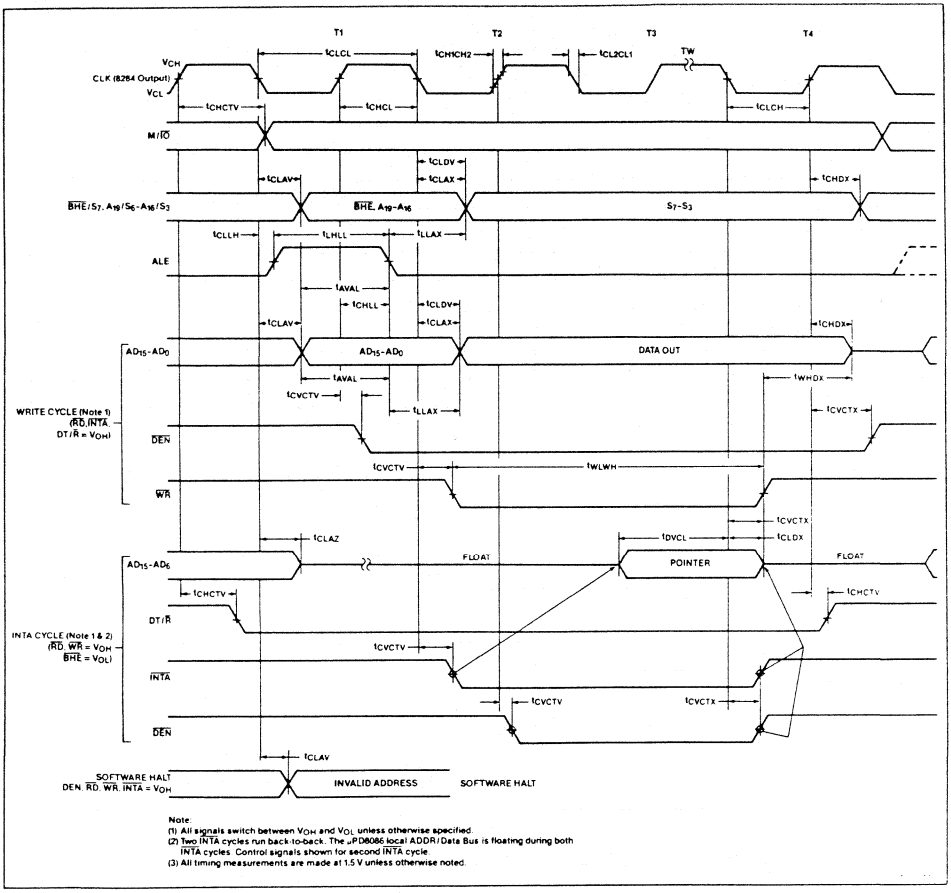
Minimum Complexity Systems (Note 4)



Note.
(1) All signals switch between V_{OH} and V_{OL} unless otherwise specified.
(2) RDY is sampled near the end of T2, T3, TW to determine if TW machines states are to be inserted.
(3) Signals at μPD8284 are shown for reference only.
(4) All timing measurements are made at 1.5 V unless otherwise noted.

AC Timing Waveforms (cont)

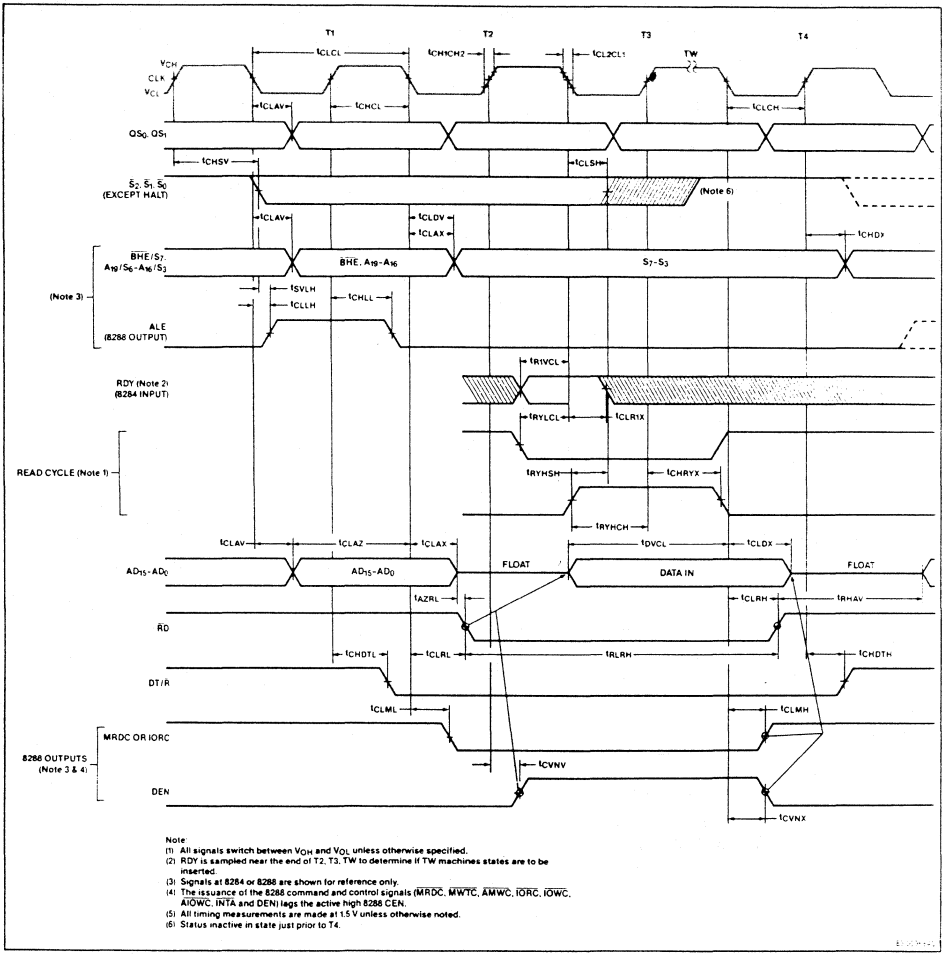
Minimum Complexity Systems (Note 3)



Note:
(1) All signals switch between V_{OH} and V_{OL} unless otherwise specified.
(2) Two $\overline{INTA}$ cycles run back-to-back. The μPD8086 local ADDR/Data Bus is floating during both $\overline{INTA}$ cycles. Control signals shown for second $\overline{INTA}$ cycle.
(3) All timing measurements are made at 1.5 V unless otherwise noted.

AC Timing Waveforms (cont)

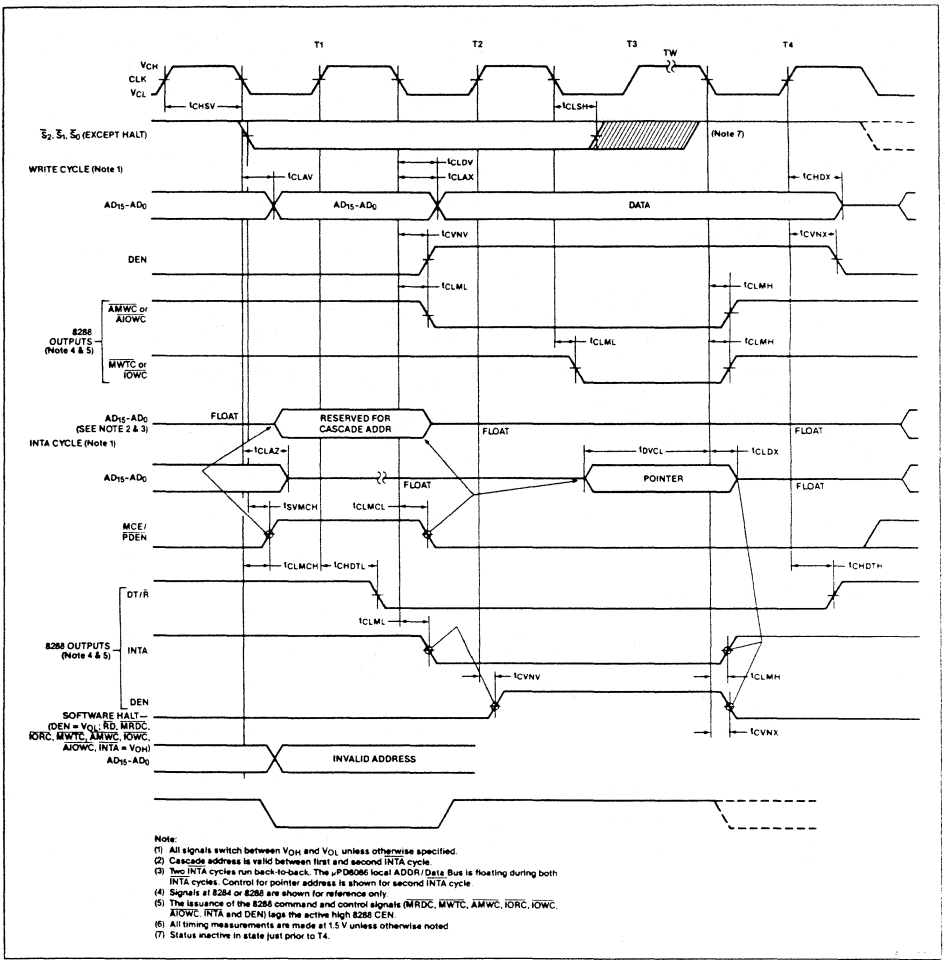
Maximum Mode System Using μPB8288 Controller (Note 5)



Note
(1) All signals switch between V_{OH} and V_{OL} unless otherwise specified.
(2) RDY is sampled near the end of T2, T3, TW to determine if TW machines states are to be inserted.
(3) Signals at 8284 or 8288 are shown for reference only.
(4) The issuance of the 8288 command and control signals ($\overline{MRDC}$, $\overline{MWTC}$, $\overline{AMWC}$, $\overline{IORC}$, $\overline{IOWC}$, $\overline{AIOWC}$, $\overline{INTA}$ and DEN) lags the active high 8288 CEN.
(5) All timing measurements are made at 1.5 V unless otherwise noted.
(6) Status inactive in state just prior to T4.

AC Timing Waveforms (cont)

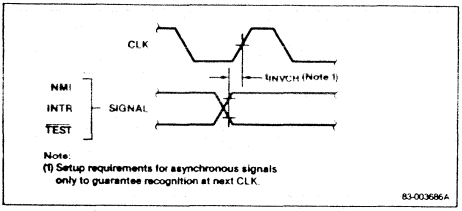
Maximum Mode System Using μPB8288 Controller (Note 6)



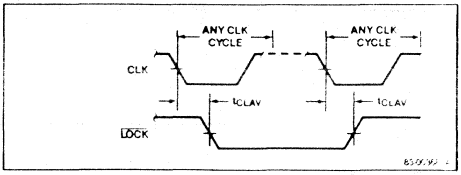
Note:
(1) All signals switch between V_{OH} and V_{OL} unless otherwise specified.
(2) Cascade address is valid between first and second INTA cycle.
(3) Two INTA cycles run back-to-back. The μPD8086 local ADDR/Data Bus is floating during both INTA cycles. Control for pointer address is shown for second INTA cycle.
(4) Signals at 8284 or 8286 are shown for reference only.
(5) The issuance of the 8288 command and control signals (MRDC, MWTC, AMWC, IORC, IOWC, AIOWC, INTA and DEN) lags the active high 8288 CEN.
(6) All timing measurements are made at 1.5 V unless otherwise noted.
(7) Status inactive in state just prior to T4.

Timing Waveforms

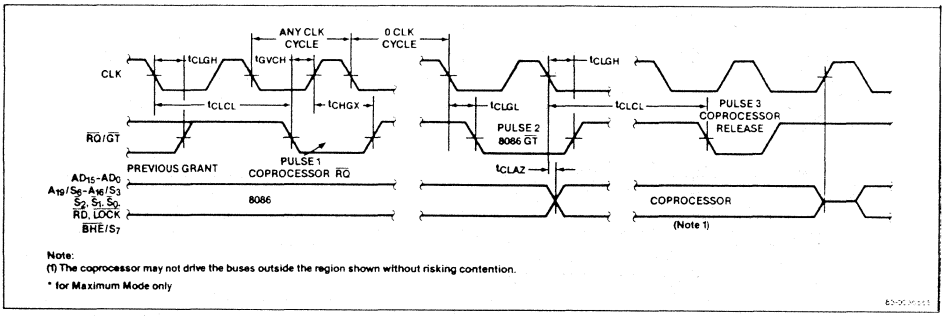
Asynchronous Signal Recognition



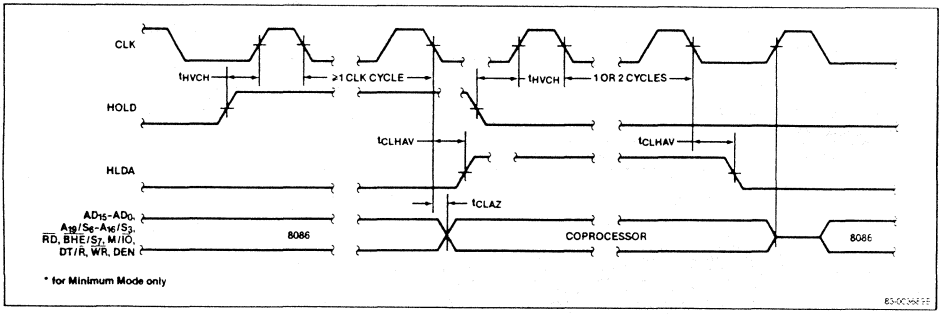
Bus Lock Signal Timing



Request/Grant Sequence Timing*



Hold/Hold Acknowledge Timing*



Description

The μPD8088 and μPD8088-2 are powerful 8-bit microprocessors that are software-compatible with the μPD8086. They have the same bus interface signals as μPD8085A, allowing them to interface directly with multiplexed bus peripherals. Both having a 20-bit address space which can be divided into four segments of up to 64K bytes each.

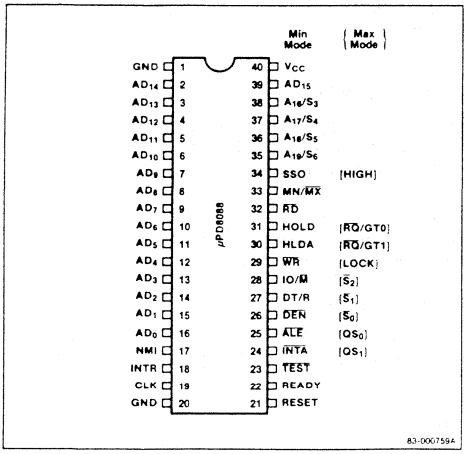
Features

- ☐ 8-bit data bus interface
- ☐ 16-bit internal architecture
- ☐ Addresses 1 Mbyte of memory
- ☐ Software-compatible with the 8086
- ☐ Provides byte, word, and block operations
- ☐ Performs 8- and 16-bit signed and unsigned arithmetic in binary and decimal
- ☐ Multiply and divide instruction
- ☐ Directly interfaces to 8155, 8355, and 8755A multiplexed peripherals

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD8088D	40-pin ceramic DIP	5 MHz
μPD8088D-2	40-pin ceramic DIP	8 MHz

Pin Configuration



Pin Identification

No.	Symbol	Function
1, 20	GND	Ground
2-8, 35-39	A_{19}-A_8	Most significant address bits
9-16	AD_7-AD_0	Address/data bus
17	NMI	Non-maskable interrupt
18	INTR	Interrupt request
19	CLK	Clock
21	RESET	Reset
22	READY	Ready
23	$\overline{TEST}$	Test
24	$\overline{INTA}$	Interrupt acknowledge
25	ALE	Address latch enable
24, 25	QS_1, QS_0	Queue status
26	$\overline{DEN}$	Data enable
27	DT/R	Data transmit/receive
28	IO/$\overline{M}$	IO status/memory
29	$\overline{WR}$	Write
29	LOCK	Lock
30	HLDA	Hold acknowledge
31	HOLD	Hold
30, 31	$\overline{RQ}/GT_0$ $\overline{RQ}/GT_1$	Request/grant
32	$\overline{RD}$	Read
33	MN/$\overline{MX}$	Minimum/maximum
34	SS0	Status line
26-28	$\overline{S}_0$-$\overline{S}_2$	Status outputs
35-38	S_3-S_6	Status outputs
40	V_{CC}	Power supply

Pin Function

Ground

Ground.

Most Significant Address Bits

Most significant bits for memory operations.

Address/Data Bus

Multiplexed address and data bus. 8-bit peripherals tied to these bits use A_0 to condition chip select functions. These lines are three-state during interrupt acknowledge and hold states.

Non-Maskable Interrupt

This edge-triggered input causes a type 2 interrupt. The processor uses a look-up table for vectoring information.

Interrupt Request

This is a level-triggered interrupt sampled on the last clock cycle of each instruction. A look-up table is used for vectoring. INTR can be masked in software by resetting the interrupt enable bit.

Clock

The clock input is a 1/3 duty cycle input providing basic timing for the processor and bus controller.

Reset

This active high signal must be high for 4 clock cycles. When it returns low, the processor restarts execution.

Ready

An acknowledgement from memory or I/O that data will be transferred. Synchronization is done by the μPD8284 clock generator.

Test

This input is examined by the "WAIT" instruction, and if low, execution continues. Otherwise the processor waits in an "Idle" state. Synchronized by the processor on the leading edge of CLK.

Interrupt Acknowledge

This is a read strobe for reading vectoring information. During T2, T3, and TW of each interrupt acknowledge cycle it is low.

Address Latch Enable

This is used in conjunction with the μPD8282/8283 latches to latch the address, during T1 of any bus cycle.

Queue Status

(Max mode) tracks the internal μPD8088 instruction queue.

Data Enable

This is the output enable for the μPD8286/8287 transceivers. It is active low during memory and I/O access and $\overline{\text{INTA}}$ cycles.

Data Transmit/Receive

Controls the direction of data flow through the transceivers.

IO Status/Memory

Separates memory access from I/O access.

Write

Depending on the state of the IO/$\overline{\text{M}}$ line, the processor is either writing to I/O or memory.

Lock

(Max mode) this output is set by the "LOCK" instruction to prevent other system bus masters from gaining control.

Hold Acknowledge

A response to the HOLD input, causing the processor to three-state the local bus. The bus becomes active one cycle after HOLD returns low.

Hold

When another device requests the local bus, HOLD is driven high, causing the μPD8088 to issue a HLDA.

Request/Grant

(Max mode) other local bus masters can force the processor to rebase the local bus at the end of the current bus cycle.

Read

Depending on the state of the IO/$\overline{\text{M}}$ line, the processor is reading from either memory or I/O.

Minimum/Maximum

This input tells the processor in which mode it is to be used. This affects some of the pin descriptions.

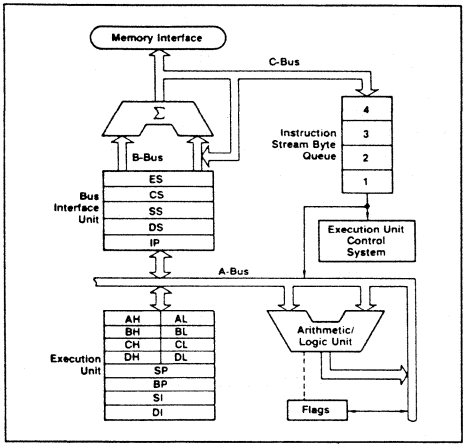
Status Outputs

(Max mode) These are the status outputs from the processor. They are used by the μPD8288 to generate bus control signals.

V_{CC}

5 V power supply input.

Block Diagram



Absolute Maximum Ratings

T_A = 25°C, Tentative

Power supply voltage, V_{DD}	−0.5 V to +7 V
Input voltage, V_I	−0.5 V to +7 V
Output voltage, V_O	−0.5 V to +7 V
Operating temperature, T_{OPT}	0°C to +70°C
Storage temperature, T_{STG}	−65°C to +150°C
Power dissipation, P_D	2.5 W

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

T_A = 0°C to +70°C, V_{CC} = +5 V ± 10%

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage low	V_{IL}	−0.5		+0.8	V	
Input voltage high	V_{IH}	2.0		V_{CC}+0.5	V	
Output voltage low	V_{OL}			+0.45	V	I_{OL} = 2.0 mA
Output voltage high	V_{OH}	2.4			V	I_{OH} = −400 μA
Input clock voltage low	V_{CL}	−0.5		+0.6	V	
Input clock voltage high	V_{CH}	3.9		V_{CC}+1.0	V	
Input leakage current	I_{LI}			±10	μA	0 V < V_I < V_{CC}
Output leakage current	I_{LO}			±10	μA	0.45 V ≤ V_O ≤ V_{CC}
Power supply current	I_{CC}					
μPD8088 /				340	mA	T_A = 25°C
μPD8088-2				350	mA	T_A = 25°C

Capacitance

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input capacitance	C_I			15	pF	(Note 1)
I/O capacitance	C_{IO}			15	pF	(Note 2)

Note:

(1) All input pins except AD_0-AD_7 and RQ/GT.

(2) Only input pins AD_0-AD_7 and RQ/GT.

AC Characteristics

Minimum Complexity Systems

T_A = 0°C to +70°C, V_{CC} = 5 V ± 10%

Parameter	Symbol	Limits μPD8088 Min	Limits μPD8088 Max	Limits μPD8088-2 Min	Limits μPD8088-2 Max	Unit	Test Conditions
CLK cycle period	t_{CLCL}	200	500	125	500	ns	
CLK low time	t_{CLCH}	$(2/3\ t_{CLCL})-15$		$(2/3\ t_{CLCL})-15$		ns	
CLK high time	t_{CHCL}	$(1/3\ t_{CLCL})+2$		$(1/3\ t_{CLCL})+2$		ns	
CLK rise time	t_{CH1CH2}		10		10	ns	From 1.0 V to 3.5 V
CLK fall time	t_{CL2CL1}		10		10	ns	From 3.5 V to 1.0 V
Data in setup time	t_{DVCL}	30		20		ns	
Data in hold time	t_{CLDX}	10		10		ns	
READY setup time into μPD8284	t_{R1VCL}	35		35		ns	(Notes 1 & 2)
READY hold time into μPD8284	t_{CLR1X}	0		0		ns	(Notes 1 & 2)
READY setup time into μPD8088	t_{RYHCH}	$(2/3\ t_{CLCL})-15$		$(2/3\ t_{CLCL})-15$		ns	
READY hold time into μPD8088	t_{CHRYX}	30		20		ns	
READY inactive to CLK	t_{RYLCL}	−8		−8		ns	(Note 3)
HOLD setup time	t_{HVCH}	35		20		ns	
INTR, NMI, $\overline{TEST}$ setup time	t_{INVCH}	30		15		ns	(Note 2)
Input rise time	t_{ILIH}		20		20	ns	From 0.8 V to 2.0 V except clock
Input fall time	t_{IHIL}		12		12	ns	From 2.0 V to 0.8 V except clock

Timing Responses

T_A = 0°C to +70°C, V_{CC} = 5 V ± 10%

Parameter	Symbol	Limits μPD8088 Min	Limits μPD8088 Max	Limits μPD8088-2 Min	Limits μPD8088-2 Max	Unit	Test Conditions
Address valid delay	t_{CLAV}	10	110	10	60	ns	(Note 4)
Address hold time	t_{CLAX}	10		10		ns	(Note 4)
Address float delay	t_{CLAZ}	t_{CLAX}	80	t_{CLAX}	50	ns	(Note 4)
ALE width	t_{LHLL}	$t_{CLCH}-20$		$t_{CLCH}-10$		ns	(Note 4)
ALE active delay	t_{CLLH}		80		50	ns	(Note 4)
ALE inactive delay	t_{CHLL}		85		55	ns	(Note 4)
Address hold time to ALE inactive	t_{LLAX}	$t_{CHCL}-10$		$t_{CHCL}-10$		ns	(Note 4)
Data valid delay	t_{CLDV}	10	110	10	60	ns	(Note 4)
Data hold time	t_{CHDX}	10		10		ns	(Note 4)
Data hold time after $\overline{WR}$	t_{WHDX}	$t_{CLCH}-30$		$t_{CLCH}-30$		ns	(Note 4)
Control active delay 1	t_{CVCTV}	10	110	10	70	ns	(Note 4)
Control active delay 2	t_{CHCTV}	10	110	10	70	ns	(Note 4)
Control inactive delay	t_{CVCTX}	10	110	10	70	ns	(Note 4)
Address float to READ active	t_{AZRL}	0		0		ns	(Note 4)
$\overline{RD}$ active delay	t_{CLRL}	10	165	10	80	ns	(Note 4)

AC Characteristics (cont)

Timing Responses (cont)

$T_A = 0°C$ to $+70°C$, $V_{CC} = 5\ V \pm 10\%$

Parameter	Symbol	Limits μPD8088 Min	Limits μPD8088 Max	Limits μPD8088-2 Min	Limits μPD8088-2 Max	Unit	Test Conditions
$\overline{RD}$ inactive delay	t_{CLRH}	10	150	10	80	ns	(Note 4)
$\overline{RD}$ inactive to next address active	t_{RHAV}	$t_{CLCL} - 45$		$t_{CLCL} - 40$		ns	(Note 4)
HLDA valid delay	t_{CLHAV}	10	160	10	100	ns	(Note 4)
$\overline{RD}$ width	t_{RLRH}	$2t_{CLCL} - 75$		$2t_{CLCL} - 50$		ns	(Note 4)
$\overline{WR}$ width	t_{WLWH}	$2t_{CLCL} - 60$		$2t_{CLCL} - 40$		ns	(Note 4)
Address valid to ALE low	t_{AVAL}	$t_{CLCH} - 60$		$t_{CLCH} - 40$		ns	(Note 4)
Output rise time	t_{OLOH}		20		20	ns	From 0.8 V to 2.0 V
Output fall time	t_{OHOL}		12		12	ns	From 2.0 V to 0.8 V

Note:

(1) Signal at μPD8284 shown for reference only.

(2) Setup requirement for asynchronous signal only to guarantee recognition at next CLK.

(3) Applies only to T2 state. (8 ns into T3)

(4) C_L = 20-100 pF for all μPD8088 outputs (in addition to μPD8088 self-load).

Maximum Mode System with μPB8288 Bus Controller

$T_A = 0°C$ to $+70°C$, $V_{CC} = 5\ V \pm 10\%$

Parameter	Symbol	Limits μPD8088 Min	Limits μPD8088 Max	Limits μPD8088-2 Min	Limits μPD8088-2 Max	Unit	Test Conditions
CLK cycle period	t_{CLCL}	200	500	125	500	ns	
CLK low time	t_{CLCH}	$(2/3\ t_{CLCL}) - 15$		$(2/3\ t_{CLCL}) - 15$		ns	
CLK high time	t_{CHCL}	$(1/3\ t_{CLCL}) + 2$		$(1/3\ t_{CLCL}) + 2$		ns	
CLK rise time	t_{CH1CH2}		10		10	ns	From 1.0 V to 3.5 V
CLK fall time	t_{CL2CL1}		10		10	ns	From 3.5 V to 1.0 V
Data in setup time	t_{DVCL}	30		20		ns	
Data in hold time	t_{CLDX}	10		10		ns	
READY setup time into μPD8284	t_{R1VCL}	35		35		ns	(Notes 1 & 2)
READY hold time into μPD8284	t_{CLR1X}	0		0		ns	(Notes 1 & 2)
READY setup time into μPD8088	t_{RYHCH}	$(2/3\ t_{CLCL}) - 15$		$(2/3\ t_{CLCL}) - 15$		ns	
READY hold time into μPD8088	t_{CHRYX}	30		20		ns	
READY inactive to CLK	t_{RYLCL}	−8		−8		ns	(Note 5)
INTR, NMI, $\overline{TEST}$ setup time	t_{INVCH}	30		15		ns	(Note 2)
RQ / GT setup time	t_{GVCH}	30		15		ns	
RQ hold time into μPD8088	t_{CHGX}	40		30		ns	
Input rise time	t_{ILIH}		20		20	ns	From 0.8 V to 2.0 V except clock
Input fall time	t_{IHIL}		12		12	ns	From 2.0 V to 0.8 V except clock

AC Characteristics (cont)

Timing Responses

μPD8088: $T_A = 0°C$ to $+70°C$, $V_{CC} = 5\,V \pm 10\%$

Parameter	Symbol	Limits μPD8088 Min	Limits μPD8088 Max	Limits μPD8088-2 Min	Limits μPD8088-2 Max	Unit	Test Conditions
Command active delay	t_{CLML}	10	35	10	35	ns	(Notes 1 & 4)
Command inactive delay	t_{CLMH}	10	35	10	35	ns	(Notes 1 & 4)
READY active to status passive	t_{RYHSH}		110		65	ns	(Notes 3 & 4)
Status active delay	t_{CHSV}	10	110	10	60	ns	(Note 4)
Status inactive delay	t_{CLSH}	10	130	10	70	ns	(Note 4)
Address valid delay	t_{CLAV}	10	110	10	60	ns	(Note 4)
Address hold time	t_{CLAX}	10		10		ns	(Note 4)
Address float delay	t_{CLAZ}	t_{CLAX}	80	t_{CLAX}	50	ns	(Note 4)
Status valid to ALE high	t_{SVLH}		15		15	ns	(Notes 1 & 4)
Status valid to MCE high	t_{SVMCH}		15		15	ns	(Notes 1 & 4)
CLK low to ALE valid	t_{CLLH}		15		15	ns	(Notes 1 & 4)
CLK low to MCE high	t_{CLMCH}		15		15	ns	(Notes 1 & 4)
ALE inactive delay	t_{CHLL}		15		15	ns	(Notes 1 & 4)
MCE inactive delay	t_{CLMCL}		15		15	ns	(Notes 1 & 4)
Data valid delay	t_{CLDV}	10	110	10	60	ns	(Note 4)
Data hold time	t_{CHDX}	10		10		ns	(Note 4)
Control active delay	t_{CVNV}	5	45	5	45	ns	(Notes 1 & 4)
Control inactive delay	t_{CVNX}	10	45	10	45	ns	(Notes 1 & 4)
Address float to READ active	t_{AZRL}	0		0		ns	(Note 4)
$\overline{RD}$ active delay	t_{CLRL}	10	165	10	100	ns	(Note 4)
$\overline{RD}$ inactive delay	t_{CLRH}	10	150	10	80	ns	(Note 4)
$\overline{RD}$ inactive to next address active	t_{RHAV}	$t_{CLCL} - 45$		$t_{CLCL} - 40$		ns	(Note 4)
Direction control active delay	t_{CHDTL}		50		50	ns	(Notes 1 & 4)
Direction control inactive delay	t_{CHDTH}		30		30	ns	(Notes 1 & 4)
$\overline{GT}$ active delay	t_{CLGL}	0	85	0	50	ns	(Note 4)
$\overline{GT}$ inactive delay	t_{CLGH}	0	85	0	50	ns	(Note 4)
$\overline{RD}$ width	t_{RLRH}	$2t_{CLCL} - 75$		$2t_{CLCL} - 50$		ns	(Note 4)
Output rise time	t_{OLOH}		20		20	ns	From 0.8 V to 2.0 V
Output fall time	t_{OHOL}		12		12	ns	From 2.0 V to 0.8 V

Note:

(1) Signal at μPB8284 or μPB8288 shown for reference only.

(2) Setup requirement for asynchronous signal only to guarantee recognition at next CLK.

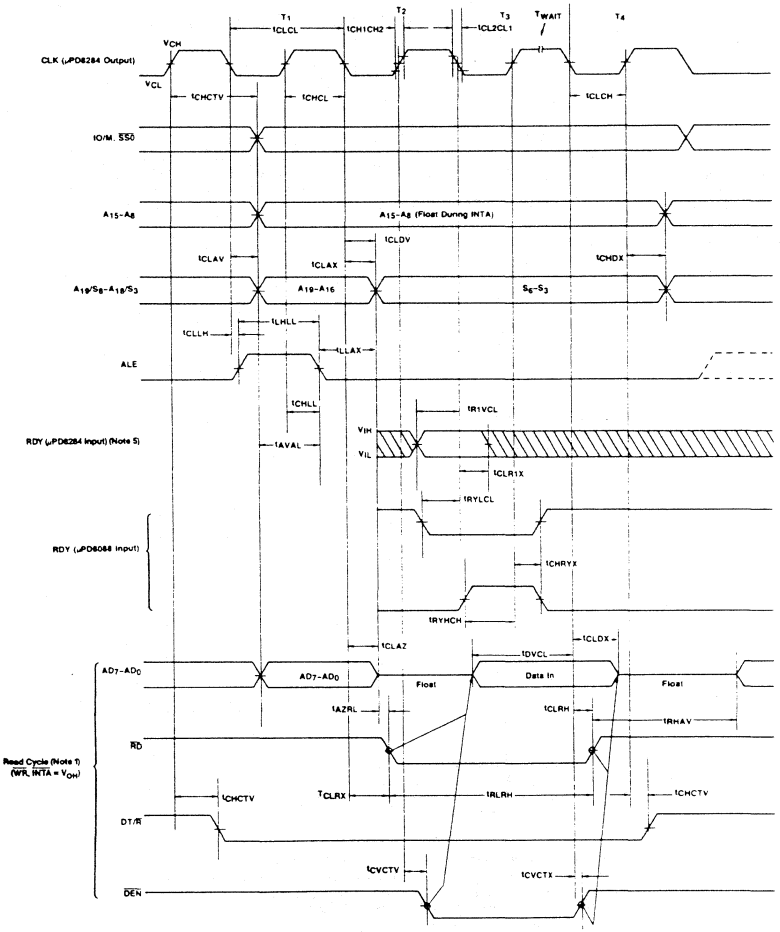
(3) Applies only to T3 and wait states.

(4) $C_L = 20$–100 pF for all μPD8088 outputs (in addition to μPD8088 self-load).

(5) Applies only to T2 state. (8 ns into T3).

Timing Waveforms

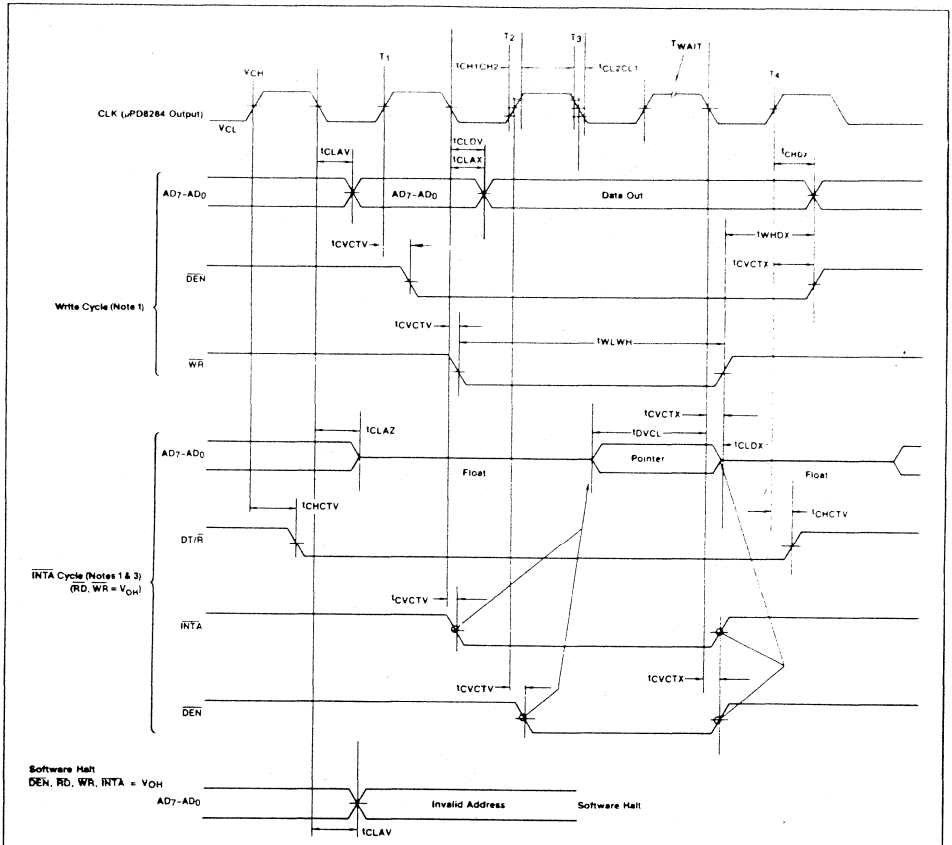
Minimum Complexity Systems (Note 5)



Note:
(1) All signals switch between V_{OH} and V_{OL} unless otherwise specified.
(2) RDY is sampled near the end of T2, T3, TWAIT to determine if TWAIT machine states are inserted.
(3) Two $\overline{INTA}$ cycles run back-to-back. The μPD8088 local Address/Data bus floats during both $\overline{INTA}$ cycles. The control signals shown are for the second $\overline{INTA}$ cycle.
(4) Signals at the μPD8284 are shown for reference.
(5) All timing measurements are taken at 1.5 V unless otherwise specified.

Timing Waveforms (cont)

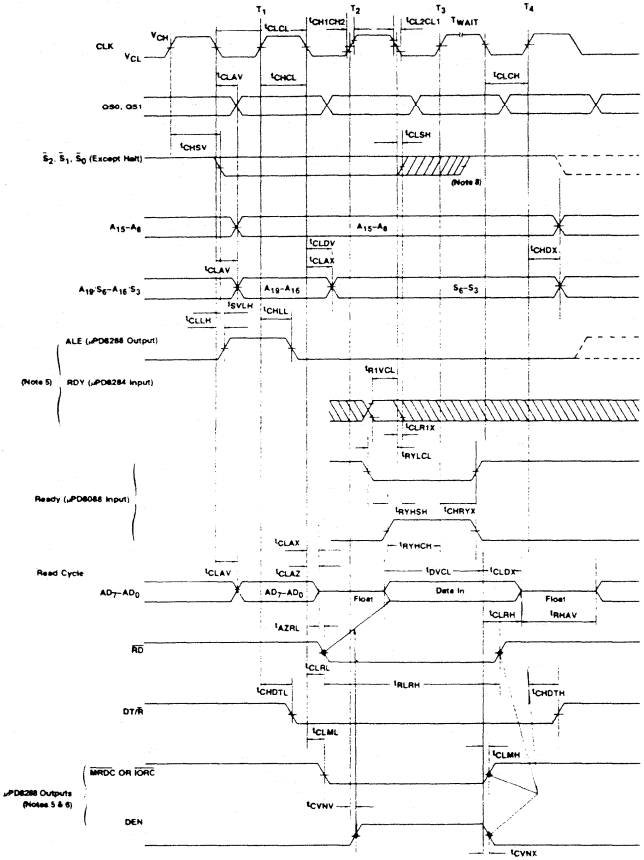
Minimum Complexity Systems (Note 5)



Note:
(1) All signals switch between V_{OH} and V_{OL} unless otherwise specified.
(2) RDY is sampled near the end of T2, T3, TWAIT to determine if TWAIT machine states are inserted.
(3) Two $\overline{INTA}$ cycles run back-to-back. The μPD8088 local Address / Data bus floats during both $\overline{INTA}$ cycles. The control signals shown are for the second $\overline{INTA}$ cycle.
(4) Signals at the μPD8284 are shown for reference.
(5) All timing measurements are taken at 1.5 V unless otherwise specified.

Timing Waveforms (cont)

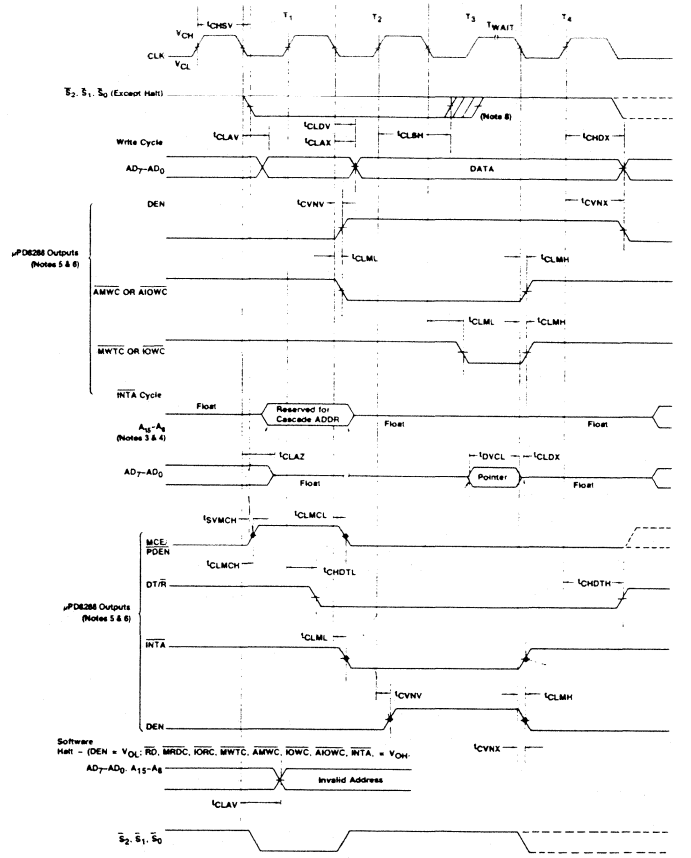
Maximum Mode System Bus Timing Using μPB8288 Bus Controller (Note 7)



Note:
(1) All signals switch between V_{OH} and V_{OL} unless otherwise specified.
(2) RDY is sampled near the end of T2, T3, TWAIT to determine if TWAIT machine states are inserted.
(3) The cascade address is valid between the first and second $\overline{INTA}$ cycles.
(4) Two $\overline{INTA}$ cycles run back-to-back. The μPD8088 local Address/Data bus floats during both $\overline{INTA}$ cycles. The control signals shown are for the second $\overline{INTA}$ cycle.
(5) Signals at the μPD8284 are shown for reference.
(6) The μPD8288 active-high CEN lags when the μPD8288 issues command and control signals ($\overline{MRDC}$, $\overline{MWTC}$, $\overline{AMWC}$, $\overline{IORC}$, $\overline{IOWC}$, $\overline{AIOWC}$, $\overline{INTA}$, and $\overline{DEN}$).
(7) All timing measurements are taken at 1.5 V unless otherwise specified.
(8) Status is inactive prior to T4.

Timing Waveforms (cont)

Maximum Mode System Bus Timing Using μPB8288 Bus Controller (cont) (Note 7)



Note:

(1) All signals switch between V_{OH} and V_{OL} unless otherwise specified.

(2) RDY is sampled near the end of T2, T3, TWAIT to determine if TWAIT machine states are inserted.

(3) The cascade address is valid between the first and second $\overline{INTA}$ cycles.

(4) Two $\overline{INTA}$ cycles run back-to-back. The μPD8068 local Address/Data bus floats during both $\overline{INTA}$ cycles. The control signals shown are for the second $\overline{INTA}$ cycle.

(5) Signals at the μPD8284 are shown for reference.

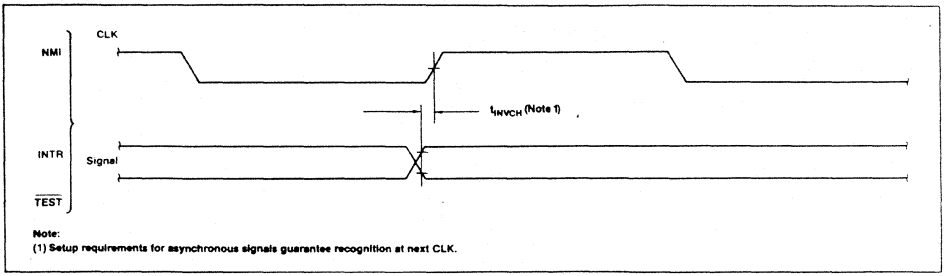
(6) The μPD8288 active-high CEN lags when the μPD8288 issues command and control signals ($\overline{MRDC}$, $\overline{MWTC}$, $\overline{AMWC}$, $\overline{IORC}$, $\overline{IOWC}$, $\overline{AIOWC}$, $\overline{INTA}$, and $\overline{DEN}$).

(7) All timing measurements are taken at 1.5 V unless otherwise specified.

(8) Status is inactive prior to T4.

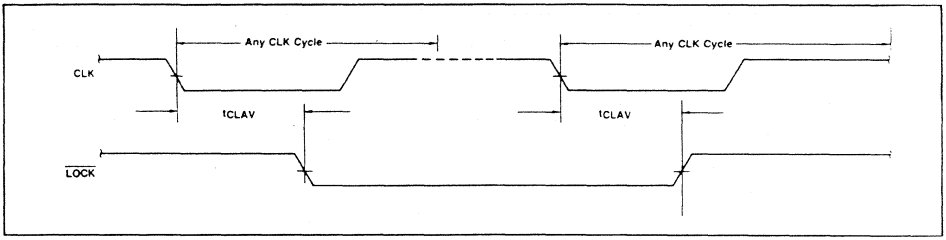
Timing Waveforms (cont)

Asynchronous Input Recognition

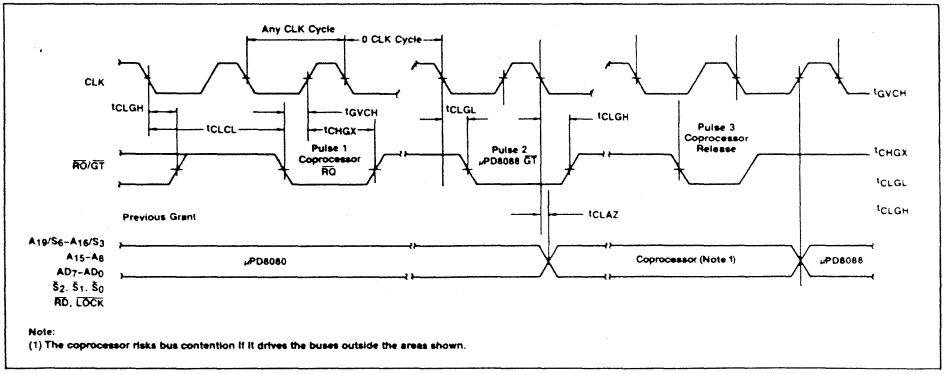


Note:
(1) Setup requirements for asynchronous signals guarantee recognition at next CLK.

Maximum Mode Bus Lock Signal Timing



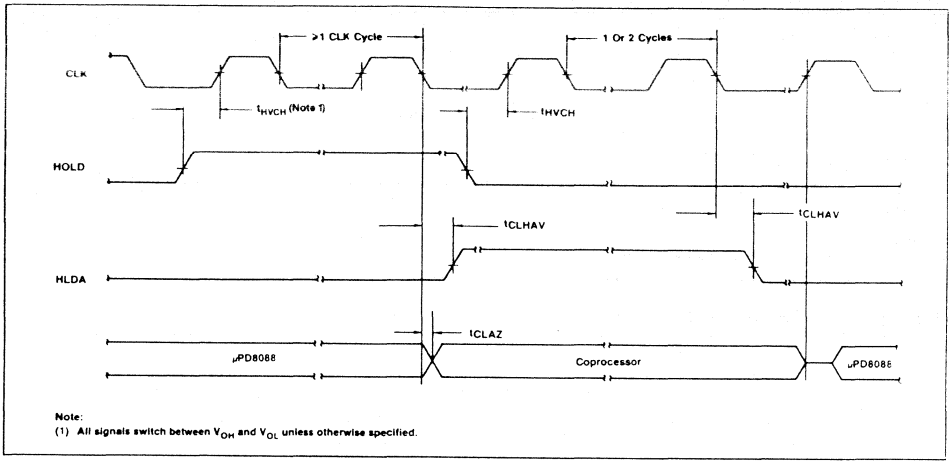
Maximum Mode Request/Grant Sequence Timing



Note:
(1) The coprocessor risks bus contention if it drives the buses outside the areas shown.

Timing Waveforms (cont)

Mimimum Mode Hold Acknowledge Timing



Note:
(1) All signals switch between V_{OH} and V_{OL} unless otherwise specified.

NEC

INTELLIGENT PERIPHERAL CONTROLLERS 5

Section 5 – Intelligent Peripheral Controllers

INTRODUCTION

NEC offers a family of floppy disk controller chips (FDCs) capable of driving different disk drives with various formats. While μPD765A, μPD765A-2 and μPD7265 are produced with NMOS technology the new μPD72065 and μPD72066 are compatible CMOS devices. The advantage of the COMS device is a much lower power consumption resulting in a big flexibility regarding various package types including PLCC. All FDCs can be driven by NEC's V-Series CMOS microprocessors and most other standard microprocessors very easily. Powerful commands and control interface drastically reduce an overhead in both hardware and software.

Format \ FDC		μPD72065/μPD765A		μPD72066/μPD7265	
		8 MHz	4 MHz	8 MHz	4 MHz
8 inch	IBM	○		△	
	ECMA/ISO	△		○	
5.25 inch	IBM	○	○	△	△
	ECMA/ISO	△	△	○	○
3.5 inch	IBM	○	○	△	△
	ECMA/ISO	△	△	○	○
3 inch	IBM		○		△
	ECMA/ISO		△		○

○ – Capable of read, write, and formatting
△ – Capable of only read and write

NOTE: In descriptions of the functional timing in this manual, the standard floppy is that which requires the 8 MHz functions to the FDC, and the mini-floppy is that which requires the 4 MHz functions.

Clock frequencies are selected as follows depending on the data transfer rate.

Clock Frequency	Data Transfer Rate [K bits/s]		Disk
	Single-density (FM)	Double-density (MFM)	
8 MHz	250	500	8", 5¼", 3.5"
4 MHz	125	250	5¼", 3"
*4.8 MHz		300	5¼"

* IBM PC-AT Format

1 FEATURES

μPD72065/μPD765A/μPD765A-2

- Compatible with IBM diskette 1 (single-sided; 128, 256, or 512 bytes/sector).
- Compatible with IBM diskette 2 (double-sided; 256 bytes/sector).
- Compatible with IBM diskette 2D (double-sided, double-density; 256 or 1,024 bytes/sector).

μPD72066/μPD7265

- Compatible with ECMA/ISO mini-floppy format.
- ECMA66 (ISO/TC 97/SC11 N419) ——— Single-sided, single-density (256 bytes/sector).
- ECMA70 (ISO/TC 97/SC11 N475) ——— Double-sided, double-density (256 bytes/sector).

All FDCs

- FM and MFM control (specified by the command for read/write operation).
- Variable recording length: 128, 256, 512, 1,024, 2,048, 4,096, or 8,192 bytes/sector.
- Multi-sector function*1
- Multi-track function*2
- Capable of controlling up to four floppy disk drives.
- Capable of parallel seek operation on up to four disk drives. (While the floppy disk drive(s) are in seek operation, the FDC accepts the seek command to other floppy disk drives.)
- Capable of specifying read/write even up to the middle of the sector (only in 128 bytes/sector, FM mode).
- Built-in CRC generating and check functions ($X^{16} + X^{12} + X^5 + 1$).
- Programmable step rate (specified by the SPECIFY command).
- Programmable head load time and head unload time (specified by the SPECIFY command).
- Data scan function (detects the sector with data equal to or larger or smaller than data in the main memory).
- DMA or Non-DMA (interrupt) data transfer (specified by the SPECIFY command).
- Built-in control signal generator for write data compensation.
- Data bus and control bus compatible with 8080 family.
- Single-phase clock—8 MHz (standard floppy disk), 4MHz (mini-floppy disk).
- Single power supply +5V

*1 This is a function which continuously reads or writes two or more sectors in the same track by a single command (controlled by the TC signal).

*2 This is a function which continuously reads or writes both tracks in side 0 and 1 in the same cylinder by a single command (specified by the MT bit of the command).

COMPARISON BETWEEN μPD72065/72066 AND μPD765A/7265

Items		μPD72065	μPD72066	μPD765A	μPD7265
Track Format		IBM	ECMA/ISO	IBM	ECMA/ISO
Recalibratable Tracks		255		77	255
Skipping Time After Detection of an Index Pulse (4 MHz)		0.2 ms		Approx. 1.2 ms	Approx. 0.2 ms.
DRQ↑ → $\overline{RD}$ ↓	ϕ_{CY}=125ns	1 ϕ_{CY} *		0.8 μs	
Response Time	ϕ_{CY}=250ns	1 ϕ_{CY}		1.6 μs	
Wait for FDD Response after Output of US signals	ϕ_{CY}=125ns	2.5 μs		0.5 μs	
	ϕ_{CY}=250ns	5.0 μs		1.0 μs	
Multi-Track Write on Tunnel Erase Head		OK		NG	
Standby Function (Standby Command)		Yes		No	
SOFTWARE RESET Command		Yes		No	

*: Clock Cycle Time

COMPARISON BETWEEN μPD765A AND μPD765A-2

The NMOS device μPD765A is preferably available as μPD765A-2 in an improved 3 μm fabrication technology. While the functionality remains the same some minor differences are detailed in the specification tables (Chapter 8).

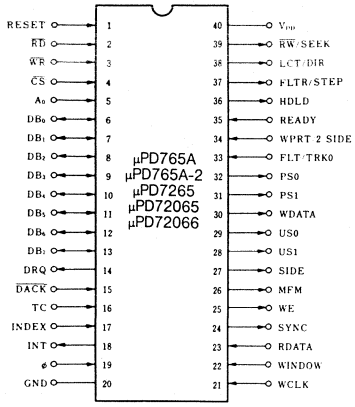
For new designs only μPD765A-2 or the CMOS type μPD72065 is recommended.

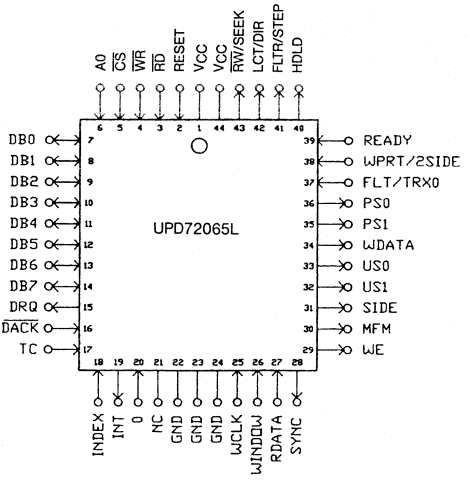
ORDERING INFORMATION

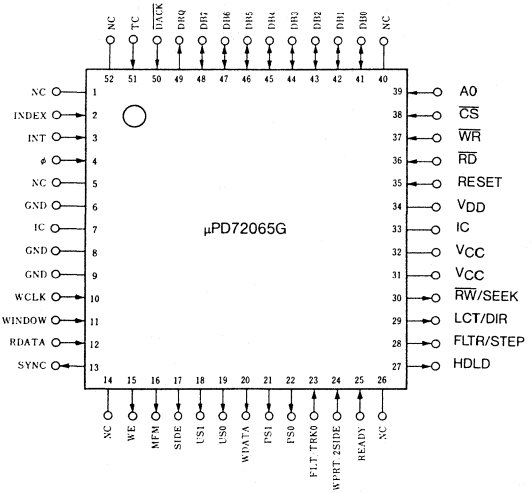
Article	Description	Package
μPD765AC	Floppy Disk Controller, IBM-Format*	40 pin DIL plastic
μPD765AD	Floppy Disk Controller, IBM-Format	40 pin DIL ceramic
μPD7265	Floppy Disk Controller, ISO-ECMA Format	40 pin DIL plastic
μPD765AC-2	Floppy Disk Controller, IBM-Format	40 pin DIL plastic
μPD72065C	Floppy Disk Controller, CMOS, IBM-Format	40 pin DIL plastic
μPD72065G	Floppy Disk Controller, CMOS, IBM-Format	52 pin flat pack
μPD72065L	Floppy Disk Controller, CMOS, IBM-Format	44 pin PLCC
μPD72066C	Floppy Disk Controller, CMOS, ISO-ECMA Format	40 pin DIL plastic
μPD72066G	Floppy Disk Controller, CMOS, ISO-ECMA	52 pin flat pack

* = not to use for new designs

Packages



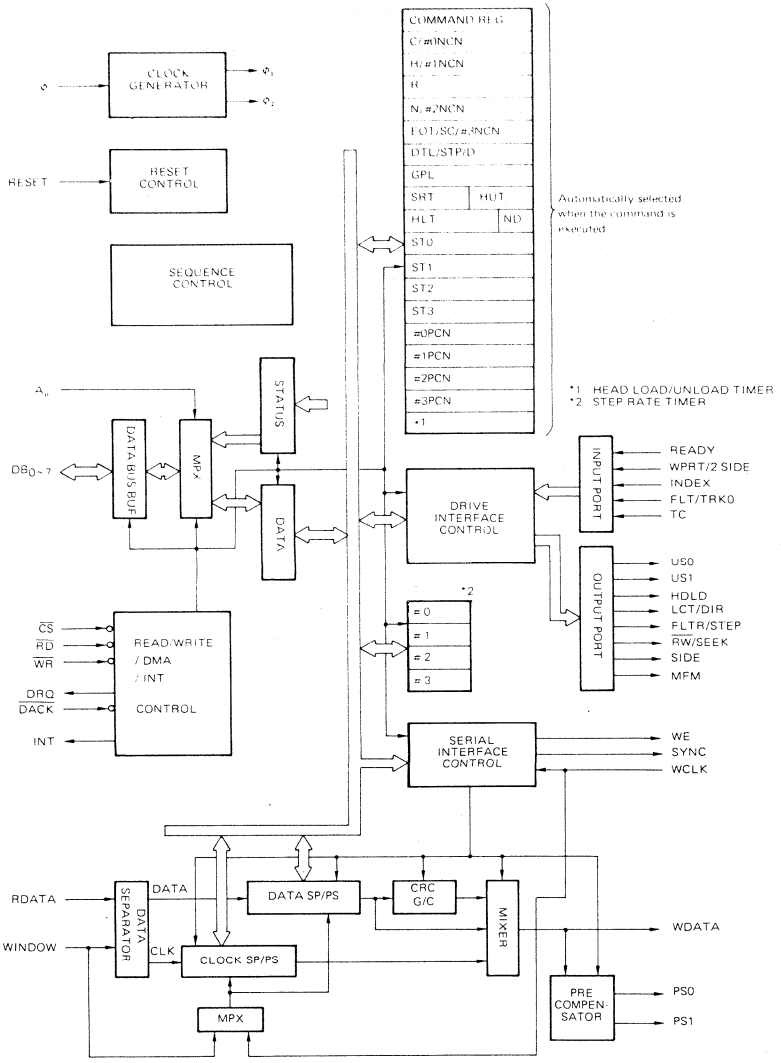




NC: Non-Connection
IC : Internally Connected

WE	: Write Enable	RESET	: Reset
MFM	: MFM Mode	RD	: Read
SIDE	: Side Select	WR	: Write
US0,1	: Unit Select	CS	: Chip Select
WDATA	: Write Data	A0	: A0
PS0,1	: Pre-Shift	DB0 ~ 7	: Data Bus
FLT	: Fault	DRQ	: DMA Request
TRK0	: Track 0	DACK	: DMA Acknowledge
WPRT	: Write Protected	TC	: Terminal Count
2SIDE	: Two Side	INDEX	: Index
READY	: Ready	INT	: Interrupt Request
HDLD	: Head Load	φ	: Clock
FLTR	: Fault Reset	GND	: Ground
STEP	: Step	WCLK	: Write Clock
LCT	: Low Current	WINDOW	: Data Window
DIR	: Direction	RDATA	: Read Data
RW/SEEK	: Read Write/Seek	SYNC	: VFO Synchronize

BLOCK DIAGRAM



CHAPTER 2 PIN FUNCTIONS

Pin Name	I/O	Function	Status at reset
RESET	I	This signal sets the FDC to idle state. • Drive interface outputs, except PS0, PS1, and WDATA (undefined), will be set to low. • In the main system, INT and DRQ will be set to low, and DB7 to DB0 will be set to input.	–
$\overline{RD}$	I	This is a control signal used by the main system to read out data from the FDC to the data bus.	
$\overline{WR}$	I	This is a control signal used by the main system to write data placed on the data bus to the FDC.	
$\overline{CS}$	I	This signal enables the $\overline{RD}$ and $\overline{WR}$ signals.	
A0	I	This signal selects either the status register or the data register inside the FDC via the address bus. 0 selects the status register, and 1 selects the data register.	
DB7 ~ DB0	I/O	This is a bidirectional three-state data bus.	Input
DRQ	O	This is a request signal for data transfer in DMA mode. A pull-up resistor is required.	Low
$\overline{DACK}$	I	This is a DMA cycle acknowledge signal.	–
TC	I	This is a data transfer termination request signal.	
INDEX	I	This signal indicates that the read/write head of the floppy disk drive is on the physical starting point of the track.	
INT	O	This signal requests the main system to deal with transfer of data or result of execution.	Low
ϕ	I	This is a single phase TTL level clock input and requires a pull-up resistor. Standard floppy: 8 MHz, Mini-floppy: 4 MHz	–
WCLK	I	This is a timing signal for data transfer in write operation. However, this signal should also be input in read operation. The rising edge of this signal should be synchronized to the rising edge of ϕ. FM: 16 ϕ cycles, MFM: 8 ϕ cycles	
WINDOW	I	This signal is generated by the VFO circuit, and is used for sampling the clock and data bits of RDATA. Whether the bit is a clock bit or a data bit is determined inside the FDC.	

<table>
<tr><th>Pin Name</th><th>I/O</th><th>Function</th><th>Status at reset</th></tr>
<tr><td>RDATA</td><td>I</td><td>This signal is the data read out from the drive and consists of clock and data bits.
Unless both WINDOW and RDATA are input at read operation, the FDC will enter the deadlock state.</td><td rowspan="6">Low</td></tr>
<tr><td>SYNC</td><td>O</td><td>This signal indicates the functional mode of the FDC. 1 indicates read operation, and 0 indicates read operation is inhibited.</td></tr>
<tr><td>WE</td><td>O</td><td>This signal requests the write operation to the drive.</td></tr>
<tr><td>MFM</td><td>O</td><td>This signal specifies the function mode of the VFO circuits. 1 specifies MFM mode, and 0 specifies FM mode.</td></tr>
<tr><td>SIDE</td><td>O</td><td>This signal selects either head 0 or 1 in a double-sided FDD. 0 selects the head 0, 1 selects the head 1.</td></tr>
<tr><td>US0, 1</td><td>O</td><td>These are drive select signals. One of four FDDs is selected by decoding these signals.</td></tr>
<tr><td>WDATA</td><td>O</td><td>This is write data to the drive and consists of the clock and data bits.</td><td rowspan="2">Undefined</td></tr>
<tr><td>PS0, 1</td><td>O</td><td>These are request signals to shift the WDATA bit in the opposite direction of the expected peak shift in order to cancel out the peak shift created when writing in MFM mode.
<table>
<tr><th>PS0</th><th>PS1</th><th>FM</th><th>MFM</th></tr>
<tr><td>0</td><td>0</td><td>No shift</td><td>No shift</td></tr>
<tr><td>0</td><td>1</td><td>–</td><td>Delays the WDATA bit</td></tr>
<tr><td>1</td><td>0</td><td>–</td><td>Advances the WDATA bit</td></tr>
<tr><td>1</td><td>1</td><td>–</td><td>–</td></tr>
</table></td></tr>
<tr><td>FLT/
TRK0</td><td>I</td><td>When $\overline{RW}$/SEEK signal specifies $\overline{RW}$, this pin becomes FLT, and inputs the signal indicating whether the drive is in FAULT state.
When $\overline{RW}$/SEEK signal specifies SEEK, this pin becomes TRK0, and inputs the signal indicating whether the read/write head of the drive is positioned at cylinder 0.</td><td rowspan="2">–</td></tr>
<tr><td>WPRT/
2 SIDE</td><td>I</td><td>When $\overline{RW}$/SEEK signal specifies $\overline{RW}$, this pin becomes WPRT and inputs the signal indicating whether the media is in the write inhibit state.
When $\overline{RW}$/SEEK signal specifies SEEK, this pin becomes 2 SIDE and inputs the signal indicating whether a double-sided floppy disk is inserted.</td></tr>
</table>

Pin Name	I/O	Function	Status at reset
READY	I	This signal indicates the drive is in the ready state.	–
HDLD	O	This signal sets the read/write head of the drive to the load state.	Low
FLTR/ STEP	O	When $\overline{RW}$/SEEK signal specifies $\overline{RW}$, this pin becomes FLTR and releases the FAULT state of the drive. When $\overline{RW}$/SEEK signal specifies SEEK, this pin becomes STEP and generates seek pulses.	
LCT/DIR	O	When $\overline{RW}$/SEEK signal specifies $\overline{RW}$, this pin becomes LCT and indicates that the read/write head of the drive is selecting a cylinder beyond the 43rd cylinder. When $\overline{RW}$/SEEK signal specifies SEEK, this pin becomes DIR and specifies the direction of the seek operation. 0 indicates the direction toward the outside, 1 indicates the direction toward the inside.	
$\overline{RW}$/SEEK	O	This signal discriminates the drive interface signals combining for read/write and for seek. 0 indicates $\overline{RW}$, 1 indicates SEEK.	
V_{CC}	–	+5V power supply	–
GND	–	Ground	

CHAPTER 3 REGISTER ORGANIZATION

3.1 REGISTERS FOR INTERFACING IN THE MAIN SYSTEM SIDE

The FDC uses the data register (DATA) and the status register (STATUS) for interfacing to the main system. Each register is selected by $\overline{CS}$, A0, $\overline{RD}$, and $\overline{WR}$ control signals. Table 3-1 shows these relationships.

Table 3-1 (x: Don't Care)

$\overline{CS}$	A0	$\overline{RD}$	$\overline{WR}$	Function
0	0	0	1	Status Register Read
		1	0	Standby Control, SOFTWARE RESET Command Write
	1	0	1	Data Register Read
		1	0	Data Register Write
1	x	x	x	Unselectable

NOTE: When $\overline{DACK}$ input is active (0), the data register will be selected regardless of the status of $\overline{CS}$ and A0. Writing ($\overline{WR}$ = 0) any code other than standby control or SOFTWARE RESET command code is inhibited when $\overline{CS}$ and A0 are 0.

(1) Data register (DATA)

This is an 8-bit register that temporarily stores various information (commands, parameters, data, and result status) transferred between the FDC and the main system.

(2) Status register (STATUS)

This is an 8-bit register that indicates the status of the FDC. Table 3-2 shows the status register organization. The main system can read the status register contents at any time.

Table 3-2 Status Register Organization

Bit	Name	Symbol	Function
D7	Request for Master	RQM	Indicates to the main system that the data communication is ready. The following functions will be performed according to the status of the DIO bit (bit D6). When DIO = 0; This status indicates that data are sent from the main system to the FDC. When data are written to the FDC by the main system, RQM is set to 0; RQM then becomes 1 when the FDC accepts the data. ● C-phase, Idle state ● E-phase of the Non-DMA write ● E-phase of seek operation When DIO = 1; This status indicates that data are sent from the FDC to the main system. When the FDC set data to the data register, RQM is set to 1; RQM is then set to 0 when the main system read the data. ● R-phase ● E-phase of the Non-DMA read (except READ ID)
D6	Data Input/Output	DIO	Indicates the direction of the data transferred between the main system and the FDC. 0 indicates that the data flow is from the main system to the FDC, 1 indicates that the data flow is from the FDC to the main system.
D5	Non-DMA mode	NDM	Indicates that data transfer is being performed (E-phase) in Non-DMA mode. This bit is reset in the C-phase and in the R-phase.
D4	FDC Busy	CB	This bit indicates the FDC is in the C-phase, R-phase, or in the E-phase of read/write command. (This bit will not be set in the E-phase of the seek group command.) When this bit is set, the FDC will not accept the next command.
D3	FD3 Busy	D3B	This bit indicates either device No. 3 is in seek operation or the interrupt of seek end is reserved (E-phase). When this bit is set, a read/write command should not be written.
D2	FD2 Busy	D2B	This bit is for device No. 2, the functions are the same as the D3 bit.
D1	FD1 Busy	D1B	This bit is for device No. 1, the functions are the same as the D3 bit.
D0	FD0 Busy	D0B	This bit is for device No. 0, the functions are the same as the D3 bit.

3.2 REGISTERS FOR INTERFACING IN THE FDD SIDE

(1) Data separator (DATA SEPARATOR)

The data separator separates read data into data bits and clock bits using the WINDOW signal in the read mode.

Separated data are sent to the data shift register, and separated clocks are sent to the clock shift register.

(2) Data shift register (DATA SP/PS)

In read mode, the data shift register converts serial data separated by the data separator to parallel data, and outputs the converted data onto the internal 8-bit bus.

In write mode, the data shift register converts 8-bit parallel data input from the internal bus to serial data and outputs to the CRC generator/checker and the mixer.

(3) Clock shift register (CLOCK SP/PS)

In read mode, the clock shift register converts serial clocks separated by the data separator to parallel clocks and outputs them onto the internal 8-bit bus.

In write mode, the clock shift register converts 8-bit parallel clocks input from the internal bus to serial clocks and outputs them to the mixer.

(4) CRC generator/checker (CRC G/C)

The CRC generator/checker generates and checks the CRC byte. The multiple formula for generating CRC is: $X^{16} + X^{12} + X^5 + 1$

In read mode, CRC of read data is calculated and compared with the CRC bytes follow the ID and data of each sector. If these CRC bytes do not match, an error is indicated.

In write mode, CRC is calculated, and two bytes of CRC are written after the ID and data of each sector.

(5) Precompensator (PRECOMPENSATOR)

The timing of read out data is out of synchronization with the timing when the data were written because of magnetic hysteresis. This deviation can be estimated from the data pattern; therefore, by shifting write data in the direction opposite the estimated direction, the deviation at read operation can be offset. This compensation becomes more important in MFM mode because the data window width in MFM mode is a half that of FM mode.

According to the write data pattern only in MFM mode, the precompensator generates preshift signals (PS0, 1) to control the external delay circuit that shifts write data. If the VFO circuit generates DATA WINDOW signal accurately enough to eliminate the problem of bit deviation of read data, the preshift function is not necessary.

CHAPTER 4 COMMANDS

4.1 DESCRIPTION OF COMMAND FUNCTIONS

The FDC executes commands given from the main system in three phases in the following order:

(1) Command phase (C-phase)

When the FDC is in idle state (waiting for a command) and if the command is given from the main system, the FDC receives the parameters specifying the command function. The main system must write every parameter in a specified order.

(2) Execution phase (E-phase)

The command is then executed according to the parameters.

- Read/write group commands (except READ ID):
  Perform data transfer between the floppy disk drive and the main system (processed by DMA or INT).
- Seek group commands:
  Generate seek pulses (STEP).

(3) Result phase (R-phase)

In this phase, data are set that indicate the result of the command execution (such as result status) to the data register.

The main system should read all of these data.

The phases for each command are organized as shown in the following table.

Command	C-phase	E-phase	R-phase	INT
Read/write group	O	O	O	YES
Seek group	O	O		YES
Sense status group	O		O	NO
INVALID				
SPECIFY	O			NO
*SOFTWARE RESET	O			NO
*SET STANDBY	O			NO
*RESET STANDBY	O		O	NO

*For the CMOS FDCs μPD72065 and μPD72066 only

4.2 INTERNAL BLOCK FUNCTIONS

Fig. 4-1 shows a block diagram simplified from the one shown in section 1.9. The sequence control section shown in the figure in section 1.9 controls functional timings in other internal blocks; however, this is abbreviated in Fig. 4-1. Figs. 4-2 through 4-5 show the general functions of each block. In these figures, solidly filled arrows indicate data flow, and arrows filled with diagonal lines indicate the flow of control signals. As shown in Fig. 4-2, the host CPU utilizes A0, $\overline{CS}$, and $\overline{WR}$ signals to control writing of the command and its parameters, and data on the data bus are taken into the data register and stored in the command register. Fig. 4-3 shows general functions of each block for each command.

In the case of seek group commands, the drive interface controller handles the control signals to or from the floppy disk drives.

In the case of the read/write group commands (except READ ID), in DMA mode, by receiving or sending DRQ, $\overline{DACK}$, and $\overline{RD}$, or $\overline{WR}$ signals, the host system controls data transfer. In Non-DMA mode, by receiving or sending A0, $\overline{CS}$, INT, and $\overline{RD}$, or $\overline{WR}$ signals, the host system controls data transfer.

In the case of READ DATA, READ DELETED DATA, and READ DIAGNOSTIC commands, serial data from the drive are converted to parallel and set in the data register one byte after another, then output to the host system.

On the contrary, in the case of the WRITE DATA, WRITE DELETED DATA commands, data from the host system is taken in one byte after another, converted to serial, and then output to the drive.

In the case of the READ ID command, ID bytes are read out from the drive, converted to parallel, and then stored in the result register.

In the case of the WRITE ID command, the format is internally generated and output to the drive. Only the ID bytes are transferred from the host system to the drive.

In the case of the SCAN command, data from the host system are taken into the data register and compared with the parallel-converted data that were taken in from the drive.

As shown in Fig. 4-4, with A0, $\overline{CS}$, and $\overline{RD}$ signals, the host system controls reading out of result status and its parameters, and places the contents of the result register in the data register. The data register contents are then output to the host system.

Fig. 4-5 shows the reading out of the status. This is always performed when the command and its parameter are written, during data transfer in Non-DMA mode, and during read out of the result status and its parameter.

The host system controls read out of the status using A0, $\overline{CS}$, and $\overline{RD}$ signals, and the contents of the status register is output to the host system.

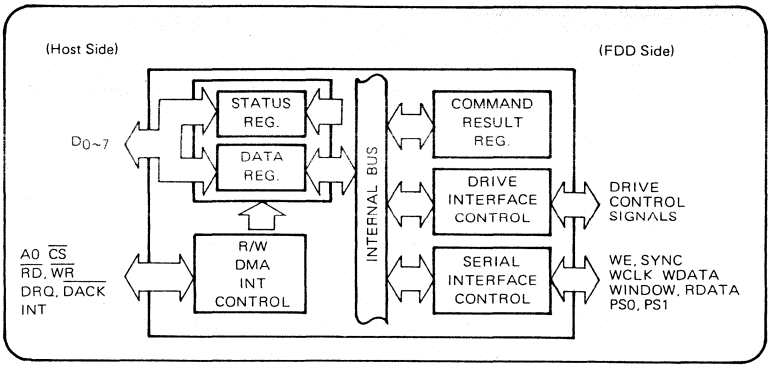


Fig. 4-1 Simplified Internal Block Diagram

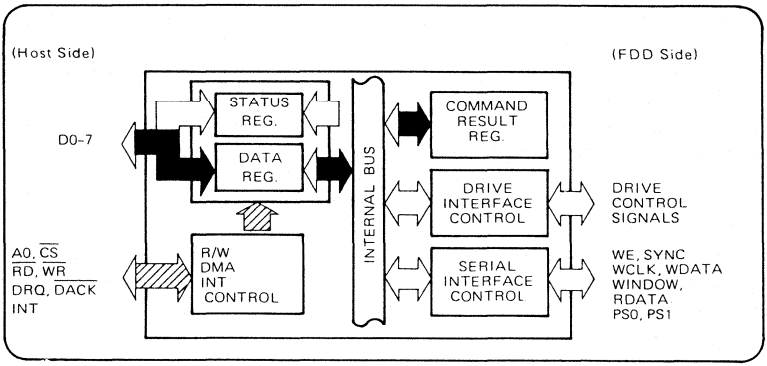


Fig. 4-2 Writing of Command

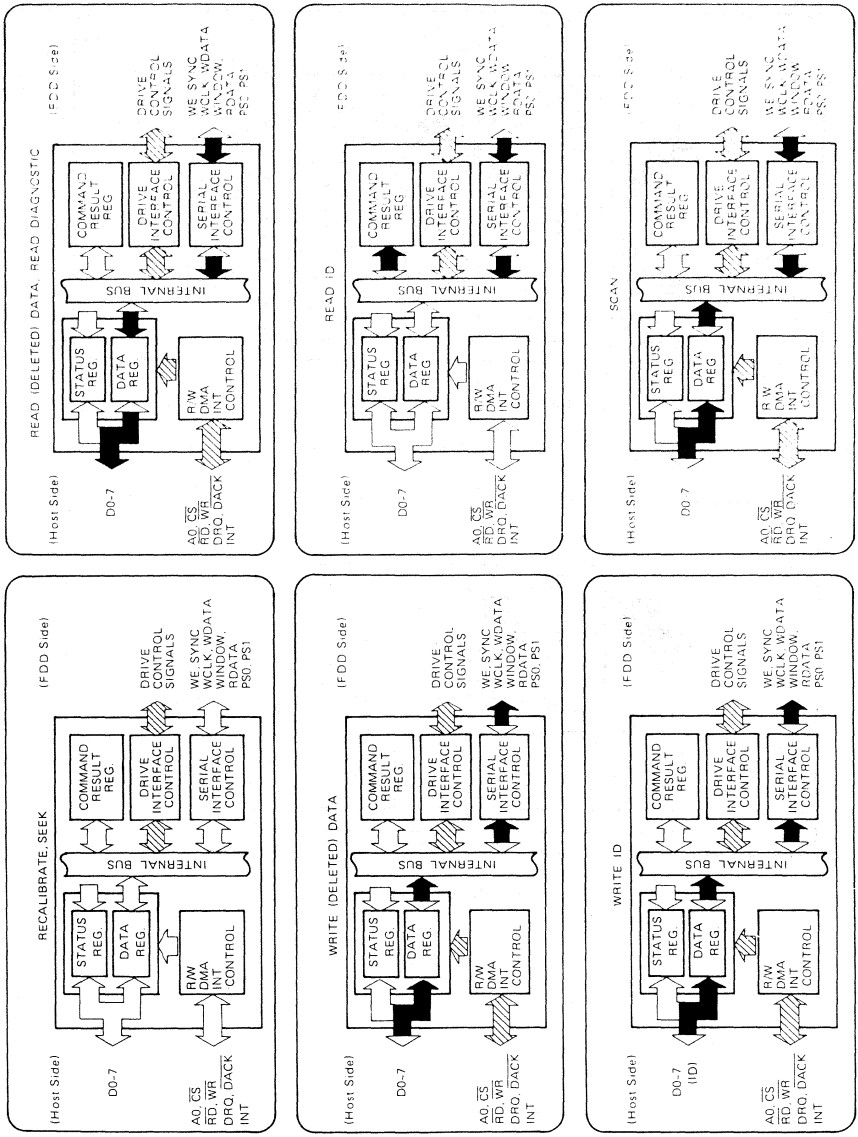


Fig. 4-3 Command Execution

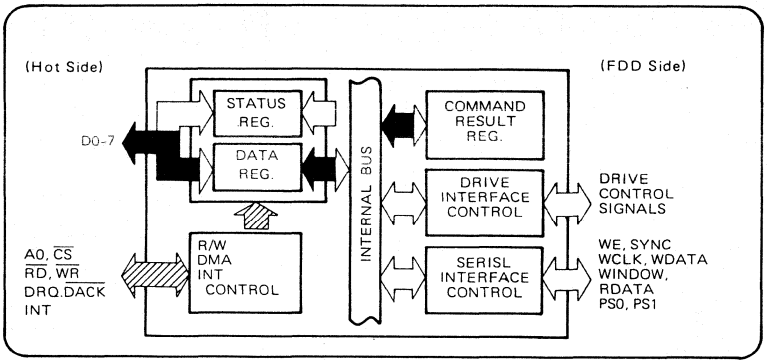


Fig. 4-4 Reading Out of Result Status

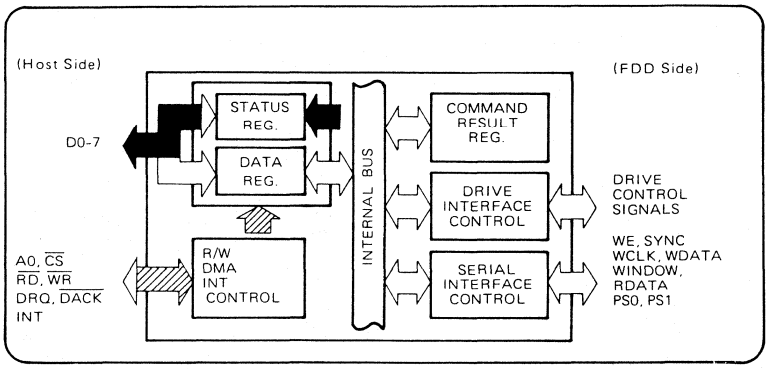


Fig. 4-5 Reading Out of Status

4.3 COMMAND FUNCTIONS

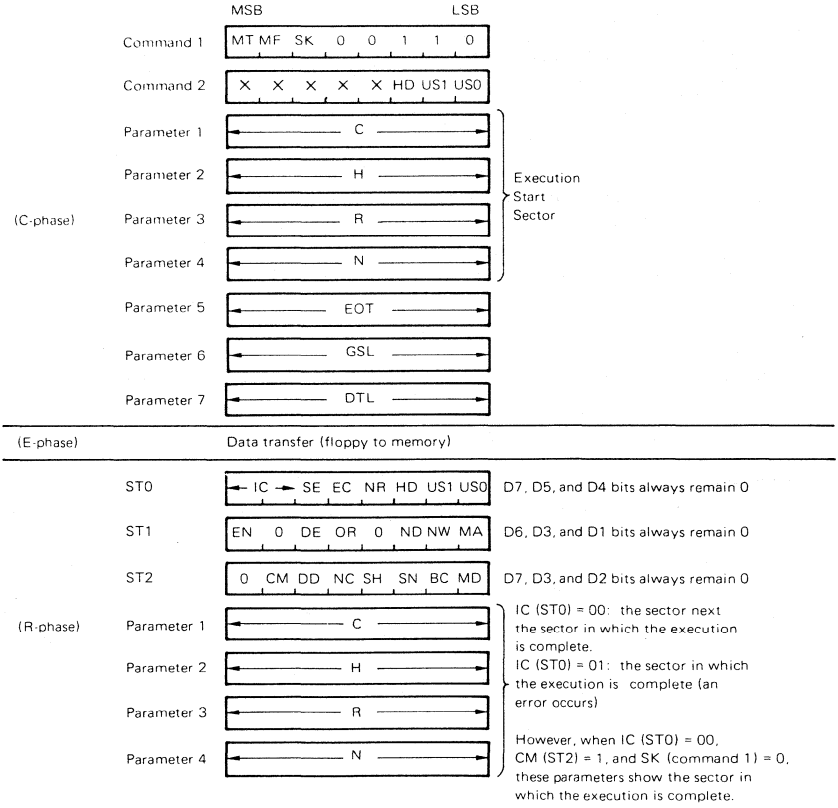
In C-phase, the host system sets $\overline{CS}$ to 0, and A0 to 1 to select the data register of the FDC and writes the command and its parameters ($\overline{WR}$ = 0).

In R-phase, in the same manner, the host system sets $\overline{CS}$ to 0, and A0 to 1 to select the data register of the FDC and reads the result status and its parameters ($\overline{RD}$ = 0).

However, before performing writing or reading data register in C-phase or R-phase, the host system should set $\overline{CS}$ to 0, and A0 to 0 to select the status register of the FDC. It then reads out the status ($\overline{RD}$ = 0) and confirms that RQM is set to 1. These read/write procedures should follow the figures shown in the beginning portions of sections 4.3.1 through 4.3.13.

However the μPD72065/μPD765A write IAM (Index Address Mark) to floppy disk in WRITE ID command, all the FDCs ignore it in the case of the other READ/WRITE group commands.

4.3.1 READ DATA



General outline

Data in the sector specified by ID bytes (IDR) given from the main system are read from the disk and set in the data register one byte after another. The main system reads out those data in Non-DMA mode or in DMA mode. (refer to the appendix 2(5))

(1) Not Ready

If the device is in Not Ready state at the start of command execution or during the SYNC bytes search of ID field, NR (Not Ready) of the ST0 is set and the command execution abnormally terminates.

(2) Head Load

At the start of disk access, if the head is in the unloaded state after being selected by the HD bit, the head is loaded and the access starts immediately after the head load time (specified by the HLT of SPECIFY command) elapses.

(3) MA error and MD error

- If IDAM is not found before two INDEX pulses are detected, MA (Missing Address Mark) of ST1 is set, and the command execution abnormally terminates.
- After ID of the sector specified by IDR is detected, if DAM or DDAM cannot be found in the specified time period (1 ms/8 MHz), MD (Missing Address Mark in Data Field) bit of ST2 is set in addition to the MA bit of ST1, and the command execution abnormally terminates.

(4) ND error

Even if IDAM is detected, if the sector (CHRN) specified by IDR cannot be found before two index pulses are detected, the ND (No Data) bit of ST1 is set, and the command execution abnormally terminates. In the case that the C byte of the ID read out does not match the C byte of IDR, if it is $FF_{(16)}$, the BC (Bad Cylinder) bit of ST2 is set in addition to the ND bit, or if it is not $FF_{(16)}$, the NC (No Cylinder) bit of ST2 is set in addition to the ND bit.

(5) CRC error

After read out, the CRC bytes immediately after the ID or data are compared with the internally generated CRC; if these do not match, the DE (Data Error) bit of ST1 is immediately set, and the command execution abnormally terminates.

(6) DDAM detection

When DDAM is detected, the CM (Control Mark) bit of ST2 is set, and one of the following two processes is performed according to the contents of the SK bit of the command.

- When SK = 0: Command execution terminates normally after data transfer of that sector. The ID bytes of the sector in which DDAM is detected will be the value for CHRN in R-phase.
- When SK = 1: That sector is skipped and the next sector is processed.

(7) Transfer capacity

The transfer capacity for each command is as shown below depending on the N byte of IDR, and MT and MF bit of the command.

MT	MF	N(16)	Transfer Capacity (Bytes)		Last Sector
0	0	00	(1 to 128) × n	n: 1 to 26 sectors	Sector 26 of head 0 or sector 26 of head 1
	1	01	256 × n		
1	0	00	(1 to 128) × n	n: 1 to 52 sectors	Sector 26 of head 1 (Multi-track)
	1	01	256 × n		
0	0	01	256 × n	n: 1 to 15 sectors	Sector 15 of head 0 or sector 15 of head 1
	1	02	512 × n		
1	0	01	256 × n	n: 1 to 30 sectors	Sector 15 of head 1 (Multi-track)
	1	02	512 × n		
0	0	02	512 × n	n: 1 to 8 sectors	Sector 8 of head 0 or sector 8 of head 1
	1	03	1,024 × n		
1	0	02	512 × n	n: 1 to 16 sectors	Sector 8 of head 1 (Multi-track)
	1	03	1,024 × n		

NOTE: The value n in the table is for standard floppy disks. In mini-floppy disks, there are fewer sectors per track than standard floppy disks; therefore, these values will be less than n in this table for mini-floppy disks.

(8) Overrun

At data transfer, if the main system does not perform the service (in active state of $\overline{RD}/\overline{WR}$ or $\overline{DACK}$) within the following specified time from request by INT or DRQ, OR (Over Run) bit of ST1 is set after the data of that sector are transferred and the command execution abnormally terminates.

- For standard floppy – FM: 27 μs, MFM: 13 μs
- For mini-floppy – FM: 54 μs, MFM: 26 μs

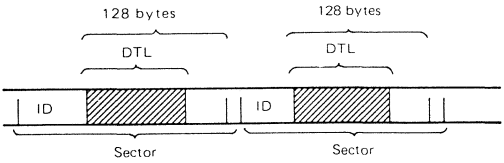
Without $\overline{DACK}$ input, DRQ is not reset. $\overline{DACK}$ must be input for the last DRQ in DMA mode.

(9) Data length

When the N byte of IDR is 00, the DTL byte specifies the data length to be processed within each sector. DTL = 01 specifies 1 byte/sector, and DTL ≧ 80(16) specifies 128 bytes/sector.

When DTL specifies to the middle of data in the sector (DTL < 80(16)), for all sectors, the following data are read out from the disk; however, these data are not set in the data register and only CRC check is performed.

When N ≠ 00, the DTL byte has no meaning.



(10) Multi-sector read

After data for one sector are transferred, if no termination request (TC) comes from the main system, R byte of IDR is modified (R ← R + 1), and the FDC searches for the sector specified by the new IDR. However, modification of R byte will be performed within the range of R ≦ EOT.

(11) Sector format and parameter

The reference value of EOT and GSL for data length is shown in the following table. GSL is a parameter used for skipping the splice points between data field and the following ID field on multi-sector access.

IBM Format \ Parameter		$N_{(16)}$	$EOT_{(16)}$	$GSL_{(16)}$	Note
FM	128 bytes/sector	00	1A	07	IBM diskette 1
	256 bytes/sector	01	0F	0E	IBM diskette 2
	512 bytes/sector	02	08	1B	
	1,024 bytes/sector	03	04	Not determined	
	2,048 bytes/sector	04	02	Not determined	
	4,096 bytes/sector	05	01	Not determined	
MFM	256 bytes/sector	01	1A	0E	IBM diskette 2D
	512 bytes/sector	02	0F	1B	
	1,024 bytes/sector	03	08	35	IBM diskette 2D
	2,048 bytes/sector	04	04	Not determined	
	4,096 bytes/sector	05	02	Not determined	
	8,192 bytes/sector	06	01	Not determined	

ECMA Format \ Parameter		$N_{(16)}$	$EOT_{(16)}$	$GSL_{(16)}$	Note
FM	128 bytes/sector	00	01	07	ECMA 66 (single -sided)
	256 bytes/sector	01	09	0E	
MFM	256 bytes/sector	01	10	0E	ECMA 70 (double-sided)

In double-density (MFM) disks of both IBM and ECMA formats, track 00 on side 0 is single-density (FM) with 128 bytes/sector.

(12) TC timing

At data transfer, when the TC signal is input in the middle of the sector, data in the remainning portion of the sector are read out, but the data are not to be set in the data register. And if a CRC error does not occur, the command execution terminates normally.

The timing to receive the TC signal is within the following specified time after the data transfer request by INT or DRQ.

- For standard floppy (1 byte time) 5 μs
- For mini-floppy (1 byte time) 10 μs

If the TC signal is input during this period, data transfer request will not be generated after the data transfer requested by the INT or the DRQ is performed.

However as for transfer request for the last byte in the sector, if TC is input within 2 bytes-time, the command execution will be terminated in that sector.

1 byte-time means, as shown in the following table, the time required to transfer one byte of data.

	FM	MFM
Standard floppy	32 μs	16 μs
Mini-floppy	64 μs	32 μs

(13) EN error

Unless the TC signal is input even if access to the last sector is complete (R = EOT), the EN (End of Cylinder) bit of ST1 is set and the command execution is abnormally terminated.

(14) IDR in normal termination

When the command execution terminates normally, the value indicated in the following table is set to IDR in R-phase according to the MT bit and the EOT byte.

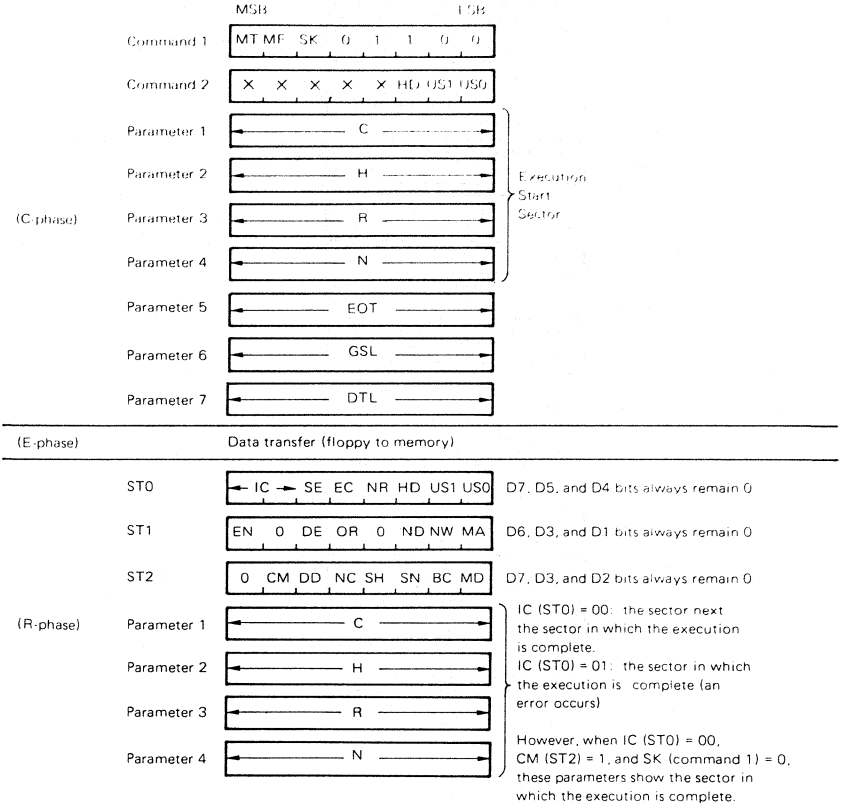
MT	EOT(16)	Sector to which the last transfer byte belongs			IDR of R-phase			
					C	H	R	N
0	1A 0F 08	Head 0	1 to 25 1 to 14 1 to 7	R < EOT	No change	No change	R + 1	No change
	1A 0F 08		26 15 8	R = EOT	C + 1	No change	01	No change
	1A 0F 08	Head 1	1 to 25 1 to 14 1 to 7	R < EOT	No change	No change	R + 1	No change
	1A 0F 08		26 15 8	R = EOT	C + 1	No change	01	No change
1	1A 0F 08	Head 0	1 to 25 1 to 14 1 to 7	R < EOT	No change	No change	R + 1	No change
	1A 0F 08		26 15 8	R = EOT	No change	Reversed LSB	01	No change
	1A 0F 08	Head 1	1 to 25 1 to 14 1 to 7	R < EOT	No change	No change	R + 1	No change
	1A 0F 08		26 15 8	R = EOT	C + 1	Reversed LSB	01	No change

(15) Head unload

The head is set to unloaded state (HDLD signal OFF) after the head unload time (specified by HUT of the SPECIFY command) has elapsed from the termination of command execution. If the read/write group command for the same device is given within this head unload time, the next command can be executed without waiting the head load time because the head is in loaded state.

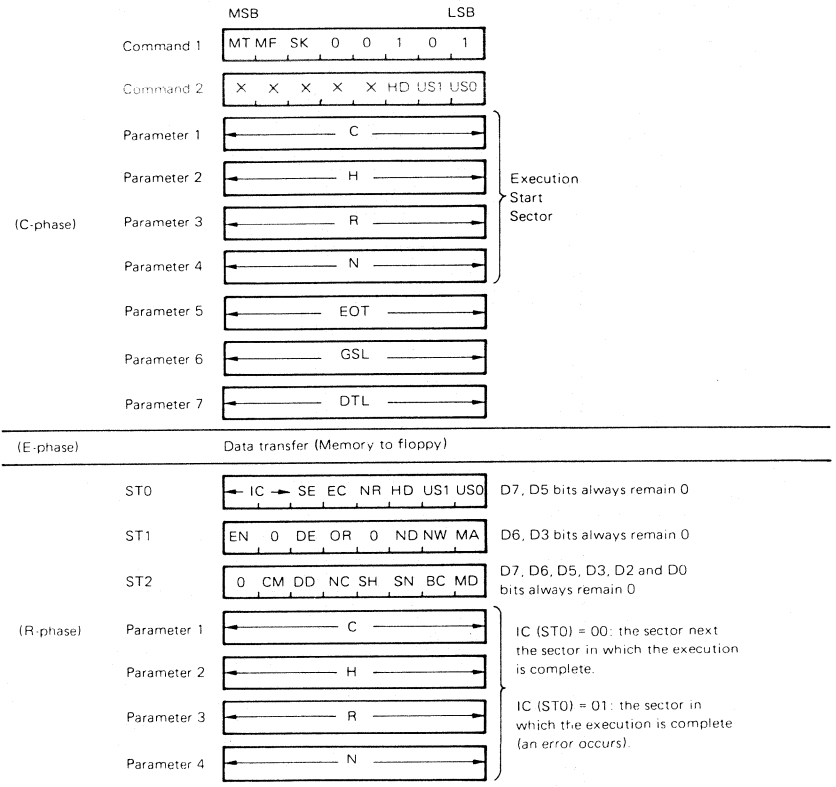
However, even within the head unload time, if the command for other device or the seek group command for other cylinder is activated, the head will be immediately set to unloaded state.

4.3.2 READ DELETED DATA



The difference from the function of READ DATA is that DAM and DDAM are alternated. (refer to the appendix II(5))

4.3.3 WRITE DATA



General description

After the DAM is written to the sector specified by IDR, data which the main system writes to the data register byte by byte are transferred to that sector. (refer to appendix II(6))

(1) Same functions as READ DATA

The following functions are the same as READ DATA

(1) Not ready (2) Head load (4) ND error (7) Transfer capacity
(11) Sector format and parameter (13) EN error (14) IDR at normal termination
(15) Head unload

(2) NW error

If WPRT signal is input at the start of command execution, NW (Not Writable) bit of the ST1 will be immediately set and the command execution will abnormally terminate.

(3) MA error

If IDAM is not found before two INDEX pulses are detected, MA (Missing Address Mark) of ST1 is set, and the command execution abnormally terminates.

(4) CRC error

When the CRC bytes immediately after the ID is read out and compared with internally generated CRC but they do not match, the DE bit of ST1 will be immediately set and the command execution will abnormally terminate.

(5) Overrun

At data transfer, if the main system does not perform the service within the following specified time from the request by INT or DRQ, the OR (Over Run) bit of ST1 is set after data are transferred to that sector and command execution abnormally terminates.

- For standard floppy – FM: 31 μs, MFM: 15 μs
- For mini-floppy – FM: 62 μs, MFM: 30 μs

Without $\overline{DACK}$ input, DRQ is not reset. $\overline{DACK}$ must be input for the last DRQ in DMA mode.

(6) Data length

When N byte of IDR is 00, DTL byte specifies the data length to be processed within each sector. DTL – 01 specifies 1 byte/sector, and DTL $\geqq$ 80(16) specifies 128 bytes/sector. When DTL specifies to the middle of data in the sector (DTL $<$ 80(16)), for all sectors, 00 is written in each byte of the following data.

When N $\neq$ 0, DTL byte has no meaning.

(7) EC error

If FLT signal is input after writing CRC of data and 1 byte of Gap, EC (Equipment Check) bit of ST0 is set and command execution abnormally terminates.

(8) Multi-sector write

After data of one sector are transferred and if the TC signal is not input from the main system, R byte of IDR is modified (R ← R + 1) and the sector specified by the renewed IDR is searched for.

However, the modification of R byte will be performed within the range of R $\leqq$ EOT.

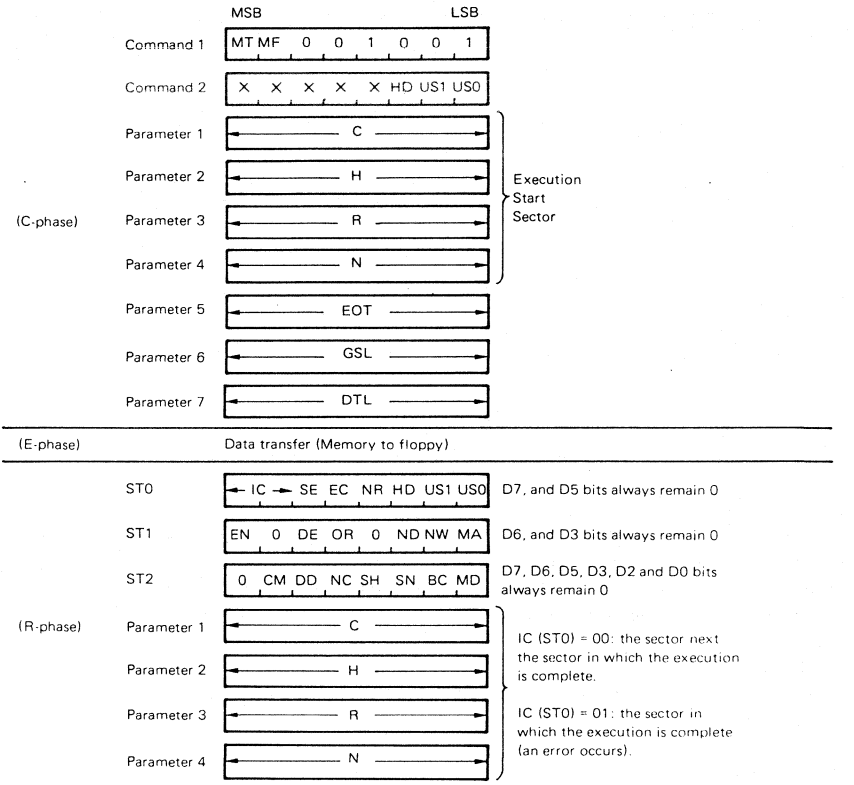
(9) TC timing

At data transfer, when the TC signal is input in the middle of the sector, 00 is written in the remaining portion of the sector, and the command execution terminates normally. The timing to receive the TC signal is within the following specified time after the data transfer request by INT or DRQ.

- For standard floppy : (1 byte-time) – 6 μs
- For mini-floppy : (1 byte-time) – 12 μs

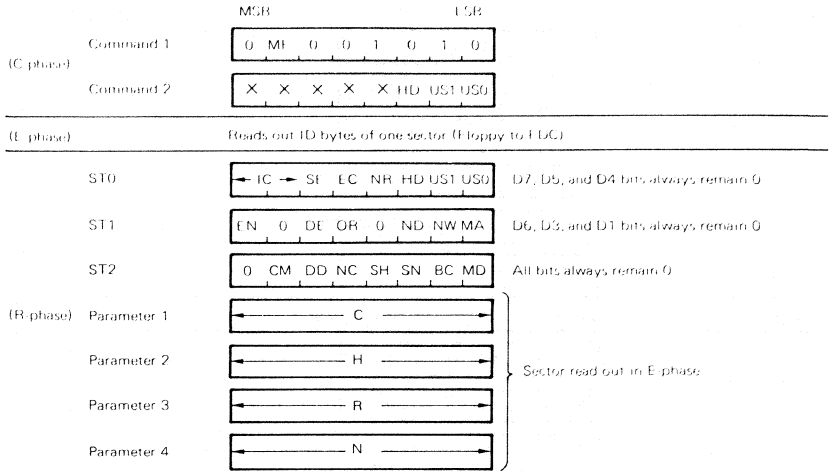
If the TC signal is input during this period, data transfer request will not be generated after the data transfer requested by the INT or the DRQ is performed. However, as for a transfer request for the last byte in the sector, if TC is input within 2 bytes-time, the command execution is terminated in that sector.

4.3.4 WRITE DELETED DATA



Same as WRITE DATA except DDAM is written instead of DAM. (refer to appendix II(6))

4.3.5 READ ID



General description

ID of the first detected sector (with no DE error or MA error) after the head load time has elapsed is set to the data register as IDR of R-phase. (refer to the appendix II(8)) The sector to be detected cannot be specified and is undefined.

(1) Same functions as READ DATA

The following functions are the same as those of READ DATA.

(1) Not ready (2) Head load (15) Head unload

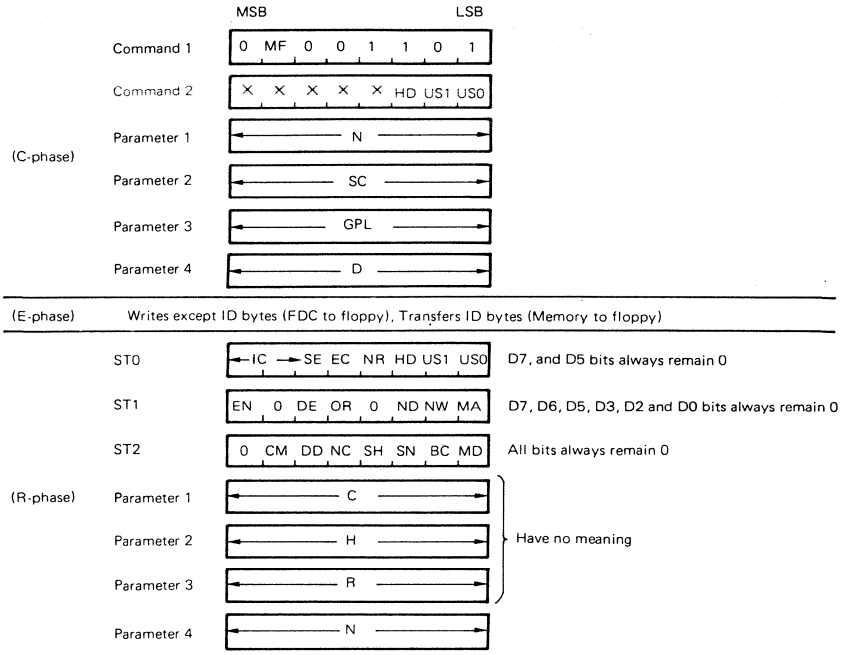
(2) MA error

If IDAM is not found before two INDEX pulses are detected, the MA bit of ST1 is set and the command execution abnormally terminates.

(3) ND error

Even if IDAM is found, unless the ID not having a CRC error is found before two INDEX pulses are detected, the ND bit of ST1 is set and the command execution abnormally terminates.

4.3.6 WRITE ID [Format Write]



General description

Data for one track are written according to the format. Data from the main system are transferred to the ID field, and D byte of the parameter is written to the data field as the data pattern. (refer to appendix II(9))

(1) Same functions as READ DATA

The following functions are the same as those of READ DATA.

(1) Not ready (2) Head load (15) Head unload

(2) Same functions as WRITE DATA

The following functions are the same as those of WRITE DATA.

(2) NW error (5) Overrun

(3) Transfer data

(Four bytes of CHRN) × (number of sectors), that is, only IDs for one track are transferred. Therefore, the sequence IDs (setting R bytes at intervals) or IDs for bad cylinder (setting C bytes to FF(16)) can be written by those data from the main system.

(4) Format

The FDC internally sets and writes data according to the format (Gap, Sync, Address Mark, Data, and CRC) except ID. However, data length, number of sectors, length of Gap 3, and data pattern can be programmed by the parameters.

(5) Sector format and parameter

The following table shows reference values of SC and GPL for data length. GPL specifies the length (number of bytes) of Gap 3 written at the end of sectors.

IBM Format \ Parameter		$N_{(16)}$	$SC_{(16)}$	$GPL_{(16)}$	Note
FM	128 bytes/sector	00	1A	1B	IBM diskette 1
	256 bytes/sector	01	0F	2A	IBM diskette 2
	512 bytes/sector	02	08	3A	
	1,024 bytes/sector	03	04	Not determined	
	2,048 bytes/sector	04	02	Not determined	
	4,096 bytes/sector	05	01	Not determined	
MFM	256 bytes/sector	01	1A	36	IBM diskette 2D
	512 bytes/sector	02	0F	54	
	1,024 bytes/sector	03	08	74	IBM diskette 2D
	2,048 bytes/sector	04	04	Not determined	
	4,096 bytes/sector	05	02	Not determined	
	8,192 bytes/sector	06	01	Not determined	

ECMA Format \ Parameter		$N_{(16)}$	$SC_{(16)}$	$GPL_{(16)}$	Note
FM	128 bytes/sector	00	10	18	ECMA66 (single-sided)
	256 bytes/sector	01	09	26	
MFM	256 bytes/sector	01	10	32	ECMA70 (double-sided)

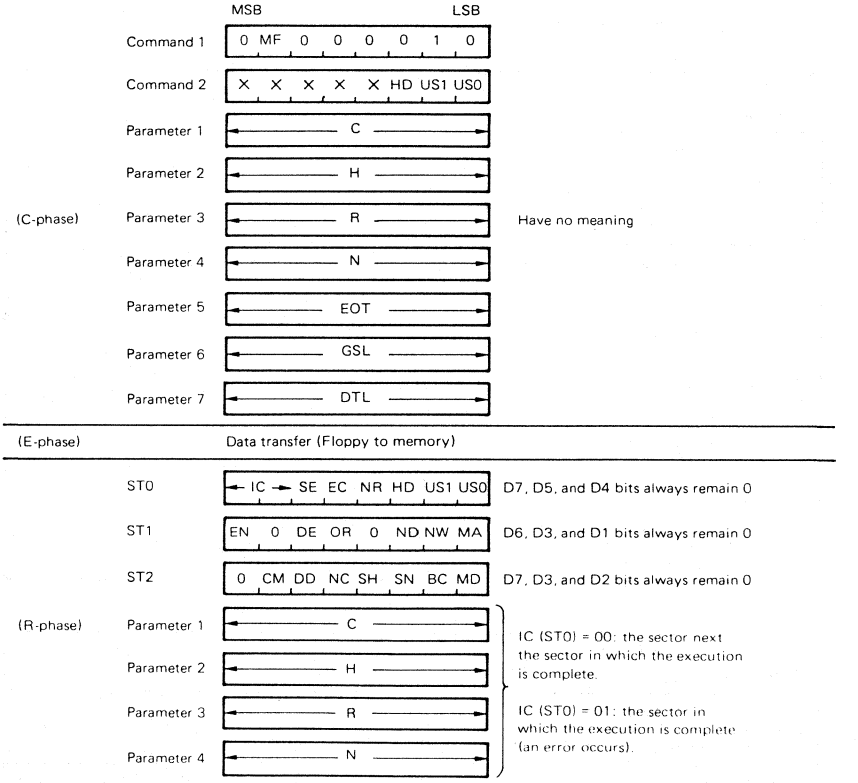
(6) Start of formatting

After the start of command execution, when an INDEX pulse is input, formatting starts. After the one sector is written, if TC is not input and the number of processed sectors does not match the SC parameter, Gap 3 will be written and then the next sector format will be processed.

(7) Completion of formatting

After one sector is written, if TC is already input or the number of processed sectors matches the SC parameter, then only Gap is written. When the INDEX pulse is input, writing operation ends.

4.3.7 READ DIAGNOSTIC

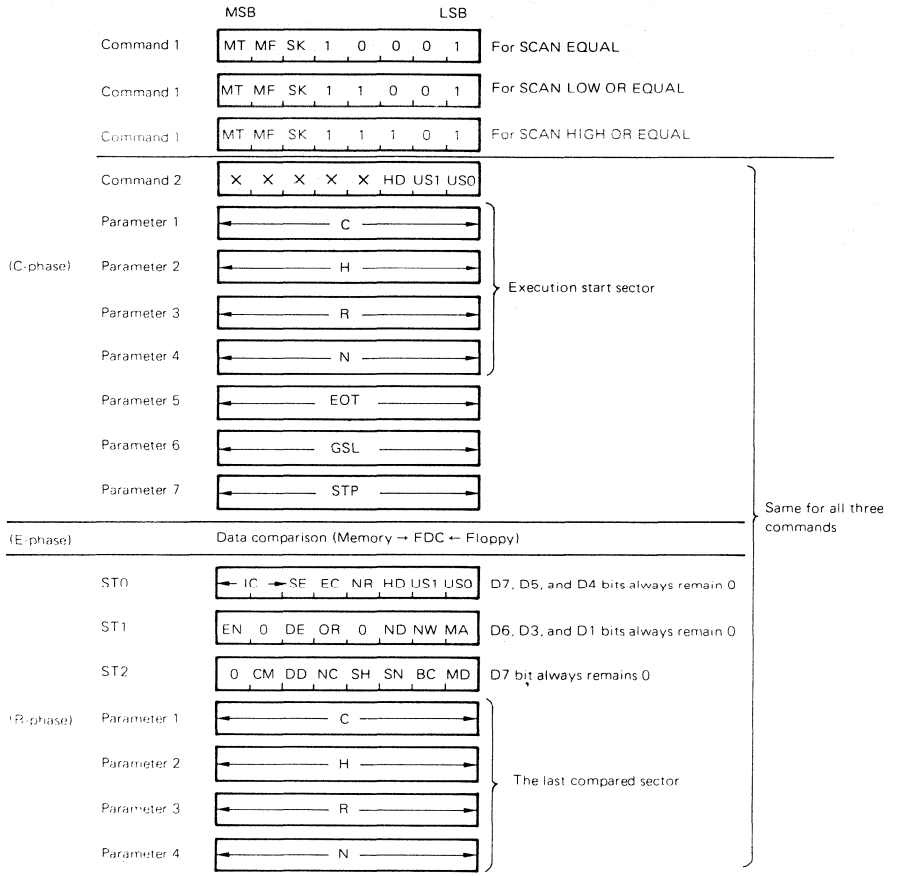


Same as READ DATA except for the following differences. (refer to appendix II(7))

- There is no specification for multi-track and skip.
- At command execution, the initial value 01 is internally set to R byte of the parameter, and processing will start from the sector immediately after the point where the INDEX pulse is input.
- Read out ID and IDR are compared; if they do not match, ND (No Data) bit of ST1 is set. However, data transfer will continue in the following sectors and command execution will terminate normally (This happens in the case of sequence ID.).
- Upon the detection of CRC error of ID or Data, DE (Data Error) bit or/DE bit and DD (Data Error in Data Field) bit are set; however, command execution will continue and will terminate normally.
- Upon the detection of DDAM, CM (Control Mark) bit is set; however, this is not the condition to terminate the command execution.

When command execution is normally terminated and if errors occur, the errors will be accumulated and output for the result status; however, the sectors in which errors have occurred cannot be known (CHRN of the result is the renewed sector in which execution was terminated).

4.3.8 SCAN EQUAL/SCAN LOW OR EQUAL/SCAN HIGH OR EQUAL



General description

By comparing data on each sector with the same amount of data in the main system, the sector which satisfies the condition (equal, high, or low) will be searched. (refer to appendix H(10))

(1) Same functions as READ DATA

The following functions are the same as those of READ DATA

(1) Not ready (2) Head load (3) MA error and MD error (4) ND error
(5) CRC error (6) DDAM detection (8) Overrun
(11) Sector format and parameter (15) Head unload

(2) Data not to be compared

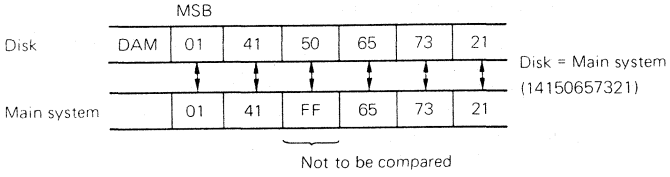
When data from the main system are FF(16), these data are not compared (they are assumed to match).

(3) Comparison method

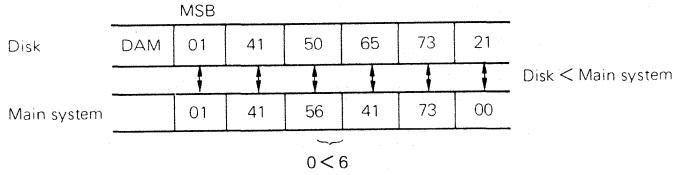
- SCAN EQUAL: Checks whether the data in the sector to be compared match the data of the main system. If they match, the command execution will terminate normally.
- SCAN LOW OR EQUAL: When the data in the sector to be compared are smaller than or equal to the data of the main system, the command execution will terminate normally.
- SCAN HIGH OR EQUAL: When the data in the sector to be compared are larger than or equal to the data of the main system, the command execution will terminate normally.

Comparison of equal, larger, and smaller is performed so that the first byte to be compared is made the most significant byte and the data group in one sector is handled as one numeric value (In the same way, a data group on the main system side is also handled as one numeric value.).

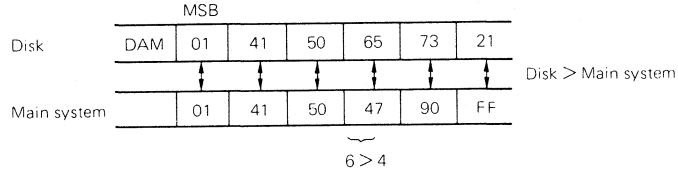
- EQUAL (matching) data string example



- Low (smaller) data string example



- HIGH (larger) data string example



(4) TC signal

Whenever the last byte in the each sector is transferred, input the TC signal (for instance, by autoloading of the DMA controller). When all bytes in each sector do not need to be compared, TC can be input in the middle of the sector and bytes beyond that point will not be compared; only data bytes up to the point of TC input will be compared in all sectors. For this command, TC input is not the condition to terminate command execution.

(5) Sector modification

When data in one sector are compared to the data of the main system, and if the condition does not meet, R byte of IDR is modified (R ← R + STP: STP = 1 or 2), and the sector specified by the new R byte is compared.

Therefore, the main system needs to send repeatedly the same data for each sector.

(6) STP

STP byte of the parameter specifies 01 or 02. However, when 02 is specified, R byte of the parameter (initial sector number) and the EOT byte should satisfy the following formula.

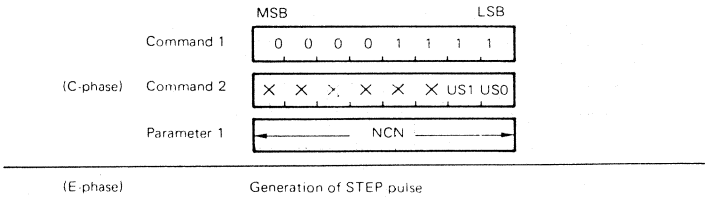
R + 2 (n − 1) = EOT n: Number of sectors to be processed

(7) Termination of the execution

If a compared sector satisfies the condition, the command execution will terminate normally at that point. In this case, if the EQUAL condition is satisfied, SH (Scan Equal Hit) bit of ST2 is set.

If the sector that satisfies the condition is not found even though the last sector is compared, SN (Scan Not Satisfied) bit of ST2 is set and the command execution will terminate normally.

4.3.9 SEEK



General description

Assuming the NCN (New Cylinder Number) byte of the parameter as the cylinder number to be seeked, the read/write head will be moved to this cylinder. (refer to appendix II(4))

(1) Not ready

At the start of command execution or during the execution of seek operation (E-phase), if the device is not ready, SE (Seek End) and NR (Not Ready) bits of ST0 are set, and the command execution abnormally terminates at that point.

(2) Seek operation

The PCN (Present Cylinder Number) byte indicating the cylinder at which the read/write head is located is compared with the NCN byte. When they are not equal, either one of the following two operations is performed.

- When NCN > PCN: DIR signal is set, a STEP pulse (STEP) is output, and PCN is incremented by one (PCN ← PCN + 1).
- When NCN < PCN: DIR signal is reset, a STEP pulse is output, and PCN is decremented by one (PCN ← PCN - 1).

After this, the above will be repeated at each step rate time specified by the SPECIFY command.

(3) Termination of seek operation

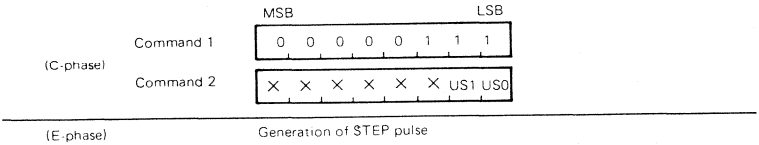
When PCN and NCN become equal, SE (Seek End) of ST0 is set, and the command execution will terminate normally. However, the contents of ST0 will be processed by the SENSE INTERRUPT STATUS command.

(4) Parallel seek

Because the FDC is in Non-Busy state in the E-phase (FD Busy), SEEK or RECALIBRATE command for other devices can be accepted, and the seek operation can be performed simultaneously in up to four devices.

However, the read/write group command should not be written at this time (FD Busy).

4.3.10 RECALIBRATE [Return to cylinder 0]



General description

Seek operation towards the outer track (DIR = 0) is made until the TRK0 signal is input. (refer to appendix II(4))

(1) Functions same as SEEK

The following functions are the same as those of SEEK operation.

(1) Not ready (2) Parallel seek

(2) Recalibrate operation

After PCN byte is cleared, the TRK0 signal is checked. If the TRK0 signal is 0, the DIR signal is reset and a STEP pulse is generated.

After this, a STEP pulse is generated at every step rate time specified by the SPECIFY command.

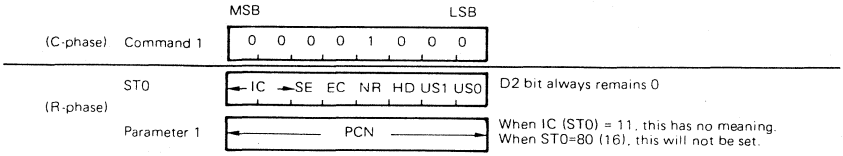
(3) Termination of recalibrate operation

When TRK0 signal becomes 1, SE (Seek End) bit of ST0 is set and command execution terminates normally. However, the contents of ST0 will be processed by the SENSE INTERRUPT STATUS command.

(4) EC error

If TRK0 signal is not input even if the recalibrate operation is repeated 255 times, SE bit and EC (Equipment Check) bit of ST0 are set, and command execution abnormally terminates.

4.3.11 SENSE INTERRUPT STATUS



General description

The result status of seek operation by the SEEK or RECALIBRATE command or the result status at a status change (Not Ready to Ready, or Ready to Not Ready) of the device not under the command execution is set to the data register. (refer to appendix II(3))

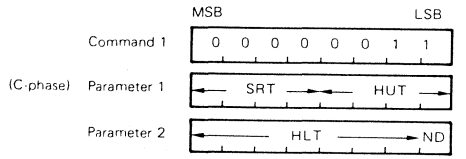
(1) PCN

PCN byte of R-phase indicates the cylinder number at the end of the seek operation. PCN byte has no meaning at the status change.

(2) Invalid

If the termination of seek operation or a status change does not occur in any device, this command will be processed as an invalid command (refer to 4.3.14 INVALID).

4.3.12 SPECIFY



General description

The initial value of various internal timers and functional mode are defined (refer to appendix H(2)).

(1) HUT

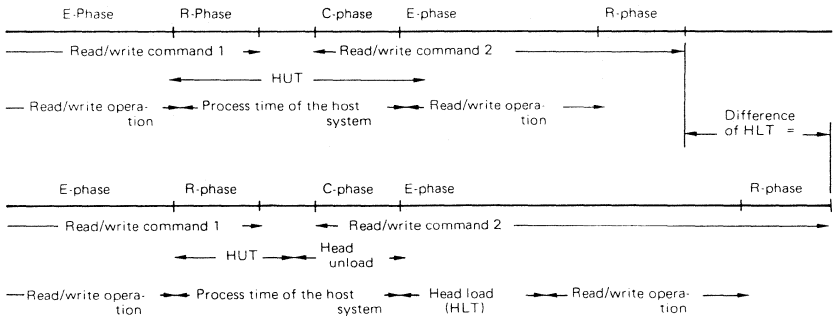
HUT (Head Unload Time) specifies the time to set the read/write head to unloaded state after the read/write group command is executed (SYNC/WE reset).

- Standard floppy: 16 to 240 ms (16 ms per unit)
- Mini floppy: 32 to 480 ms (32 ms per unit)

$HUT_{(16)}$	Time (ms)
0	Inhibited
1	16/32
2	32/64
3	48/96
4	64/128
5	80/160
6	96/192
7	112/224

$HUT_{(16)}$	Time (ms)
8	128/256
9	144/288
A	160/320
B	176/352
C	192/384
D	208/416
E	224/448
F	240/480

When read/write commands are executed continuously, the access time can be shortened by setting HUT longer than the process time of the host system between the E-phases because the head remains in loaded state and HLT will be ignored.



(2) SRT

SRT (Step Rate Time) specifies the interval of step pulses generated by seek group commands.

- For standard floppy: 1 to 16 ms (1 ms per unit)
- For mini-floppy: 2 to 32 ms (2 ms per unit)

$SRT_{(16)}$	Time (ms)
0	16/32
1	15/30
2	14/28
3	13/26
4	12/24
5	11/22
6	10/20
7	9/18

$SRT_{(16)}$	Time (ms)
8	8/16
9	7/14
A	6/12
B	5/10
C	4/8
D	3/6
E	2/4
F	1/2

If C-phase occurs over the STEP signal generating timing, the STEP signal is delayed until the end of the phase, causing a shortened step signal interval for the next STEP signal. This occurs when the duration of C-phase of the seek group command is longer than the step rate time (Fig. 4-6(a)) or when an other command is written (for example, parallel seek operation) while the seek group command is being executed (Fig. 4-6(b)). In these cases, the minimum value of the step pulse interval will be shorter than the values shown in the table by 1 ms (for standard floppy) and 2 ms (for mini-floppy).

To avoid seek errors, shorten as much as possible the duration of C-phase of the seek group command or the duration of C-phase when another command is written in E-phase. If neither is possible, set a longer step rate time. As long as the duration of each C-phase is less than 20 μs × [Step Rate], seek error will not occur. For instance, if the step rate time is 3 ms, the parameter of C-phase can be written within 60 μs.

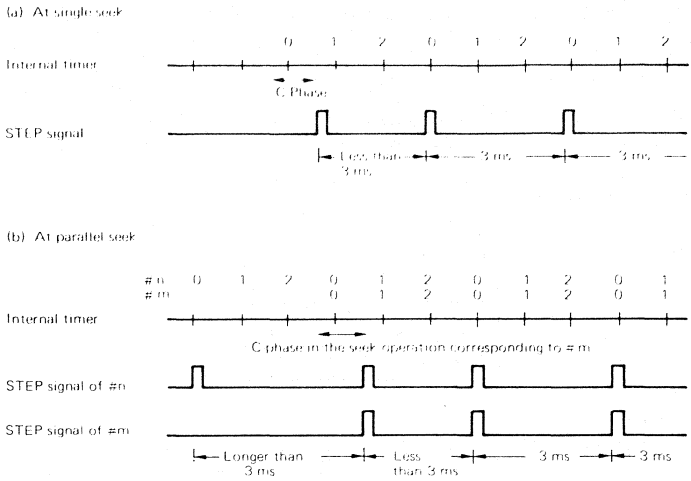


Fig. 4-6 Shortened Step Rates

(3) HLT

HLT (Head Load Time) specifies the stabilizing time of the read/write head after loading at the start of the read/write group commands (set to the specification of the drive).

- For standard floppy: 2 to 254 ms (2 ms per unit)
- For mini-floppy: 4 to 508 ms (4 ms per unit)

However, if the head is in loaded state (within the HUT of the previous command) at the start of command execution, HLT is meaningless.

$HLT_{(16)}$	Time (ms)
00	Inhibited
01	2/4
02	4/8
03	6/12
04	8/16
05	10/20
06	12/24
07	14/28

$HLT_{(16)}$	Time (ms)
08	16/32
09	18/36
⋮	⋮
7D	250/500
7E	252/504
7F	254/508

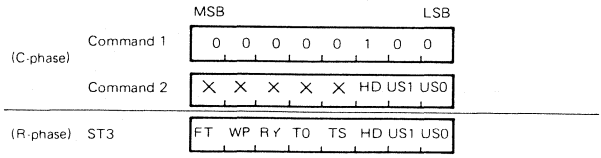
The minimum value of the head load time will be shorter than the values shown in the table by 1 ms (for standard floppy) and 2 ms (for mini-floppy).

Settling time need not be specified because it is shorter than the head load time (assuming that the settling will be completed in the head load time).

(4) ND

ND (Non-DMA Mode) specifies data transfer mode in the E-phase of the read/write group command. 1 specifies Non-DMA transfer, and 0 indicates DMA transfer.

4.3.13 SENSE DEVICE STATUS



General description

The state of the signals (FLT, WPRT, READY, TRKO, and 2 SIDE) indicating the device status and the state of the HD, US0, and US1 bits specified in C-phase are set to ST3 and loaded to the data register. (refer to appendix II(3))

4.3.14 INVALID

General description

In the following two cases, $10_{(2)}$ (IC: Invalid command) is set to the Interrupt Code (highest two bits) of ST0, and 0 is set to all remaining bits (ST0 = 80H).

This is then loaded to the data register. (refer to appendix II(1))

- When an undefined command code is given; or
- When the SENSE INTERRUPT STATUS command is activated even though an INT request by termination of the seek group command or by a drive status change is not generated.

4.3.15 SET STANDBY*

FDC internal clocks are stopped, and the FDC is set into standby mode.

The contents of RAM and the state of output pins are held in standby mode.

The SET STANDBY command can be written when CB = 0, DIO = 0 and RQM = 1 on status register as usual. The FDC is set into standby mode about 3μs later than the accepting of this command. The standby mode can be released by RESET STANDBY or SOFTWARE RESET command or RESET input.

This command has only C-phase.

4.3.16 RESET STANDBY*

The FDC is released from standby mode. This command is written any time in standby mode.

This command is processed as invalid command. Therefore this command has C-phase and R-phase.

4.3.17 SOFTWARE RESET*

The FDC is reset in the same way as the RESETsignal input. This command can be written any time.

This command has only C-phase.

*For CMOS FDCs μPD72065 and μPD72066 only

4.4 NORMAL AND ABNORMAL DISPLAYING BITS OF THE RESULT STATUS (1 INDICATES THE BIT TO BE SET)

Command	Conditions at the end of execution		ST0					ST1						ST2						
			NT	AT	SE	EC	NR	EN	DE	OR	ND	NW	MA	CM	DD	NC	SH	SN	BC	MD
READ DATA	Normal termination		00																	
	Not ready			01			1													
	ID field	IDAM not detected		01									1							
		C not matched (≠FFH)		01							1					1				
		C not matched (=FFH)		01							1								1	
		H not matched		01							1									
		R not matched (in one track)		01							1									
		N not matched		01							1									
		CRC not matched		01					1											
	Data field	DAM not detected		01									1							1
		DDAM detected	00											1						
		CRC not matched		01					1						1					
		Overrun		01						1										
	Incomplete at the last sector			01				1												
READ DELETED DATA	Normal termination		00																	
	Not ready			01			1													
	ID field	IDAM not detected		01									1							
		C not matched (≠FFH)		01							1					1				
		C not matched (=FFH)		01							1								1	
		H not matched		01							1									
		R not matched (in one track)		01							1									
		N not matched		01							1									
		CRC not matched		01					1											
	Data field	DDAM not detected		01									1							1
		DAM detected	00											1						
		CRC not matched		01					1						1					
		Overrun		01						1										
	Incomplete at the last sector			01				1												
WRITE DATA	Normal termination		00																	
	Not ready			01			1													
	Write protect			01								1								
	ID field	IDAM not detected		01									1							
		C not matched (≠FFH)		01							1					1				
		C not matched (=FFH)		01							1								1	
		H not matched		01							1									
		R not matched (in one track)		01							1									
		N not matched		01							1									
		CRC not matched		01					1											
	Data field	Fault		01		1														
		Overrun		01						1										
	Incomplete at the last sector			01				1												

Command	Conditions at the end of execution		ST0					ST1						ST2						
			NT	AT	SE	EC	NR	EN	DE	OR	ND	NW	MA	CM	DD	NC	SH	SN	BC	MD
WRITE DELETED DATA	Normal termination		00																	
	Not ready			00			1													
	Write protect			01								1								
	ID field	IDAM not detected		01									1							
		C not matched (≠FFH)		01							1					1				
		C not matched (=FFH)		01							1								1	
		H not matched		01							1									
		R not matched (in one track)		01							1									
		N not matched		01							1									
		CRC not matched		01					1											
	Data field	Fault		01		1														
		Overrun		01						1										
	Incomplete at the last sector			01				1												
READ ID	Normal termination		00																	
	Not ready			01			1													
	ID field	IDAM not detected		01									1							
		CRC not matched		01							1									
WRITE ID	Normal termination		00																	
	Not ready			01			1													
	Write protect			01								1								
	Fault			01		1														
	Overrun			01						1										
READ DIAGNOSTIC	Normal termination		00																	
	Not ready			01			1													
	ID field	IDAM not detected		01									1							
		C not matched (Incomplete termination)	00								1									
		H not matched (Incomplete termination)	00								1									
		R not matched (Incomplete termination)	00								1									
		N not matched (Incomplete termination)	00								1									
		CRC not matched (Incomplete termination)	00						1											
	Data field	DAM not detected		01									1							1
		DDAM detected (Incomplete termination)	00											1						
		CRC not matched (Incomplete termination)	00						1						1					
		Overrun		01						1										
	Incomplete at the last sector			01				1												

Command	Conditions at the end of execution		ST0					ST1							ST2						
			NT	AT	SE	EC	NR	EN	DE	OR	ND	NW	MA	CM	DD	NC	SH	SN	BC	MD
SCAN EQUAL/ SCAN LOW OR EQUAL/ SCAN HIGH OR EQUAL	LOW/HIGH condition met		00																	
	EQUAL condition met		00														1			
	Condition not met		00															1		
	Not ready			01			1													
	ID field	IDAM not detected		01									1							
		C not matched (FFH)		01							1					1				
		C not matched (FFH)		01							1								1	
		H not matched		01							1									
		R not matched (in one track)		01							1									
		N not matched		01							1									
		CRC not matched		01					1											
	Data field	DAM not detected		01									1							1
		DDAM detected	00											1						
		CRC not matched		01					1						1					
		Overrun		01						1										
SEEK (accepted by the SENSE INTERRUPT STATUS)	Normal termination		00		1															
	Not ready			01	1		1													
RECALIBRATE (accepted by the SENSE INTERRUPT STATUS)	Normal termination		00		1															
	Not ready			01	1		1													
	Track 0 not detected			01	1	1														

4.5 SYMBOLS IN THE COMMAND TABLE (SHOWN IN 4.6)

Symbol (Name)	Function
R/W (Read/Write)	Indicates that $\overline{RD}$ or $\overline{WR}$ signal will be set to active state.
D7 – D0 (Data Bus)	Indicates correspondence to the 8-bit data bus.
MT (Multi-track)	When this is 1, the multi-track mode is specified.
MF (MEM Mode)	1 specifies MFM mode, 0 specifies FM mode.
SK (Skip)	Specifies to skip the sector with the DDAM or DAM.
HD (Head)	Specifies physical head number, either 0 (side 0) or 1 (side 1).
US0, 1 (Unit Select)	Specifies the drive number (0 to 3).
C (Cylinder Number)	Indicates cylinder number.
H (Head Number)	Indicates logical head number (data on the media).
R (Record Number)	Indicates sector number.
N (Record Length)	Code indicating the data length in one sector.
EOT (End of Track)	Indicates the last sector number to be accessed on the track.
GPL (Gap Length)	Indicates number of bytes to be written for Gap 3.
GSL (Gap Skip Length)	Indicates number of bytes to be skipped in Gap 3.
DTL (Data Length)	Specifies the data length per sector to be processed.
ST0, 1, 2, 3 (Status)	Indicates contents of result status.
SC (Sector)	Indicates number of sectors per track to be formatted by the WRITE ID command.
D (Data)	Indicates the data pattern to be written to the data field by WRITE ID command.
STP (Step)	During execution of SCAN command, if STP is 1, the next sector is processed, if STP is 2, every other sector is processed.
NCN (New Cylinder Number)	Indicates the cylinder number being seeked.
PCN (Present Cylinder Number)	Indicates the cylinder number at the time of completion of the SENSE INTERRUPT STATUS command.
SRT (Step Rate Time)	Specifies the interval of the step pulses.
HUT (Head Unload Time)	Specifies head unloading time.
HLT (Head Load Time)	Specifies head loading time.
ND (Non-DMA Mode)	When this is 1, Non-DMA mode is specified.

4.6 COMMAND TABLE (X: DON'T CARE, REFER TO SECTION 4.5 FOR SYMBOLS)

Command	Phase	R/W		D7 — D0	Note
READ DATA	C	W	1	MT MF SK 0 0 1 1 0	SK: Skip DDAM
			2	X X X X X HD US1 US0	
			3	C	ID of execution start sector
			4	H	
			5	R	
			6	N	
			7	EOT	
			8	GSL	
			9	GTL	
	E	R			Data transfer
	R	R	1	ST0	When normally terminated (except CM), ID of the sector next to execution end sector; when abnormally terminated or when CM (Table 4-6), ID of execution end sector
			2	ST1	
			3	ST2	
			4	C	
			5	H	
			6	R	
			7	N	
READ DELETED DATA	C	W	1	MT MF SK 0 1 1 0 0	SK: Skip DMA
			2	X X X X X HD US1 US0	Same as READ DATA
			3	C	
			4	H	
			5	R	
			6	N	
			7	EOT	
			8	GSL	
			9	DTL	
	E	R			Data transfer
	R	R	1	ST0	Same as READ DATA
			2	ST1	
			3	ST2	
			4	C	
			5	H	
			6	R	
			7	N	

Command	Phase	R/W		D7 — D0	Note
READ ID	C	W	1	0 MF 0 0 1 0 1 0	
			2	X X X X X HD US1 US0	
	E	–		–	Stores first read ID having no error (No data transfer)
	R	R	1	ST0	Same as READ DATA
			2	ST1	
			3	ST2	
			4	C	ID read in the E-phase
			5	H	
			6	R	
			7	N	
WRITE ID	C	W	1	0 MF 0 0 1 1 0 1	
			2	X X X X X HD US1 US0	
			3	N	
			4	SC	
			5	GPL	
			6	D	
	E	W			Transfers ID (SC X 4 bytes) of sectors for one track
	R	R	1	ST0	Same as READ DATA
			2	ST1	
			3	ST2	
			4	C	Have no meaning
			5	H	
			6	R	
			7	N	N byte specified in C-phase

Command	Phase	R/W		D7 — D0	Note
WRITE DATA	C	W	1	MT MF 0 0 0 1 0 1	Same as READ DATA
			2	X X X X X HD US1 US0	
			3	C	
			4	N	
			5	R	
			6	N	
			7	EOT	
			8	GSL	
			9	GTL	
	E	W			Data transfer
	R	R	1	ST0	Same as READ DATA
			2	ST1	
			3	ST2	
			4	C	
			5	H	
			6	R	
			7	N	
WRITE DELETED DATA	C	W	1	MT MF 0 0 1 0 0 1	Same as READ DATA
			2	X X X X X HD US1 US0	
			3	C	
			4	H	
			5	R	
			6	N	
			7	EOT	
			8	GSL	
			9	DTL	
	E	W			Data transfer
	R	R	1	ST0	Same as READ DATA
			2	ST1	
			3	ST2	
			4	C	
			5	H	
			6	R	
			7	N	

Command	Phase	R/W		D7 — D0	Note
READ DIAGNOSTIC	C	W	1	0 MF 0 0 0 0 1 0	Same as READ DATA (except that R has no meaning)
			2	X X X X X HD US1 US0	
			3	C	
			4	H	
			5	R	
			6	N	
			7	EOT	
			8	GSL	
			9	DTL	
	E	R			Data transfer
	R	R	1	ST0	Same as READ DATA
			2	ST1	
			3	ST2	
			4	C	
			5	H	
			6	R	
			7	N	
SCAN EQUAL	C	W	1	MT MF SK 1 0 0 0 1	Same as READ DATA
			2	X X X X X HD US1 US0	
			3	C	
			4	H	
			5	R	
			6	N	
			7	EOT	
			8	GSL	
			9	STP	
	E	W			Data comparison
	R	R	1	ST0	Last sector compared
			2	ST1	
			3	ST2	
			4	C	
			5	H	
			6	R	
			7	N	

Command	Phase	R/W		D7 ——— D0	Note
SCAN LOW OR EQUAL	C	W	1	MT MF SK 1 1 0 0 1	Same as READ DATA
			2	X X X X X HD US1 US0	
			3	C	
			4	H	
			5	R	
			6	N	
			7	EOT	
			8	GSL	
			9	STP	
	E	W			Data comparison
	R	R	1	ST0	Last sector compared
			2	ST1	
			3	ST2	
			4	C	
			5	H	
			6	R	
			7	N	
SCAN HIGH OR EQUAL	C	W	1	MT MF SK 1 1 1 0 1	Same as READ DATA
			2	X X X X X HD US1 US0	
			3	C	
			4	H	
			5	R	
			6	N	
			7	EOT	
			8	GSL	
			9	STP	
	E	W			Data comparison
	R	R	1	ST0	Last sector compared
			2	ST1	
			3	ST2	
			4	C	
			5	H	
			6	R	
			7	N	

Command	Phase	R/W		D7							D0	Note
SEEK	C	W	1	0	0	0	0	1	1	1	1	
			2	X	X	X	X	X	X	US1	US0	
			3	NCN								
	E	–		–								Seek operation
RECALI-BRATE	C	W	1	0	0	0	0	0	1	1	1	
			2	X	X	X	X	X	X	US1	US0	
	E	–		–								Recalibrate operation
SENSE INTER-RUPT STATUS	C	W	1	0	0	0	0	1	0	0	0	
	R	R	1	ST0								
			2	PCN								Cylinder number at the end of command execution (has no meaning at the drive status change)
SENSE DEVICE STATUS	C	W	1	0	0	0	0	0	1	0	0	
			2	X	X	X	X	X	HD	US1	US0	
	R	R		ST3								Status of the drive
SPECIFY	C	W	1	0	0	0	0	0	0	1	1	
			2	SRT				HUT				
			3	HLT								
INVALID	C	W	1	Other code								
	R	R	1	ST0								ST0 = $80_{(16)}$
SET STANDBY*	C	W	1	0	0	1	1	0	1	0	1	
RESET STANDBY*	C	W	1	0	0	1	1	0	1	0	0	
	R	R	1	ST0								ST0 = $80_{(16)}$
SOFTWARE RESET*	C	W	1	0	0	1	1	0	1	1	0	

*For the CMOS FDCs μPD72065 and μPD72066 only

4.7 RESULT STATUS

Table 4-2 Result Status 0 (ST0)

Bit	Name	Symbol	Function
D7 D6	Interrupt Code	IC	Indicates cause of INT request D7 D6 0 0 Normal termination of command execution (NT) 0 1 Abnormal termination of command execution (AT) 1 0 Indicates the command was not executed because it was invalid (IC) 1 1 Indicates a change in device status
D5	Seek End	SE	This bit is set when seek operation by SEEK or RECALIBRATE command is terminated normally or abnormally.
D4	Equipment Check	EC	This bit is set when the Fault signal from the device is aceepted or when the Track 0 signal cannot be detected within a certain period in execution of the RECALIBRATE command.
D3	Not Ready	NR	This bit is set when the specified device is not ready.
D2	Head Address	HD	Indicates the head status at the time of INT request. This bit is set to 0 when SENSE INTERRUPT STATUS command is executed.
D1	Unit Select 1	US1	Indicates the device number at the time of INT request
D0	Unit Select 0	US0	

NT: Normal Terminate
IC: Invalid Command
AT: Abnormal Terminate
AI: Attention Interrupt

Table 4-3 Result Status 1 (ST1)

Bit	Name	Symbol	Function
D7	End of Cylinder	EN	This bit is set when read or write is attempted beyond the last sector specified by the EOT
D6	–	–	0
D5	Data Error	DE	This bit is set when the CRC error of ID or data is detected (except READ ID). DD bit (D5) of ST2 specifies either ID or data.
D4	Overrun	OR	This bit is set when service by the main system is not performed within the specified amount of time at the data transfer.
D3	–	–	0
D2	No Data	ND	1. This bit is set if the sector specified by the IDR cannot be detected on the track when any one of the following five commands is executed: • READ DATA • READ DELETED DATA • WRITE DATA • WRITE DELETED DATA • SCAN 2. This bit is set when an ID with no CRC error is not detected on the track in the execution of READ ID command. 3. This bit is set when the sector ID and the contents of the specified IDR are not matched at the READ DIAGNOSTIC command execution.
D1	Not writable	NW	This bit is set when the write protect signal is detected by execution of a write group command.
D0	Missing Address Mark	MA	1. This bit is set when the IDAM cannot be found before two index pulses are detected by the execution of a command that accesses the ID of the disk. 2. This bit is set when the DAM or DDAM cannot be found after the IDAM is found. MD bit of ST2 is also set at this time.

Table 4-4 Result Status 2 (ST2)

Bit	Name	Symbol	Function
D7	–	–	0
D6	Control Mark	CM	This bit is set when the DDAM is detected at the READ DATA, READ DIAGNOSTIC or SCAN execution or when the DAM is detected at the READ DELETED DATA execution.
D5	Data Error in Data Field	DD	This bit is set when a CRC error is detected.
D4	No Cylinder	NC	When neither C byte of ID matches nor FF(16), this bit is set together with ND bit of ST1 (except READ DIAGNOSTIC).
D3	Scan Equal Hit	SH	This bit is set when the Equal condition is satisfied at the SCAN command execution.
D2	Scan Not Satisfied	SN	This bit is set when the condition is not satisfied at the SCAN command execution up to the last sector.
D1	Bad Cylinder	BC	This bit is set together with the ND bit of ST1 when the C byte of ID is FF(16) (except READ DIAGNOSTIC)
D0	Missing Address Mark in Data Field	MD	This bit is set in the case of [2.] where MA bit of ST1 is set (DAM, DDAM cannot be found).

Table 4-5 Result Status 3 (ST3)

Bit	Name	Symbol	Function
D7	Fault	FT	Status of the Fault signal from the device
D6	Write Protected	WP	Status of the Write Protected signal from the device
D5	Ready	RY	Status of the Ready signal from the device
D4	Track 0	T0	Status of the Track 0 signal from the device
D3	Two Side	TS	Status of the 2 Side signal from the device
D2	Head Address	HD	Status of the Side Select signal to the device
D1	Unit Select 1	US1	Status of the Unit Select 1 signal to the device
D0	Unit Select 0	US0	Status of the Unit Select 0 signal to the device

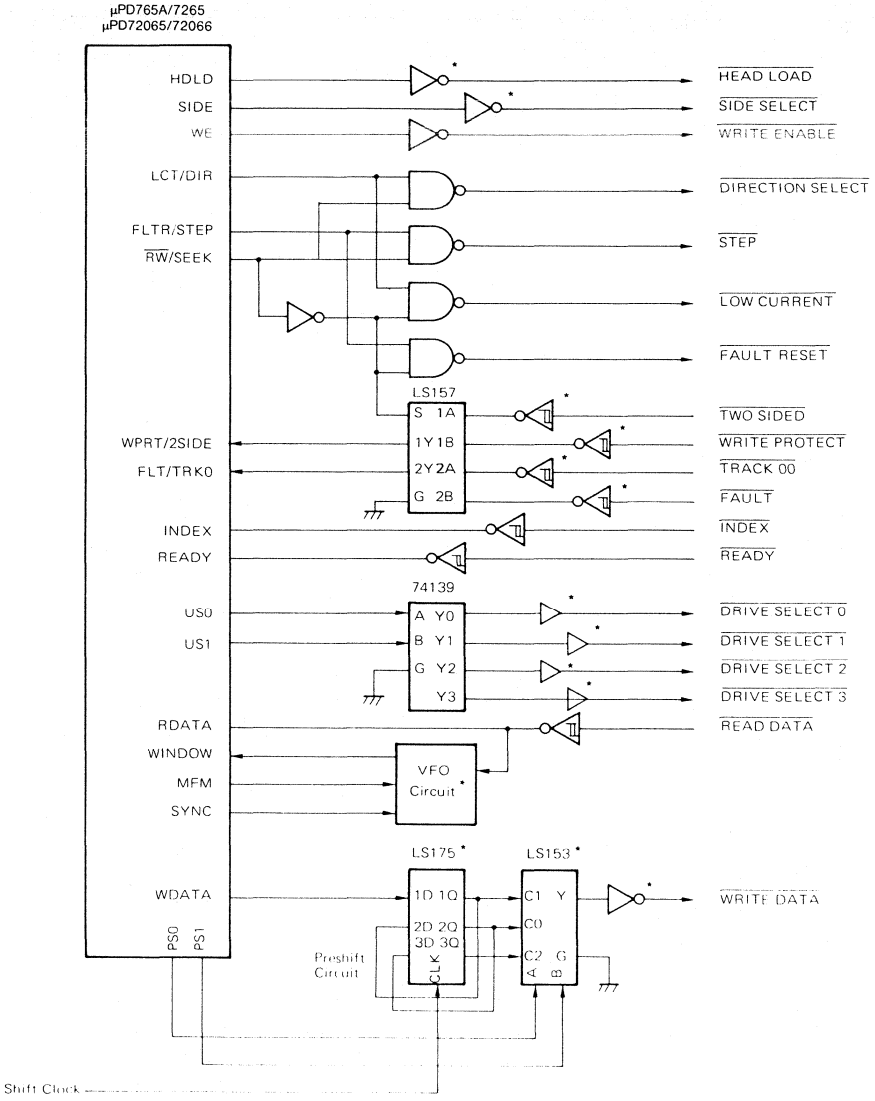


Fig. 7-2 Interfacing of FDC to FDD (Reference Circuit)

*Included in the Floppy Disk Interface μPB9201
Output drivers can sink 24 mA

SPECIFICATION

Absolute Maximum Ratings

T_A = 25°C)

Power supply voltage, V_{CC}	−0.5 to +7V
Input voltage, V_I	−0.5 to +7V
Output Voltage, V_O	0.5 to +7V
Operating temperature, T_{OPT}	10°C to +70°C
Storage temperature, T_{STG} (μPD765A/7265)	−40°C to +125°C
Storage temperature, T_{STG} (μPD765A-2/72065/72066)	−65°C to +150°C

Comment: Exposing the device to stresses above those listed in the Absolute Maximum Ratings could cause permanent damage. The device should not be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

T_A = 25°C, f_C = 1MHz, V_{CC} = 0V

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input clock capacitance	$C_{IN(0)}$			20	pF	(Note 1)
Input capacitance	C_{IN}			10	pF	(Note 1)
Output capacitance	C_{OUT}			20	pF	(Note 1)

Note:
(1) All pins except pin under test tied to AC ground

DC Characteristics

T_A = −10°C to +70°C, V_{CC} = +5V ± 5% unless otherwise specified for μPD765A and μPD7265 else V_{CC} = +5V ± 10%

		μPD765A/7265		μPD765A-2/7265-2		μPD72065/72066			
		Limits							Test
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Unit	Conditions
Input voltage low	V_{IL}	−0.5	+0.8	−0.5	+0.8	−0.5	0.65	V	
Input voltage high	V_{IH}	2.0	V_{CC}+0.5	2.0	V_a +0.5	2.2	V_{CC}+0.5	V	
Output voltage low	V_{OL}		0.45				0.45	V	I_{OL} = 2.0 mA
Output voltage high	V_{OH}	2.4	V_{CC}	2.4	V_{CC}	2.4	V_{CC}	V	I_{OH} = −200 μA
Input voltage low (CLK + $\overline{WR}$ clock)	$V_{IL(\Phi)}$	−0.5	0.65	−0.5	+0.65	−0.5	+0.65	V	
Input voltage high (CLK + WCLK)	$V_{IH(\Phi)}$	2.4	V_{CC}+0.5	2.4	V_{CC} +0.5	2.4	V_{CC} +0.5	V	
Supply current (V_{CC})	I_{CC}		150		140		10	mA	Φ = 125ns
Input load current high	I_{LIH}		10		10		10	μA	V_{IN} = V_{CC}
Input load current low	I_{LIL}		−10		−10		−10	μA	V_{IN} = 0V
Output leakage current high	I_{LOH}		10		10		10	μA	V_{OUT} = V_{CC}
Output leakage current low	I_{LOL}		−10		−10		−10	μA	V_{OUT} = +0.45V
Supply current (Stand-by)	I_{CC1} I_{CC2} I_{CC3}		–		–		500 250 100		Φ = 125ns Φ = 250ns clock stopped

AC Characteristics

T_A = −10°C to + 70°C, V_{CC} = +5V ± 5% for μPD765A/7265, otherwise V_{CC} = +5V ± 10%

Parameter	Symbol	765A, 7265			765A-2, 7265-2			72065, 72066			Unit	Test Conditions
		Min	Typ (1)	Max	Min	Typ (1)	Max	Min	Typ (1)	Max		
Clock period	Φ_{CY}	120	125	500	120	125	500	120	125	500	ns	(Note 4)
			125			125			125		ns	8" FDD
			250			250			250		ns	5¼" FDD
			125			125			125		ns	3½" Sony (3)
Clock active (high)	Φ_0	40			40			40			ns	
Clock rise time	Φ_r			20			20			20	ns	
Clock fall time	Φ_f			20			20			20	ns	
A_0, $\overline{CS}$, $\overline{DACK}$ setup time to $\overline{RD}\downarrow$	t_{Ar}	0			0			0			ns	
A_0, $\overline{CS}$, $\overline{DACK}$ hold time from $\overline{RD}\uparrow$	t_{RA}	0			0			0			ns	
$\overline{RD}$ width	t_{RR}	250			200			200			ns	
Data access time from $\overline{RD}\downarrow$	t_{RD}			200			140			140	ns	C_L = 100 pF
DB to float delay time from $\overline{RD}\uparrow$	t_{DF}	20		100	10		85	10		85	ns	C_L = 100 pF
A_0, $\overline{CS}$, $\overline{DACK}$ setup time to $\overline{WR}\downarrow$	t_{AW}	0			0			0			ns	
A_0, $\overline{CS}$, $\overline{DACK}$ hold time to $\overline{WR}\uparrow$	t_{WA}	0			0			0			ns	
$\overline{WR}$ width	t_{WW}	250			200			200			ns	
Data setup time to $\overline{WR}\uparrow$	t_{DW}	150			100			100			ns	
Data hold time from $\overline{WR}\uparrow$	t_{WD}	5			0			0			ns	
INT delay time from $\overline{RD}\uparrow$	t_{RI}			500			400			400	ns	
INT delay time from $\overline{WR}\uparrow$	t_{WI}			500			400			400	ns	
DRQ cycle time	t_{MCY}	13			13			13			μs	Φ_{CY} = 125ns (4)
$\overline{DACK}\downarrow \rightarrow DRQ\downarrow$ delay	t_{AM}			200			140			140	ns	
$DRQ\uparrow \rightarrow \overline{DACK}\downarrow$ delay	t_{MA}	200			200			200			ns	Φ_{CY} = 125ns (4)
$\overline{DACK}$ width	t_{AA}	2			2			2			Φ_{CY}	
TC width	t_{TC}	1 Φ_{CY}			1 Φ_{CY}			60ns			Φ_{CY}	
Reset width	t_{RST}	14			14			14			Φ_{CY}	
Clock hold time at standby	t_{WC}							32			Φ_{CY}	
Clock hold time release	t_{CW}							16			Φ_{CY}	
WCLK cycle time	t_{CY}		16			16			16		Φ_{CY}	MFM = 0
			8			8			8		Φ_{CY}	MFM = 1
WCLK active time (high)	t_0		2			2			2		Φ_{CY}	
WCLK rise time	t_r			20			20			20	ns	
WCLK fall time	t_f			20			20			20	ns	
Preshift delay time from $WCLK\downarrow$	t_{CP}	20		100	20		100	10		80	ns	
$WCLK\uparrow$ - $WE\downarrow$ delay	t_{CWE}	20		100	20		100	10		80	ns	
WDA delay time from $WCLK\downarrow$	t_{CD}	20		100	20		100	10		80	ns	
RDD active time (high)	t_{RDD}	40			40			40			ns	

AC Charakteristics (cont)

T_A = −10°C to 70°C, V_{CC} = +5V ± 5% for μPD765A/7265, otherwise V_{CC} = +5V ± 10%

Parameter	Symbol	765A, 7265			765A-2, 7265-2			72065, 72066			Unit	Test Conditions
		Min	Typ (1)	Max	Min	Typ (1)	Max	Min	Typ (1)	Max		
Window cycle time	tWCY		16			16			16		Φ_{CY}	MFM = 0
			8			8			8		Φ_{CY}	MFM = 1
Window hold time to RDATA	tRDW	15			15			15			ns	
Window hold time from RDATA	tWRD	15			15			15			ns	
$US_{0,1}$ hold time to $\overline{RW}$/seek*	tUS	12			12			12			μs	8 MHz clock period(4)
$\overline{RW}$/seek hold time to low current/direction*	tSD	7			7			7			μs	8 MHz clock period(4)
Low current/direction hold time to fault reset/step*	tDST	1			1			1			μs	8 MHz clock period(4)
$US_{0,1}$ hold time from fault reset/ step 1	tSTU	5			5			5			μs	8 MHz clock period(4)
Step active time (high)	tSTP	6	7	8	6	7	8	6	7	8	μs	(Note 4)
Step cycle time	tSC	33	(Note 2)	(Note 2)	33	(Note 2)	(Note 2)	33			μs	(Note 4)
Fault reset active time (high)	tFR	8		10	8		10	8		10	μs	(Note 4)
Write data width	tWDD	t0−50			t0−50			t0−50			ns	
$US_{0,1}$ hold time after seek	tSU	15			15			15			μs	8 MHz clock period(4)
Seek hold time from DIR	tDS	30			30			30			μs	8 MHz clock period(4)
DIR hold time after step	tSTD	24			24			24			μs	8 MHz clock period(4)
Index pulse width	tIDX	10			4			4			Φ_{CY}	
$\overline{RD}$↓ delay from DRQ	tMR	800			800			125			ns	8 MHz clock period(4)
$\overline{WR}$↓ delay from DRQ	tMW	250			250			250			ns	8 MHz clock period(4)
$\overline{WR}$ or $\overline{RD}$ response time from DRQ*	tMRW			12			12				μs	8 MHz clock period(4)

Note:

(1) Typical values for T_A = 25°C and nominal supply voltage.

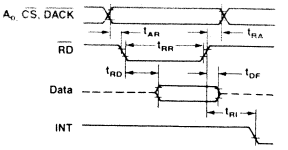
(2) Under software control. The range is form 1 ms to 16 ms at 8 MHz clock period, and 2 ms to 32 ms at 4 MHz clock period.

(3) Sony Micro Floppydisk 3½" drive.

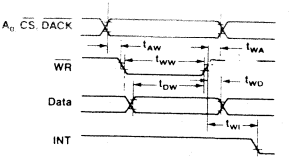
(4) Double these values for a 4 MHz clock period.

Timing Waveforms

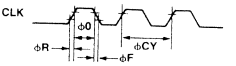
Processor Read Operation



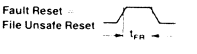
Processor Write Operation



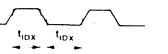
Clock



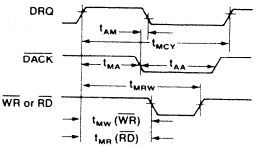
FLT Reset



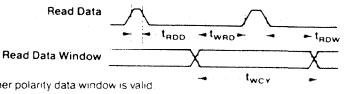
Index



DMA Operation

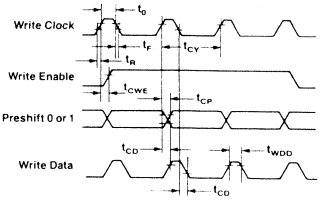


FDD Read Operation

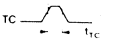


Note: Either polarity data window is valid

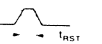
FDD Write Operation



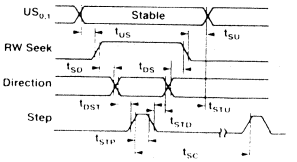
Terminal Count



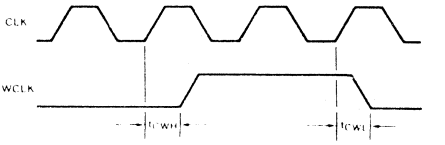
Reset



Seek Operation



Write Clock



Description

The μPB9201 floppy disk interface (FDI) is an LSI device that provides a wide range of functions commonly needed in a floppy disk controller design. A floppy disk controller design using the μPD765A and the μPB9201 requires only four to five chips, depending on individual requirements.

The digital phase lock loop implemented in the FDI simulates the function of an analog PLL. If higher resolution is required, the device provides for the addition of an external VCO chip. This essentially converts the digital PLL to an analog one. The external VCO is seldom required, however, due to the excellent performance of the digital PLL.

The FDI generates the write clock and processor clock for the μPD765A. The clocks are automatically switched in frequency when the 8" or 5-1/4" mode is selected. These clocks are changed synchronously so that random clock edges are not generated.

The FDI includes a precompensation circuit that allows delays of 0 ns, 125 ns, 187.5 ns, and 250 ns.

The on-chip drive select logic combined with the head load (HDL) signal eliminates the normally required selection logic. The on-chip buffers allow direct connections from $\overline{DS_0}$-$\overline{DS_3}$ and $\overline{HS_0}$-$\overline{HS_3}$ to the FDD.

The FDI provides the designer with the ability to delay the DRQ signal that normally goes from the FDC to the host DMA controller. The minimum delay is either 0.75 μs or 1.5 μs, depending on the selection of 8" or 5-1/4" mode. This allows the use of fast DMA controllers such as the μPD8237A-5.

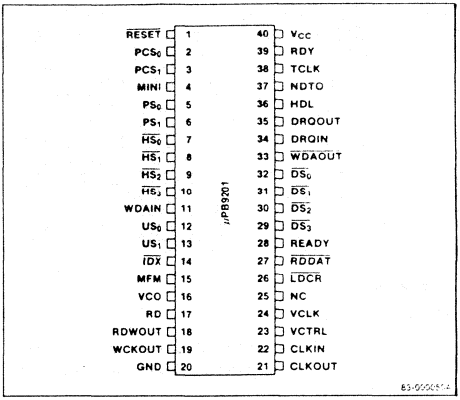
Features

- ☐ Programmable digital write precompensation
- ☐ Write clock generation for 5-1/4" and 8" drives
- ☐ Data separation
- ☐ 5-1/4" and 8" drives select
- ☐ External VCO hook-up provision (optional)
- ☐ Processor clock generation
- ☐ Internal buffers capable of sinking 24 mA
- ☐ TTL-compatible
- ☐ Drive select logic
- ☐ Head select logic
- ☐ DRQ delay
- ☐ No data time out

Ordering Information

Part Number	Package Type
μPB9201C	40-pin plastic DIP

Pin Configuration



Pin Identification

No.	Symbol	Function
1	$\overline{RESET}$	Reset input
2, 3	PCS_0, PCS_1	Precompensation select input
4	MINI	Mode select
5, 6	PS_0, PS_1	Precompensation input
7-10	$\overline{HS_0}$-$\overline{HS_3}$	Head select
11	WDAIN	Write data input
12, 13	US_0, US_1	Unit select input
14	$\overline{IDX}$	Index output
15	MFM	MFM mode input
16	VCO	VCO sync input
17	RD	Read data output
18	RDWOUT	Read data window output
19	WCKOUT	Write clock output
20	GND	Ground
21	CLKOUT	Clock output
22	CLKIN	Clock input
23	VCTRL	VCO control
24	VCLK	VCO clock input
25	NC	No connect
26	$\overline{LDCR}$	Load control register input
27	$\overline{RDDAT}$	Read data input
28	READY	Ready input
29-32	$\overline{DS_3}$-$\overline{DS_0}$	Drive select outputs

Pin Identification (cont)

No.	Symbol	Function
33	$\overline{WDAOUT}$	Write data output
34	DRQIN	DMA request input
35	DRQOUT	DMA request output
36	HDL	Head load input
37	NDTO	No data time out input/output
38	TCLK	Test clock output
39	RDY	Ready output
40	V_{CC}	Power supply

Pin Functions

$\overline{RESET}$

When $\overline{RESET}$ is low, the FDI internal logic is reset. This feature is used mainly for text purposes. Normally this pin is pulled high.

$\overline{HS_0}$-$\overline{HS_3}$

These head select outputs are derived from the head load and the US_0 - US_1 signals from the μPD765A. Each of these open collector output sinks 24 mA.

PCS_0, PCS_1

These inputs select the precompensation delay according to the following table:

PCS_1	PCS_0	Delay
0	0	0 ns
0	1	125 ns
1	0	187.5 ns
1	1	250 ns

PS_0, PS_1

These are the precompensation input signals from the μPD765A.

WDAIN

Write data from the μPD765A is input at this pin. It passes through the circuitry which is controlled by PS_0. PS_1 and the FDI control register to provide various precompensation levels.

MINI

When this input is high, 5-1/4" mode is selected. When it is low, 8" mode is selected.

US_0, US_1

These are the unit select input pins. The μPD765A uses them to select up to four double-sided drives.

$\overline{IDX}$

The FDI uses this signal to generate index pulses to the μPD765A when there is no data coming from the disk drive.

MFM

This signal controls the read data window to conform to MFM (double density) or FM (single density) recording modes. It also controls the frequency of the WCKOUT signal. MFM is input from the μPD765A.

VCO

This is the VCO sync input from the μPD765A. It is used for internal control.

RD

The read data output signal is the same as the data coming from the FDD but it has been shaped and synchronized to the 16 MHz clock. RD is directly connected to the RD signal of the μPD765A.

RDWOUT

This signal is generated by the FDI PLL circuitry. It is controlled by the MFM signal from the μPD765A and by the selection of 5-1/4" or 8" mode.

WCKOUT

This write clock output signal is output to the WCK pin of the μPD765A.

CLKOUT

This signal provides the processor clock for the μPD765A and is programmable via the FDI control register for an 8 MHz or 4 MHz square wave output. The switching between 4 MHz and 8 MHz is synchronous.

CLKIN

This input signal should be a 16 MHz TTL-compatible square wave. All timing for the FDI is derived from this signal.

VCLK

If an external VCO chip is used, this pin should be connected to the output of the VCO. If an external VCO is not used, then this pin should be connected to the 16 MHz clock input.

VCTRL

This three-state signal controls the external VCO frequency. It is the equivalent of combined pump-up and pump-down signals.

TCLK

This signal is used to test different modes of the FDI. Depending upon the mode, this pin outputs a 4 MHz, 8 MHz or 16 MHz square wave. It is not used in controller design.

$\overline{\text{LDCR}}$

This input signal is level triggered. When $\overline{\text{LDCR}}$ is low, PSC_0, PSC_1, and MINI are transferred to the internal control register. When $\overline{\text{LDCR}}$ goes high, the data on pins 6-8 will remain latched. Pins 6-8 may be connected to a data bus and $\overline{\text{LDCR}}$ may be used as a strobe, or they may be driven from external latches by connecting $\overline{\text{LDCR}}$ to GND.

$\overline{\text{RDDAT}}$

This input is directly connected to the read data signal from the floppy disk interface.

READY

This input signal is connected through an inverter to the FDD. The RDY output signal is generated by this signal.

RDY

This output signal is directly connected to the RDY pin of the μPD765A. When the 8" mode is selected, the READY signals from the floppy disk drive is sent directly to the μPD765A. When the FDI is in the 5-1/4" mode, RDY is set to 1 at all times.

DRQIN

This is an input from the μPD765A. DRQIN is delayed 3 to 4 clock pulses before being output (DRQOUT). This achieves the DRQ to RD delay that is required by the μPD765A.

DRQOUT

This is the output of the delayed DRQIN signal.

$\overline{\text{WDAOUT}}$

This open collector output is directly connected to the floppy disk drive and writes data to it. $\overline{\text{WDAOUT}}$ sinks 24 mA.

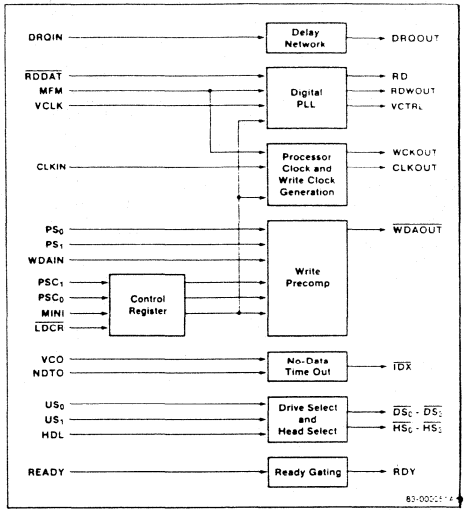
NDTO

The FDI uses this pin to generate a time out when there is no data coming from the floppy disk drive. External RC components are required for the timing.

HDL

The head load input is used in conjunction with the US_1 and US_0 signals from the μPD765A to generate the drive and head select signals.

Block Diagram



Absolute Maximum Ratings

$T_A = +25°C$

Operating temperature, T_{OPT}	0 to −70°C
Storage temperature, T_{STG}	−65 to −150°C
All output voltages, V_O	−5 to −5.5 V
All input voltages, V_I	−5 to −7 V
Power supply voltage, V_{CC}	−5 to −7 V
Power dissipation, P_D	1.5 W

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damange. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

T_A = 0 to +70°C; V_{CC} = +5 V ±10% unless otherwise specified

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Low level input voltage	V_{IL}			0.8	V	
High level input voltage	V_{IH}	2.0			V	
Input clamp voltage	V_{IC}	1.5			V	V_{CC} = 4.5 V I_{IL} = −18 mA
Low level output voltage	V_{OL}		0.3	0.5	V	V_{CC} = 4.5 V I_{OL} = 12 mA
High level output voltage	V_{OH}	2.5	3.4		V	V_{CC} = 4.5 V I_{OH} = 1 mA (1)
Short circuit output current	I_{OS}	−100		−25	mA	V_{CC} = 5.5 V V_O = 0 V
Low level input current	I_{IL}	−100			μA	V_{CC} = 5.5 V V_I = 0.4 V
High level input current	I_{IH}			20	μA	V_{CC} = 5.5 V V_I = 2.7 V
High level output current	I_{OH}			100	μA	V_{CC} = 4.5 V V_O = 4.5 V (2)
Off state output current						
Three state output	I_{OZ1}	−20			μA	V_{CC} = 5.5 V V_O = 0.4 V/2.7 V
Bidirectional	I_{OZ2}	−100		+40	μA	(VCO CNTRL pin)
V_{CC} supply current	I_{CC}		170	296	mA	T_A = +25°C

Note:

(1) Does not apply to open collector outputs.

(2) For open collector outputs only.

Capacitance

T_A = +25°C; f_C = 1 MHz

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Clock input	C_{IN} (φ)			20	pF	All pins except those under test tied to AC GND
Input	C_{IN}			10	pF	
Output	C_{OUT}			15	pF	

AC Characteristics

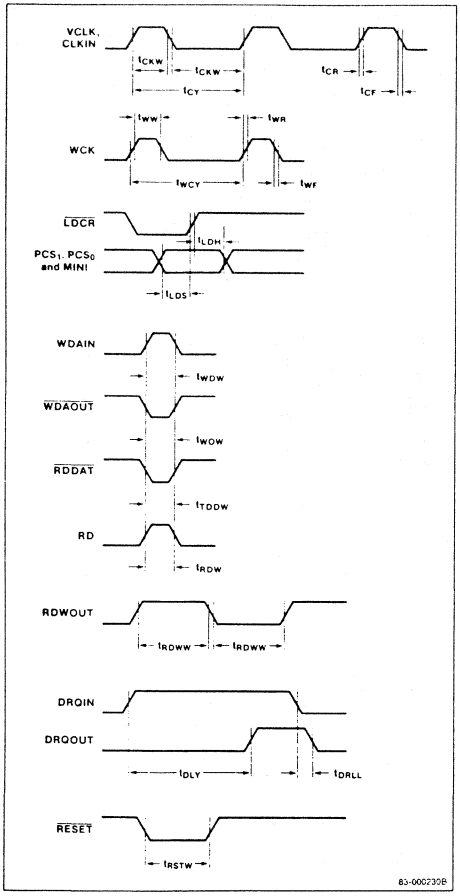
T_A = 0 to +70°C; V_{CC} = +5 V ±10% unless otherwise specified

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
CLKIN high and low width	t_{CKW}	20			ns	
CLKIN period	t_{CY}	55	62.5		ns	
CLKIN rise time	t_{CR}			10	ns	
CLKIN fall time	t_{CF}			10	ns	
WCK cycle time	t_{WCY}		1		μs	MFM, 8"
			2		μs	FM, 8"
			2		μs	MFM, 5-1/4"
			4		μs	FM, 5-1/4" CLKIN = 16 MHz
WCK high width	t_{WW}		250		ns	
WCK rise time	t_{WR}			20	ns	
WCK fall time	t_{WF}			20	ns	
PCS_0, PCS_1, MINI set up time to $\overline{LDCR}$	t_{LDS}	10			ns	
PCS_0, PCS_1, MINI hold time from $\overline{LDCR}$	t_{LDH}	10			ns	
WDAIN high width	t_{WDW}	25			ns	
$\overline{WDAOUT}$ low width	t_{WOW}		$4t_{CY}$			t_{WOW} = 250 ns where CLKIN = 6 MHz
$\overline{RDDAT}$ high width	t_{RDDW}	25			ns	
RD high width	t_{RDW}		$2t_{CY}$			MINI = 0
			$4t_{CY}$			MINI = 1
RDWOUT width	t_{RDWW}		1		μs	MFM, 8"
			2		μs	FM, 8"
			2		μs	MFM, 5-1/4"
			4		μs	FM, 5-1/4" CLKIN = 16 MHz
DRQOUT delay time from DRQIN	t_{DLY}	0.75		1	μs	MINI = 0
		1.5		2	μs	MINI = 1
DRQOUT low from DRQIN low	t_{DRLL}			30	ns	
$\overline{RESET}$ low width	t_{RSTW}	250			ns	
VCLK period	t_{CY}	55	62.5		ns	
VCLK high and low width	t_{CKW}	20			ns	

Note:

The FDI is designed to run at 16 MHz, and all of the test conditions for signals generated by the FDI are at 16 MHz.

Timing Waveforms



Interfacing

Figure 1 shows all the required interconnections between the FDI and a typical FDC chip such as the μPD765A. An external 16 MHz clock input to the CLKIN pin is required. The FDI generates all the internal timing from this input clock.

An alternate method of utilizing the μPB9201 is shown in figure 2. This method minimizes the parts count and fully utilizes all of the FDI features.

The type of the drive can be selected by setting the value of the MINI pin; ie, MINI = 0: 8" and MINI = 1: 5-1/4". This can be achieved by either a jumper or a peripheral port.

The PCS_0 and PCS_1 pins are used to program the device for a desired amount of precompensation. The PS_0 and PS_1 signals from the μPD765A inform the FDI whether the bit shift is late, normal, or early.

The $\overline{LDCR}$ (load control register) pin can be used as a strobe to latch the values of MINI, PCS_1, and PCS_0 into the control register of the FDI. Whenever $\overline{LDCR}$ is low, the control register is updated. If the strobing of $\overline{LCRC}$ is not preferred, then $\overline{LDCR}$ should be connected to ground and MINI, PCS_1, and PCS_0 should be connected either to logic 1 or 0, depending upon the desired mode of operation.

The FDI uses the US_1, US_0, and $\overline{HDSL}$ signals from the μPD765A to generate the $\overline{DS_0}$-$\overline{DS_3}$ (drive select) and the $\overline{HS_0}$-$\overline{HS_3}$ (head select) signals. All these output signals are capable of sinking 24 mA and can be directly connected to the corresponding FDD signals. (This assumes that the FDD contains 220/330 termination resistors. Some drives contain 150-ohm pull-up resistors, which will require the use of a buffer external to the μPB9201.) The designer has two options available when using the head select signals. The first option is to connect all the head select signals together to the HEAD LOAD 0 signal of the FDD interface. This method generates one common "head load" signal for all drives. The second option is to add external delay circuits to each head select signal. This causes the head for the particular drive to stay loaded for the amount of specified time delay when the drive is deselected. The advantage of this method, as compared to the former one, is that it eliminates redundant head loading and unloading when copying diskettes from one to another.

Figure 1. Typical Personal Computer Application of the μPB9201

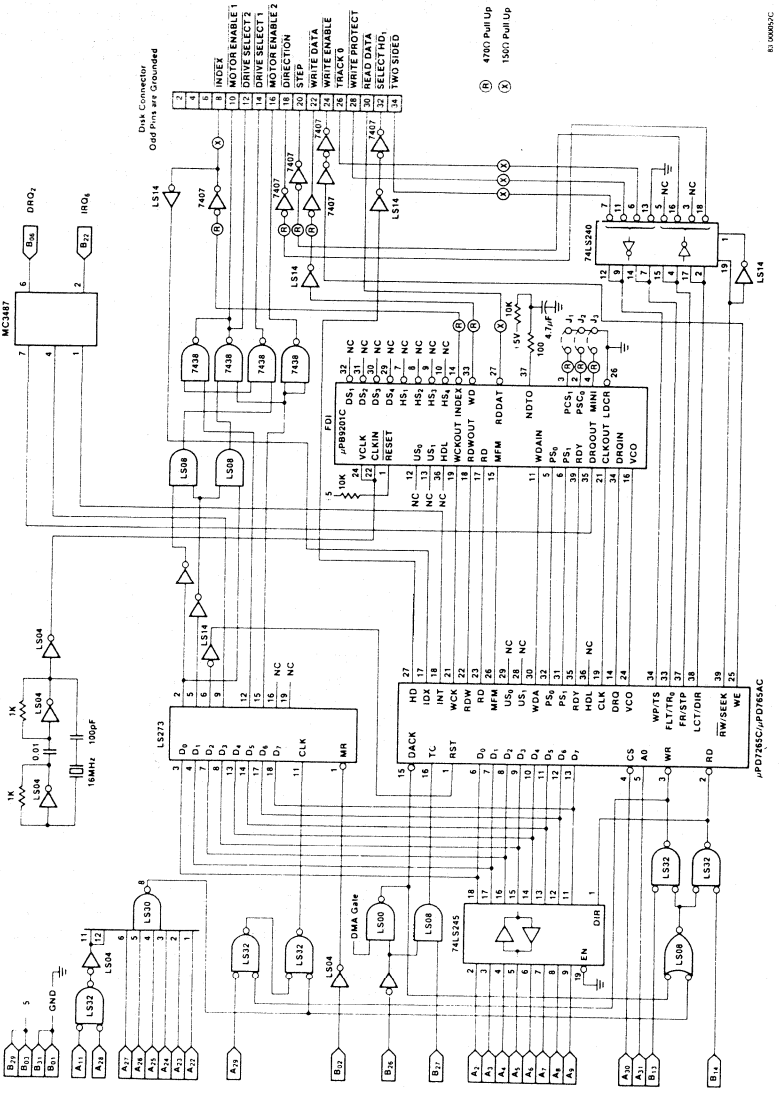
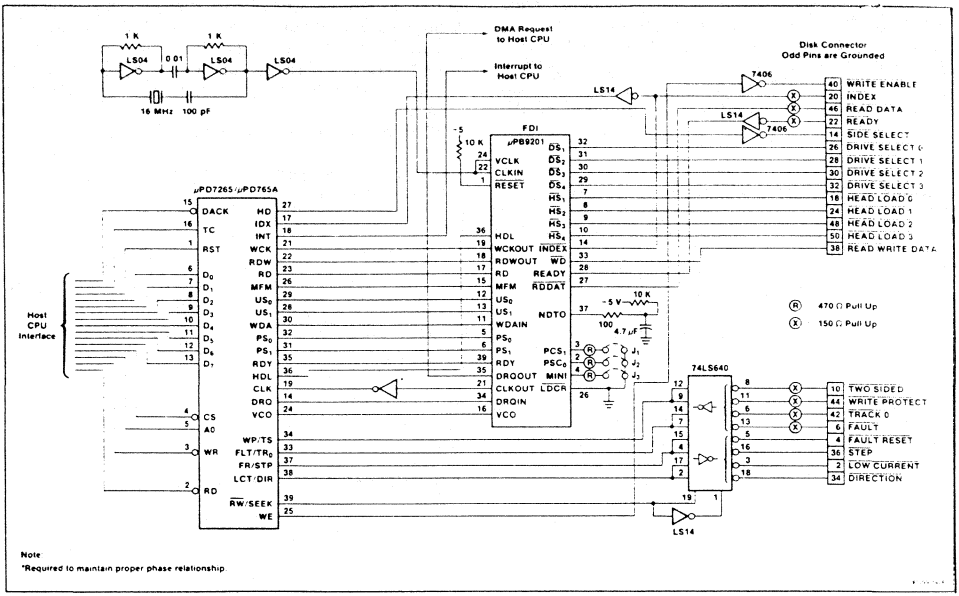


Figure 1. Typical Personal Computer Application of the μPB9201

Figure 2. Typical 8" Floppy Disk Controller; Minimum Parts Count



Optionally, an external VCO chip can be added to achieve better performance. As an example, figure 3 illustrates the necessary interconnections between the 74LS624 VCO chip and the FDI. The input frequency control of the VCO is connected to the VCTRL pin of the FDI through an integrator (a simple RC circuit). The VCTRL signal is the output of the internal digital phase comparator. When there is no data bit coming in, this pin stays at approximately 2.0 volts (high impedance state). Since the frequency control pin of 74LS624 is also at 2.0 volts (adjusted by R2), the voltage across R1 will be 0 volts. As a result of this, C1 is neither charged nor discharged and the VCO will be running at its nominal frequency (16 MHz).

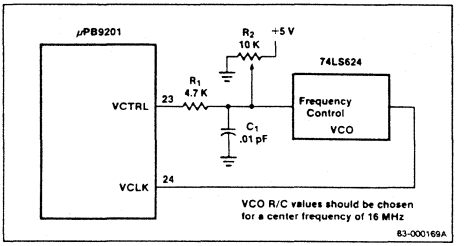
When a data bit occurs, the VCTRL pin goes first to a high state, then to a low state, and finally back to the high impedance state. The high and low states correspond to ramp-up and ramp-down respectively. The duration of ramp-up and ramp-down are determined by the position of the data bit in the read window.

If the data always arrives early, then ramp-up will have a longer period than ramp-down, causing an increase in VCO frequency. If the data arrives late, the converse is true. The integrator averages the frequency changes of the signal coming from the VCTRL pin. The values of R1 and C1 determine the time constant for the intergrator. These values can be selected so that the VCO follows the slow speed variations of the disk drive. The VCLK pin should be connected to the output of the VCO when using the external VCO. If the VCO is not used, then the VCLK pin should be connected to the 16 MHz input clock.

The μPD765A requires a fairly long delay from DRQ going high to the issuance of a READ pulse to the chip. It is usually necessary to delay the DRQ signal going to the host DMA controller so that the READ pulse does not arrive early. The FDI is capable of delaying the DRQ from the μPD765A controller for approximately 1 μs (8" drive), or 2 μs for a 5-1/4" drive. In figure 1, the DRQ from the μPD765A is connected to the DRQIN pin of the FDI and the DRQOUT is connected to the host DMA controller. DRQOUT is automatically reset when DRQIN goes low.

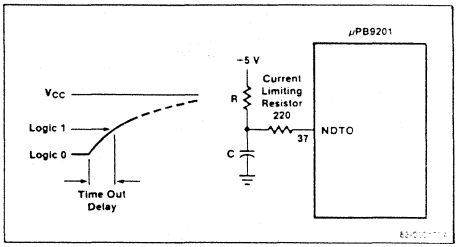
The FDI provides the necessary logic for the READY signal when the μPD765A is in mini-floppy mode. When the 8" mode is selected, the FDI passes the READY signal from the FDD interface directly to the μPD765A. When 5-1/4" mode is selected, it sets the RDY pin of the μPD765A high. If you have 5" drives that have a ready signal, it is not necessary to use this signal.

Figure 3. Using the μPB9201 with an External VCO



The FDI is capable of correcting a rare hang-up condition that occurs when there is no data coming from the disk drive to the μPD765A. When no data is coming from the FDD, the FDI waits for the time determined by the RC circuit connected to the NDTO pin. Once the time-out signal occurs, the FDI generates index pulses to the μPD765A. This causes the controller to leave the hang-up condition (see figure 4).

Figure 4. Implementing the No-Data Time Out Function



Additional Application Information

The logic diagram, shown in figure 1, illustrates a floppy disk controller as implemented on a personal computer. It is compatible with the existing controllers but has the ability to control 8" drives and single and double density as well.

Description

The μPD71065 and μPD71066 are CMOS devices that interface a floppy-disk drive (FDD) with a floppy-disk controller (FDC). The controller can be μPD765A, μPD7265, μPD72065, μPD72066, μPD7260, or one of the FD179X series.

The floppy-disk interface can operate at various data rates, including the 300-kb/s rate that results from using high-density 5-inch drives with media formatted at the standard 250-kb/s rate. Also, the μPD71065/66 generates the write clock needed by the selected controller and provides synchronous switching when changing data rates.

Features

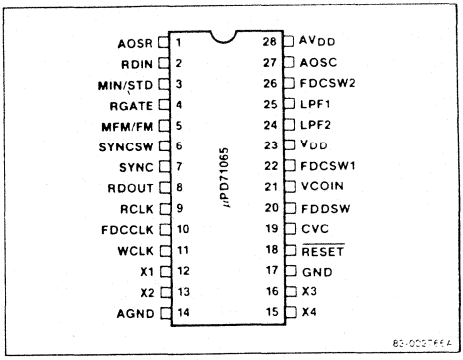
- ☐ Compatible with all industry-standard controllers
- ☐ Multiple data rates: 500/300/250/150/125 kb/s
- ☐ Internal or external sync field detection logic
- ☐ Head-loading timer for FD179X-series controllers
- ☐ No analog adjustments required
- ☐ CMOS, low power consumption
- ☐ 5-volt power supply

Ordering Information

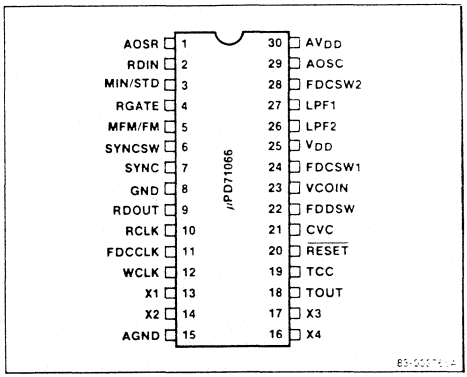
Part Number	Package	Internal Timer
μPD71065G	28-pin plastic SO	Not included
μPD71066CT	30-pin plastic shrink DIP	Implemented to FD179X-series controllers as head-loading timer.

Pin Configurations

28-Pin Plastic SO



30-Pin Plastic Shrink DIP



Pin Identification

Symbol	Input/Output	Function
ACOS		Capacitor connection pin for analog one-shot
AGND		Ground for analog circuits
AOSR		Resistor connection pin for analog one-shot
AV_{DD}		Power supply for analog circuits
CVC		Capacitor connection pin for VCO
FDCCLK	Output	Clock to FDC
FDCSW1	Input*	FDC selection pin or timer trigger input
FDCSW2	Input*	FDC selection pin
FDDSW	Input*	Data transfer rate selection pin
GND		Ground
LPF1, LPF2	Output	Connection pins to external lowpass filter
MFM/FM	Input*	Recording density selection pin
MIN/STD	Input*	5- or 8-inch FDD selection pin
RCLK	Output	Read data sampling clock
RDOUT	Output	Read data to FDC
RGATE	Input*	Read enable/disable
RDIN	Input*	Read data from FDD
$\overline{RESET}$	Input*	System reset
SYNC	Input*	External PLL gain selection
SYNCSW	Input*	Determines whether gain selection is internal or external
TCC		External RC time constant connection to internal timer (μPD71066)
TOUT	Output	Timer signal (μPD71066)
VCOIN	Input	External lowpass filter output to internal VCO
V_{DD}		+5-volt power supply
WCLK	Output	Write clock to FDC
X1, X2		Connection pins for 16-MHz crystal (X1, X2) or external clock input (X1)
X3, X4		Connection pins for 19.2-MHz crystal (X3, X4) or external clock input (X3)

*Input pin has an on-chip pull-up resistor

Pin Functions

The following paragraphs supplement the brief descriptions of certain pins in the preceding table. Pin symbols are in alphabetical order.

FDCSW1 and FDCSW2. The μPD71065/66 is configured for the applicable FDC by applying logic levels L and H (or open) to these pins.

FDCSW1	FDCSW2	Floppy-Disk Controller
Open or H	Open or H	μPD765A/7265
L	Open or H	μPD7260
*	L	FD179X series

* FDCSW1 is the trigger input to the timer circuit when FDCSW2 is low.

FDDSW. The logic level applied to this pin selects the data transfer rate of the FDD.

FDDSW	Data Transfer Rate
Open or H	500/250/125 kb/s
L	500/250/300/150 kb/s

MFM/FM Pin. The logic level applied to this pin and the FDCSW2 pin selects the modulation type. Double-density and single-density recording use MFM (modified FM) and FM modulation, respectively.

FDCSW2	MFM/FM	Modulation
H	H	MFM
H	L	FM
L	H	FM
L	L	MFM

MIN/STD. Logic level L on this pin selects a 5-inch FDD. An open or H selects an 8-inch FDD.

RDIN. This is a composite read data and clock signal input from the FDD.

RDOUT. The read data output from this pin is synchronized with the read clock (RCLK) derived from the RDIN composite signal.

RGATE. In conjuction with FDCSW2, RGATE enables or disables the read operation that is sent from the FDC.

FDCSW2	RGATE	Read Operation
H	H	Enable
H	L	Disable
L	H	Disable
L	L	Enable

SYNC and SYNCSW. The PLL gain is determined by the intput signal at the SYNC pin and the logic levels at the FDCSW1 and SYNCSW pins.

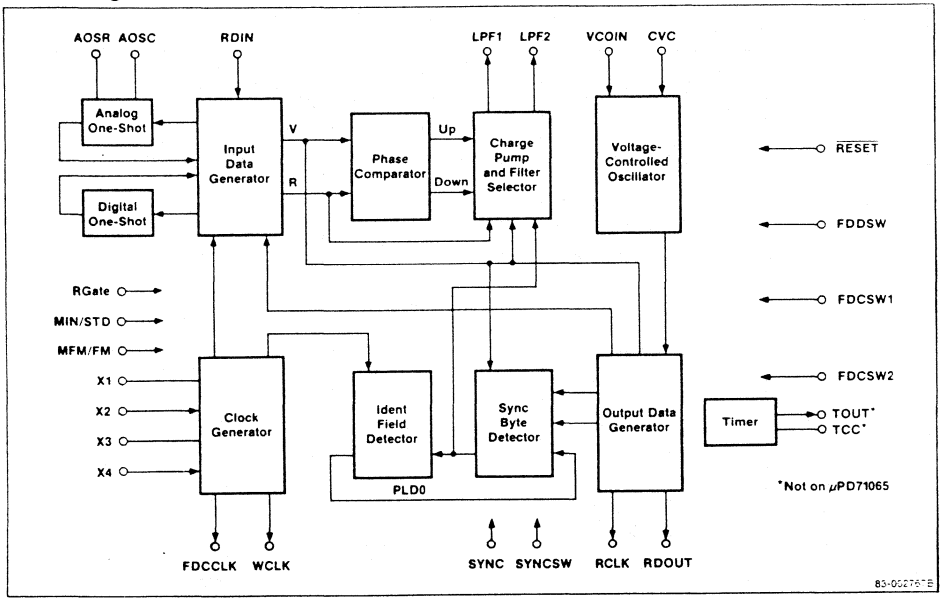
FDCSW1	SYNCSW	SYNC	PLL Gain
Open or H	Open or H	H (1)	Low
		L (1)	High
	L	H (2)	Low
		L (2)	High

Note:

(1) Input signal at SYNC is the PLL gain selection signal between the ID and DATA fields.

(2) Input signal at SYNC Is the SYNC field detection signal from the FDC.

Block Diagram



Functions of the block diagram components are explained below.

Clock Generator. Using both 16-MHz and 19.2-MHz oscillators, outputs clock signals corresponding to the mode used to the FDCCLK and WCLK pins.

Input Data Generator. According to the input data, generates the R and V signals to be input to the phase comparator. In addition to this, the input data generator determines whether the analog one-shot circuit or the digital one-shot circuit is used.

Charge Pump and Filter Selector. According to the PLL (phase-locked loop) gain selection signal, enables or disables the LPF2 side charge pump to control the PLL gain.

Output Data Generator. Generates the window signal (RCLK) and read data signal (RDOUT) depending on the mode and FDC to be used.

Sync Byte Detector. Detects the sync field within 16 to 20 pulses regardless of FM or MFM mode.

Ident Field Detector. Determines whether the sync field detected by the sync byte detector is ID or DATA field and sets the PLL gain.

Basic External Circuit

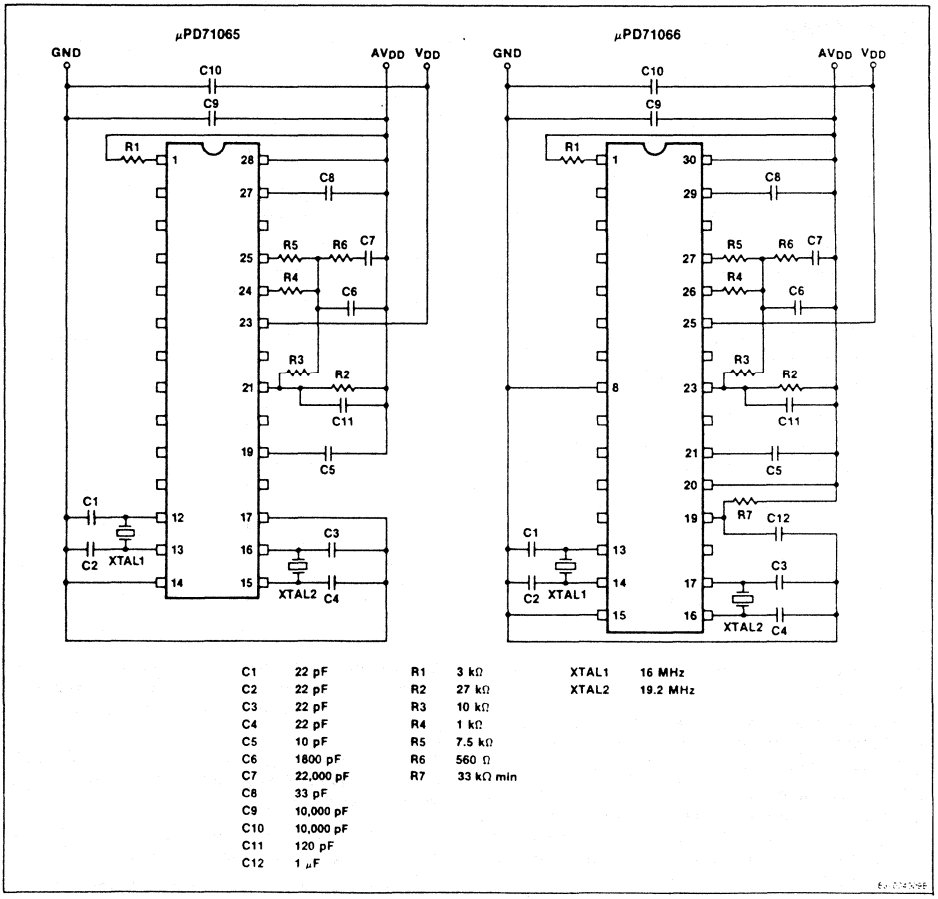
Figure 1 shows the basic external circuit including the lowpass filter and crystals. The data transfer rate is selected by strapping pins FDDSW, MIN/STD, and MFM/FM to L (low) or open (high). See table 1.

The VCO frequency and the phase delay between RDIN and RDOUT can be optimized by adjusting resistors R2 and R1, respectively.

VCO Frequency

For this procedure, the data transfer rate is undefined. Strap RGATE to H and RDIN to L. Adjust resistor R2 to set the VCO frequency at the RCLK pin to the same numerical value as the data transfer rate; for example, 500 kHz and 500 kb/s.

Figure 1. Basic External Circuit



C1	22 pF	R1	3 kΩ	XTAL1	16 MHz
C2	22 pF	R2	27 kΩ	XTAL2	19.2 MHz
C3	22 pF	R3	10 kΩ		
C4	22 pF	R4	1 kΩ		
C5	10 pF	R5	7.5 kΩ		
C6	1800 pF	R6	560 Ω		
C7	22,000 pF	R7	33 kΩ min		
C8	33 pF				
C9	10,000 pF				
C10	10,000 pF				
C11	120 pF				
C12	1 μF				

Data Read Phase Delay

For this procedure, set the data transfer rate to 500 kb/s, set the RDIN signal to a 2-μs cycle time, and strap RGATE to H. Adjust resistor R1 to set the value of t_{STW} (figure 2) to 950 ns.

Figure 2. Read Data Timing Diagram

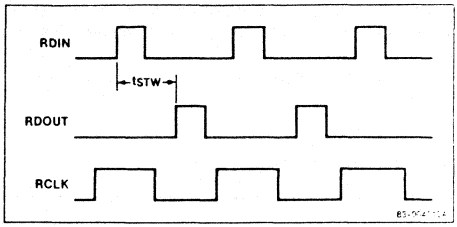


Table 1. Data Transfer Rate Selection

Floppy-Disk Controllers	Data Transfer Rate (kb/s)	Clock Output Frequencies from μPD71065/71066			Selection Pins (Note 1)		
		FDCCLK (MHz)	RCLK (kHz)	WCLK (kHz)	FDDSW	MIN/STD	MFM/FM
μPD765A, μPD7265, μPD72065, μPD72066 (Note 2)	250	4	250	500	Open	Open	Open
	125	4	125	250	Open	Open	L
	500	8	500	1 MHz	Open	L	Open
	250	8	250	500	Open	L	L
	300	4.8	300	600	L	Open	Open
	150	4.8	150	300	L	Open	L
	500	8	500	1 MHz	L	L	Open
	250	8	250	500	L	L	L
μPD7260 (Note 3)	250	4	500	500	Open	Open	Open
	125	4	250	250	Open	Open	L
	500	8	1 MHz	1 MHz	Open	L	Open
	250	8	500	500	Open	L	L
	300	4.8	600	600	L	Open	Open
	150	4.8	300	300	L	Open	L
	500	8	1 MHz	1 MHz	L	L	Open
	250	8	500	500	L	L	L
FD179X Series (Note 4)	250	1	250	500	Open	Open	L
	125	1	125	250	Open	Open	Open
	500	2	500	1 MHz	Open	L	L
	250	2	250	500	Open	L	Open
	300	1.2	300	600	L	Open	L
	150	1.2	150	300	L	Open	Open
	500	2	500	1 MHz	L	L	L
	250	2	250	500	L	L	Open

Note:

(1) Selection pin states: L = low; Open = open or H (high)

(2) μPD765A/7265/72065/72066:
FDCSW1 and FDCSW2 = Open

(3) μPD7260:
FDCSW1 = L and FDCSW2 = Open.
FDCLK clock is not used

(4) FD179X Series:
FDCSW1 = Don't care and FDCSW2 = L.
WCLK clock is not used.

Electrical Characteristics

Figures 3 through 8 are test circuits for verifying certain parameters in the dc and ac characteristics tables.

Absolute Maximum Ratings

$T_A = +25°C$

Power supply voltage, V_{DD}	−0.3 to +6 V
Input voltage, V_I	−0.3 to V_{DD} + 0.3 V
Output voltage, V_O	−0.3 to V_{DD} + 0.3 V
Operation temperature, T_{OPT}	−10 to +70°C
Storage temperature, T_{STG}	−40 to +125°C

DC Characteristics

$T_A = -10$ to $+70°C$; $V_{DD} = +5$ V ±10%

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage, low	V_{IL}	−0.3		0.8	V	
Input voltage, high	V_{IH}	2.2		V_{DD} + 0.3	V	
Output voltage, low	V_{OL}			0.45	V	$I_{OL} = 2$ mA
Output voltage, high	V_{OH}	0.7 V_{DD}		V_{DD}	V	$I_{OH} = -200$ μA
Clock input level	$V_{Kp\text{-}p}$	1		V_{DD}	V	
Input leakage current, low	I_{LIL}	−150		−50	μA	$V_I = 0$ V
Input leakage current, high	I_{LIH}	−10		+10	μA	$V_I = V_{DD}$
Output leakage current, low	I_{LOL}	−10			μA	$V_O = 0.45$ V
Output leakage current, high	I_{LOH}			+10	μA	$V_O = V_{DD}$
Power supply current	I_{DD}			25	mA	XTAL: 16 MHz, 19.2 MHz
				20	mA	XTAL: 16 MHz

AC Characteristics

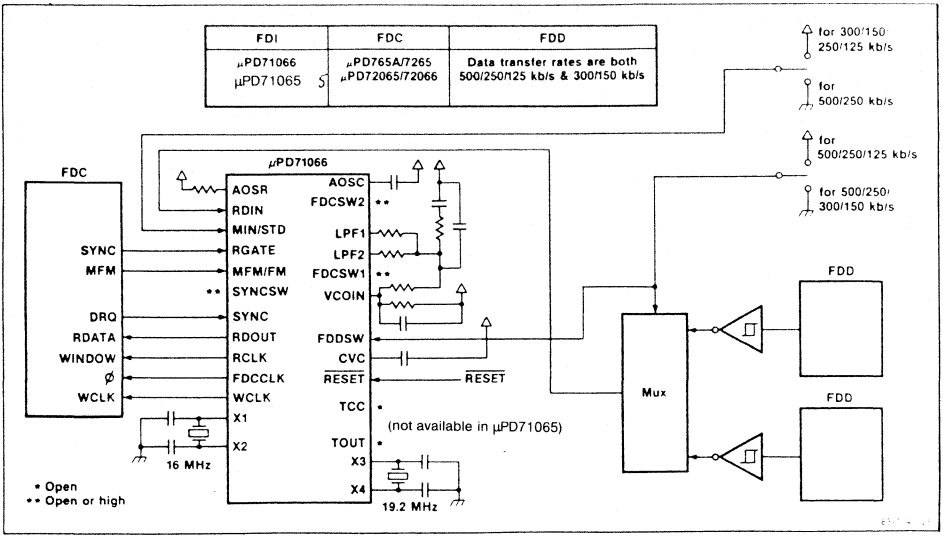
$T_A = -10$ to $+70°C$; $V_{DD} = +5$ V ±10%

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Rise time	t_R	0		20	ns	
Fall time	t_F	0		20	ns	
RDOUT setup time to RCLK ↑	t_{SRR}	40			ns	For μPD7260
CLK high/low level width	t_{KK}	20			ns	
VCO oscillation frequency	f_o			8	MHz	$V_F = V_{DD}$
VCO free-run frequency	f_i	3.6	4	4.4	MHz	FDDSW = H, V_F = open
		2.1	2.4	2.7	MHz	FDDSW = L, V_F = open
VCO control voltage sensitivity	K_V	2.5	3.5	4.6	MHz/V	$\lvert(V_{DD}/2) - V_F\rvert \leq 0.5$ V
K_V voltage coefficient	$\Delta K_V/V_{DD}$	−1	−19	−22	%/V	
f_i power supply voltage coefficient	$\Delta f_i/V_{DD}$	0		5	%/V	
f_i temperature coefficient	$\Delta f_i/T_A$	0	−500	−1000	ppm/°C	
Phase detect sensitivity	K_P	0.7	0.8	0.9	V/rad	
RCLK jitter	t_j	0	30	50	ns	500-kb/s mode
RDIN ↑ to RDOUT ↑ delay time	t_{DRR}	900	950	1000	ns	
Capture range (Note 1)	f_{CAP}	537		427	kHz	500-kb/s mode
		286		213	kHz	250-kb/s mode
		143		107	kHz	125-kb/s mode
		343		256	kHz	300-kb/s mode
		172		128	kHz	150-kb/s mode

Note:

(1) The frequencies in the Max and Min columns are the lower and upper limits, respectively, of the capture range. For example, in the 500-kb/s mode, the capture range is from 427 kHz (or lower) to 537 kHz (or higher).

Figure 3. System Example μPD71066 FDI and μPD765A FDC



Description

The μPD7260 is a single-chip disk controller that is capable of interfacing to a maximum of four floppy or hard disks in any combination. The chip utilizes the ST-506 defacto standard for the Winchester disks and is compatible with 8-inch, 5-1/4-inch and 3-1/2-inch floppy disks. The μPD7260 is based on the μPD7261A architecture, but with changes to enhance performance and flexibility. The μPD7260 can generate both IBM- and ECMA-compatible floppy disks and hard disks with the standard format. ECC and CRC capabilities along with many high-level commands provide excellent system throughput, and the single-chip design provides for efficient board space utilization.

Features

- ☐ Hard and floppy disk interface
- ☐ Controls four drives (any combination) simultaneously
- ☐ Programmable track format
- ☐ Transfer rate 6 MHz maximum
- ☐ 16 high-level disk commands
- ☐ Parallel seek capability
- ☐ Multi-sector, -track, -cylinder read/write capability
- ☐ Implied seek function
- ☐ CRC error detection
- ☐ ECC error detection and correction
- ☐ DMA data transfer
- ☐ Single +5 volt supply
- ☐ NMOS 40-pin ceramic DIP

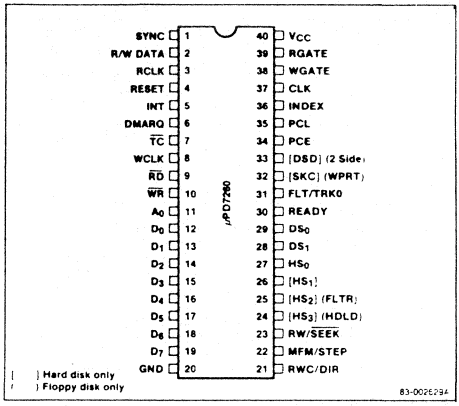
μPD7260 Commands

Check	Sense Intr. Status
Detect Error	Sense Status
Read Data	Specify1
Read Diagnostic	Specify2
Read ID	Verify Data
Recalibrate	Verify ID
Scan	Write Data
Seek	Write Format

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD7260D	40-pin ceramic DIP	12 MHz

Pin Configuration



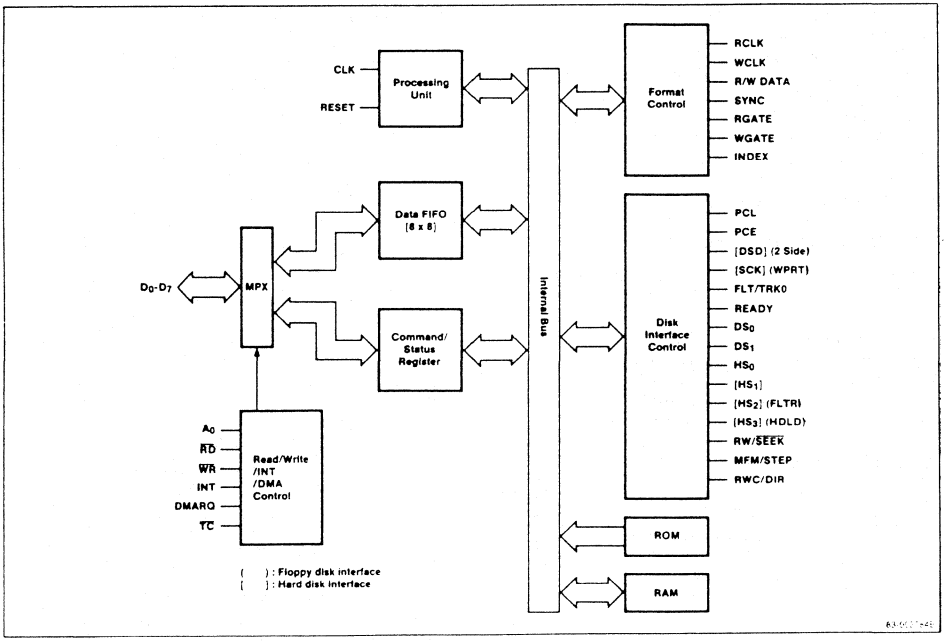
Pin Identification

No.	Symbol	Function
1	SYNC	PLL synchronization output
2	R/W DATA	Read data input or write data output
3	RCLK	Read clock input
4	RESET	System reset input from host computer
5	INT	Interrupt request output
6	DMARQ	DMA request output
7	$\overline{TC}$	Terminal count input from DMA
8	WCLK	Write clock input
9	$\overline{RD}$	Host computer read control input
10	$\overline{WR}$	Host computer write control input
11	A_0	Status/command register or FIFO select pin
12-19	D_0-D_7	System data bus connections
20	GND	System ground
21	RWC/DIR	If RW/$\overline{SEEK}$ = 1, outputs read/write current decrease signal. If RW/$\overline{SEEK}$ = 0, outputs the direction RW head is to move.
22	MFM/STEP	If RW/$\overline{SEEK}$ = 1, outputs MFM signal to VCO circuit. If RW/$\overline{SEEK}$ = 0, outputs STEP signal to move RW head.
23	RW/$\overline{SEEK}$	Output signal that specifies function of some multiplexed signals

Pin Identification (cont)

No.	Symbol	Function
24	[HS_3] (HDLD)	For hard disk, head select 3 output. For floppy disk, head load output.
25	[HS_2] (FLTR)	For hard disk, head select 2 output. For floppy disk, output to clear drive fault state.
26	[HS_1]	Head select output to disk drive.
27	HS_0	Head select output to disk drive.
28-29	DS_1-DS_0	Drive select outputs.
30	READY	Ready input from disk drive.
31	FLT/TRK0	If RW/$\overline{SEEK}$ = 1, inputs a fault flag from the disk drive. If RW/$\overline{SEEK}$ = 0, inputs a signal indicating R/W head is over cylinder zero.
32	[SKC] (WPRT)	Seek complete input from hard disk drive, or write protected input from floppy disk drive.
33	[DSD] (2 Side)	Drive selected input from hard disk drive, or double-sided disk input from floppy disk drive.
34-35	PCE, PCL	Precompensation early/late output to disk drive
36	INDEX	Index hole detect input from disk drive
37	CLK	System clock input from host computer
38	WGATE	Write gate output to disk drive
39	RGATE	Read gate output to disk drive
40	V_{CC}	+5 V (typical)

Block Diagram



2. Disk Command List

Command	Phase	R/W		A0	Hard disk D7 — D0	Floppy Disk D7 — D0	Remarks
SPECIFY1	C	W	1	0	MODE	Same as left.	
			2		HESN		
			3		←HEHN→ 0 ←HDTL→		
			4		FESN		
			5		HGPL2		
			6		HCOH		
			7		0000← FWRT →		
				1	0 0 1 0 0 000		
	R	R		1	STR		
SPECIFY2	C	W	1	0	← HNSR → 0 HBSR	Same as left.	FGPL2 can be omitted.
			2		HRWCH		
			3		HRWCL		
			4		FRWC		
			5		←FNSR→ ← HST →		
			6		HLT		
			7		HUT		
			8		FGPL2		
				1	0 0 1 0 1 000		
	R	R		1	STR		
RECALI-BRATE	C	W	1	0	SNLH	SNLH	SNLH,L can be omitted.
			2		SNLL	SNLL	
				1	01010 0 DS1 DS0	0101 HL DS1 DS0	
	E	-			-	-	Recalibrate
	R	R		1	STR	STR	
			1	0	IST	IST	
SEEK	C	W	1	0	PCNH	PCNH	
			2		PCNL	PCNL	
				1	0110 BS0DS1 DS0	01100 HL DS1 DS0	
	E	-			-	-	Seek
	R	R		1	STR	STR	
			1	0	IST	IST	
WRITE FORMAT	C	W	1	0	0000 ← PHN →	0000000 PHN	
			2		SCT	SCT	
			3		DPAT	DPAT	
			4		HGPL1	FGPL3	
			5		HGPL3	00000 ← FDTL →	
				1	011100DS1 DS0	0111 EF MF DS1 DS0	
	E	W		0			Transfers IDs (SCT x 4 bytes) of the sectors on a track.
	R	R		1	STR	STR	
			1	0	EST	EST	
			2		SCT	SCT	

Command	Phase	R/W		A0	Hard disk D7 ——— D0	Floppy Disk D7 ——— D0	Remarks
VERIFY ID	C	W	1	0	0000 ← PHN →	0000000 PHN	
			2		SCT	SCT	
			3		-	00000 ← FDTL →	
				1	100000 DS1 DS0	100000MF DS1 DS0	
	E	W		0			Compares IDs.
	R	R		1	STR	STR	
			1	0	EST	EST	
			2		SCT	SCT	
READ ID	C	W	1	0	0000 ← PHN →	0000000 PHN	LCNH is omitted if IM=0.
			2		SCT	SCT	
			3		LCNH	00000 ← FDTL →	
				1	1001 1M0DS1 DS0	1001 1M DS1 DS0	
	E	R		0			Transfers ID.
	R	R		1	STR	STR	
			1	0	EST	EST	
			2		SCT	SCT	
READ DIAGNOSTIC	C	W	1	0	0000 ← PHN →	0000000 PHN	
			2		SCT	SCT	
			3		-	00000 ← FDTL →	
				1	101000 DS1 DS0	10100 MF DS1 DS0	
	E	R		0			Transfers data.
	R	R		1	STR	STR	
			1	0	EST	EST	
			2		SCT	SCT	
SENSE UNIT STATUS	C	W		1	001100 DS1 DS0		
	R	R		1	STR		
			1	0	UST	Same as left.	
			2		PCNH		
			3		PCNL		
SENSE INTERRUPT STATUS	C	W		1	00010000		
	R	R		1	STR		
			1	0	IST		
READ DATA	C	W	1	0	← ISO → ← PHN →	← ISO → SK00PHN	FESN is Omissible.
			2		LCNH	LCN	
			3		LCNL	0000000 LHN	
			4		0000 ⟵ LHN ⟶	LSN	
			5		LSN	00000 ⟵ FDTL ⟶	
			6		SCTH	SCTH	
			7		SCTL	SCTL	
			8		-	FESN	
				1	1011IB0DS1 DS0	1011 DAMF DS1 DS0	

Command	Phase	R/W		A0	Hard disk D7 — D0	Floppy Disk D7 — D0	Remarks
READ DATA (Cont'd)	E	R		0			Transfer data.
	R	R		1	STR	STR	The ID of the sector next to the sector where the command execution was completed successfully; or the ID of the sector where the command execution aborted.
			1		EST	EST	
			2		← ISO → ← PHN →	← ISO → SK00PHN	
			3		LCNH	LCN	
			4		LCNL	0000000 LHN	
			5		0000 ← LHN →	LSN	
			6		LSN	00000 ← FDTL →	
			7		SCTH	SCTH	
			8	0	SCTL	SCTL	
CHECK	C	W	1	0	← ISO → ← PHN →	← ISO → SK00PHN	Same as READ DATA.
			2		LCNH	LCN	
			3		LCNL	0000000 LHN	
			4		0000 ← LHN →	LSN	
			5		LSN	00000 ← FDTL →	
			6		SCTH	SCTH	
			7		SCTL	SCTL	
			8		-	FESN	
				1	1100 IBxDS1 DS0	1100 DAMF DS1 DS0	
	E	-			-	-	Data check
	R	R		1	STR	STR	Same as READ DATA.
			1		EST	EST	
			2		← ISO → ← PHN →	← ISO → SK00 PHN	
			3		LCNH	LCN	
			4		LCNL	0000000 LHN	
			5	0	0000 ← LHN →	LSN	
			6		LSN	00000 ← FDTL →	
			7		SCTH	SCTH	
			8		SCTL	SCTL	

Command	Phase	R/W		A0	Hard disk D7 — D0	Floppy Disk D7 — D0	Remarks
SCAN	C	W	1	0	← ISO → ← PHN →	← ISO → SK00PHN	Same as READ DATA.
			2		LCNH	LCN	
			3		LCNL	0000000 LHN	
			4		0000 ← LHN →	LSN	
			5		LSN	00000 ← FDTL →	
			6		SCTH	SCTH	
			7		SCTL	SCTL	
			8		-	FESN	
				1	1101 IB0DS1 DS0	1101 DAMF DS1 DS0	
	E	W		0			Compares data.
	R	R		1	STR	STR	Last sector to be compared. For NCI, however, the ID of the sector next to the last sector to be compared.
			1	0	EST	EST	
			2		← ISO → ← PHN →	← ISO → SK00 PHN	
			3		LCNH	LCN	
			4		LCNL	0000000 LHN	
			5		0000 ← LHN →	LSN	
			6		LSN	00000 ← FDTL →	
			7		SCTH	SCTH	
			8		SCTL	SCTL	
VERIFY DATA	C	W	1	0	← ISO → ← PHN →	← ISO → SK00PHN	Same as READ DATA.
			2		LCNH	LCN	
			3		LCNL	0000000 LHN	
			4		0000 ← LHN →	LSN	
			5		LSN	00000 ← FDTL →	
			6		SCTH	SCTH	
			7		SCTL	SCTL	
			8		-	FESN	
				1	1110 IB0DS1 DS0	1110 DAMF DS1 DS0	
	E	W		0			Compares data.
	R	R		1	STR	STR	Same as READ DATA.
			1	0	EST	EST	
			2		← ISO → ← PHN →	← ISO → SK00 PHN	
			3		LCNH	LCN	
			4		LCNL	0000000 LHN	
			5		0000 ← LHN →	LSN	
			6		LSN	00000 ← FDTL →	
			7		SCTH	SCTH	
			8		SCTL	SCTL	

Command	Phase	R/W		A0	Hard disk D7 — D0	Floppy Disk D7 — D0	Remarks
WRITE DATA	C	W	1	0	← ISO → ← PHN →	← ISO → SK00PHN	Same as READ DATA.
			2		LCNH	LCN	
			3		LCNL	0000000 LHN	
			4		0000 ← LHN →	LSN	
			5		LSN	00000 ← FDTL →	
			6		SCTH	SCTH	
			7		SCTL	SCTL	
			8		-	FESN	
				1	1111 IB0DS1 DS0	1111 DAMF DS1 DS0	
	E	W		0			Transfers data.
	R	R		1	STR	STR	Same as READ DATA.
			1	0	EST	EST	
			2		← ISO → ← PHN →	← ISO → SK00 PHN	
			3		LCNH	LCN	
			4		LCNL	0000000 LHN	
			5		0000 ← LHN →	LSN	
			6		LSN	00000 ← FDTL →	
			7		SCTH	SCTH	
			8		SCTL	SCTL	
DETECT ERROR	C	W		1	010000 DS1 DS0		
	R	R		1	STR		
			1	0	EAOH		
			2		EAOL		
			3		EPAT1		
			4		EPAT2 .		
			5		EPAT3		

3. ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Parameter	Symbol	Test Conditions	Ratings	Units
Power Supply Voltage	V_{CC}		-0.5 to +7.0	V
Input Voltage	V_I		-0.5 to +7.0	V
Output Voltage	V_O		-0.5 to +7.0	V
Operating Temperature	T_{opt}		0 to +70	°C
Storage Temperature	T_{stg}		-65 to +150	°C

DC CHARACTERISTICS (Ta = 0 to +70°C, V_{CC} = +5.0V ± 10%)

Parameter	Symbol	Test Conditions	MIN	TYP	MAX	Units
Input Low Voltage	V_{IL1}	Except CLK, RCLK, WCLK	-0.5		+0.8	V
	V_{IL2}	CLK, RCLK, WCLK	-0.5		+0.6	V
Input High Voltage	V_{IH1}	Except CLK, RCLK, WCLK	+2.2		Vcc+0.5	V
	V_{IH2}	CLK, RCLK, WCLK	+3.3		Vcc+0.5	V
Output Voltage Low	V_{OL}	I_{OL} = +2.0mA			+0.45	V
Output Voltage High	V_{OH1}	I_{OH} = -100uA, Except Pin 21-29,34	+2.4			V
	V_{OH2}	I_{OH} = -50uA Pin 21-29,34	+2.4			V
Input Leakage Current	I_{LI1}	V_I = 0.45V to Vcc Except Pin 30-34			±10	uA
	I_{LI2}	V_I = 0.45V to Vcc Pin 30-33			-500	uA
Output Leakage Current	I_{LO}	V_O = 0.45V to Vcc			±30	uA
Supply Current	I_{CC}			250	320	mA

CAPACITANCE (Ta = 25°C, Vcc = GND = 0V)

Parameter	Symbol	Test Conditions	MIN	TYP	MAX	Units
Input Capacitance	C_I	f = 1MHz Unmeasured pin returned to 0V			15	pF
Output Capacitance	C_O				15	pF
I/O Capacitance	C_{IO}				20	pF

AC CHARACTERISTICS (Ta = 0°C to +70°C, V_{CC} = +5.0 + 10%)

Main System side:

Parameter	Symbol	Test Conditions	MIN	MAX	Units
CLK Cycle Time	t_{CY}		83		ns
CLK Active High	t_{CH}		30		ns
CLK Active Low	t_{CL}		30		ns
CLK Rise Time	t_{CR}			10	ns
CLK Fall Time	t_{CF}			10	ns
A0 Setup Time to RD	t_{AR}		0		ns
A0 Hold Time from RD	t_{RA}		0		ns
RD Pulse Width	t_{RR}		180		ns
Data Output Delay from A0	t_{AD}			150	ns
Data Output Delay from RD	t_{RD}			130	ns
Data Float Delay from RD	t_{RDF}		0	100	ns
A0 Setup Time to WR	t_{AW}		0		ns
A0 Hold Time from WR	t_{WA}		0		ns
WR Pulse Width	t_{WW}		190		ns
Data Setup Time to WR	t_{DW}		100		ns
Data Hold Time from WR	t_{WD}		5		ns
Recovery Time from RD, WR	t_{RV}		160		ns
INT Delay Time from WR	t_{WI}			200	ns
DREQ Delay Time from WR	t_{WRQ}			250	ns
DREQ Delay Time from RD	t_{RRQ1}	*1		250	ns
DREQ Delay Time from RD	t_{RRQ2}	*2		150	ns
TC Pulse Width	t_{TC}		100		ns
RESET Pulse Width	t_{RES}		100		t_{CY}

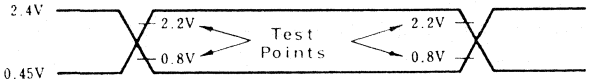
*1 : During Disk Read Operation
*2 : After Disk Read Operation

Disk Drive Interface side:

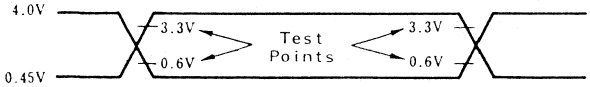
Parameter	Symbol	Test Conditions		MIN	MAX	Units
RCLK, WCLK Cycle Time	t_{RWCY}			83	5000	ns
RCLK, WCLK Pulse Width High	t_{RWCH}			30		ns
RCLK, WCLK Pulse Width Low	t_{RWCL}			30		ns
RCLK, WCLK Rise Time	t_{RWCR}				10	ns
RCLK, WCLK Fall Time	t_{RWCF}				10	ns
Data Setup Time to RCLK	t_{RDRC}			40		ns
Data Hold Time from RCLK	t_{RCRD}			5		ns
Data Output Delay from WCLK	t_{WCWD}			5	83	ns
RGATE Delay Time from RCLK	t_{RCRG}				300	ns
WGATE Delay Time from WCLK	t_{WCWG}				150	ns
PCE,PCL Delay Time from WCLK	t_{RWCPC}			5	83	ns
SYNC Delay Time from RCLK	t_{RCSY}				150	ns
INDEX Pulse Width	t_{IDXF}			8		t_{RWCY}
DS0, 1 Setup Time to STEP	t_{DSST}			4000		t_{CY}
DIR Setup Time to STEP	t_{DIST}			80		t_{CY}
STEP Pulse Width	t_{STEP}			69	85	t_{CY}
DS0, 1 Hold Time from STEP	t_{STDS}			2700		t_{CY}
DIR Hold Time from STEP	t_{STDI}			6600		t_{CY}
DS0, 1 Setup Time to DIR	t_{DSDI}			3900		t_{CY}
DIR Hold Time from SKC	t_{SKDI}	Hard Disk Drive		590		t_{CY}
HS0,1,2,3 Hold Time from WGATE	t_{WGHS}			3800		t_{CY}
DS0,1 Setup Time to HDLD	t_{DSHD}	Floppy Disk Drive		2100		t_{CY}
STEP Cycle Time	t_{STCY}	Hard Disk Buffered Step Mode	HBSR=1	190	290	t_{CY}
			HBSR=0	700	920	t_{CY}

AC Timing Test Points (C_L=100pF)

(Except CLK, RCLK, WCLK)

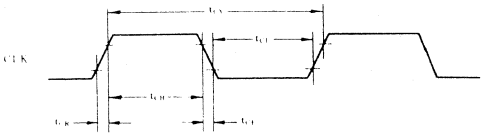


(CLK, RCLK, WCLK)

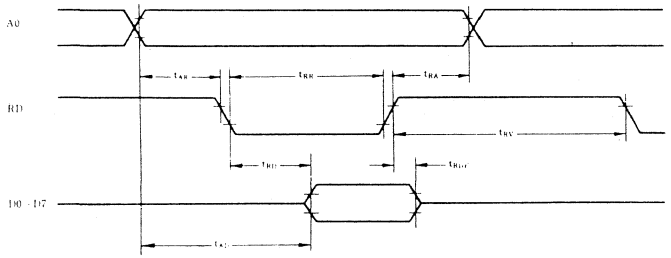


Timing Waveforms

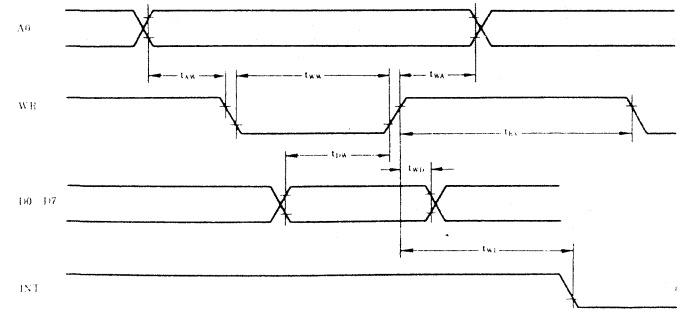
CLK Waveform



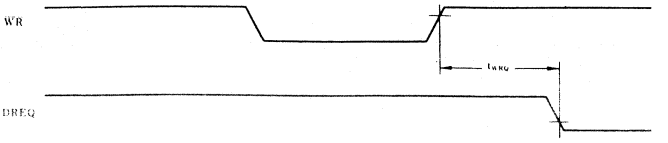
Read Timing



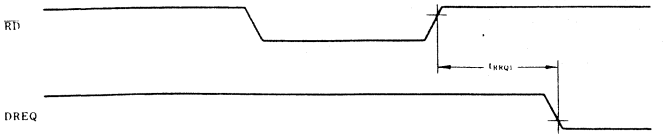
Write Timing



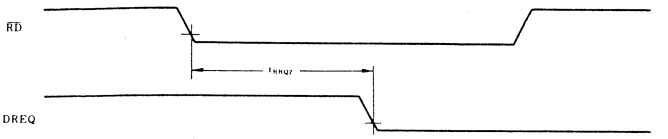
DMA Write Timing

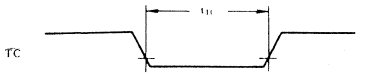


DMA Read Timing (During Disk Read Operation)

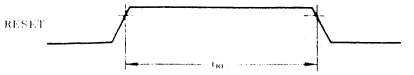


DMA Read Timing (After Disk Read Operation)

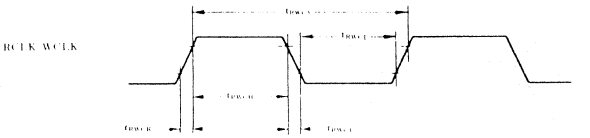




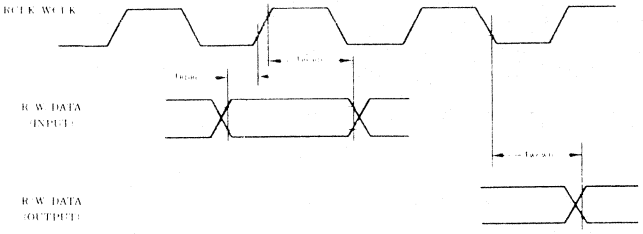
RESET Waveform



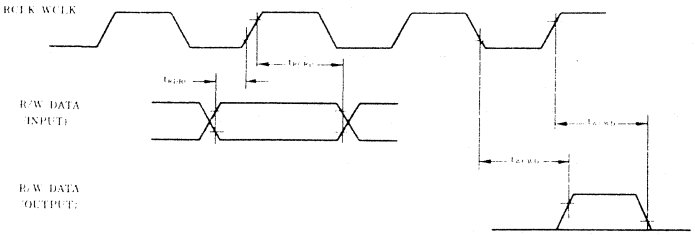
RCLK, WCLK Waveform



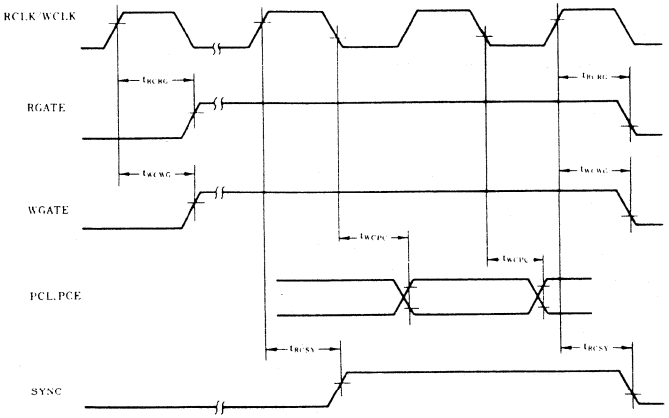
Data Read/Write Operation (MFM)



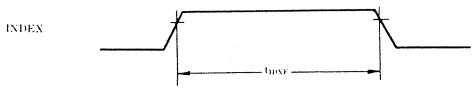
Data Read/Write Operation (FM)



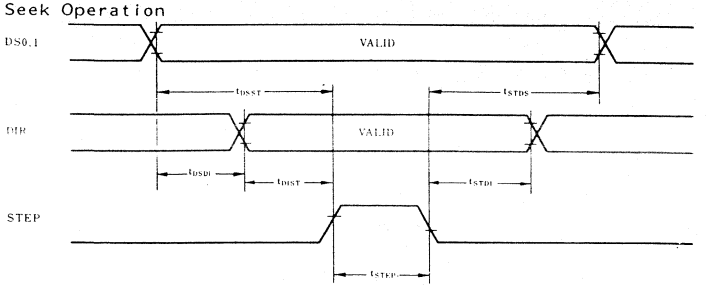
Read/Write Operation



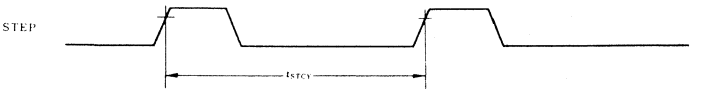
INDEX Waveform



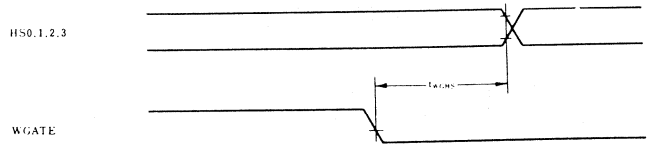
Seek Operation



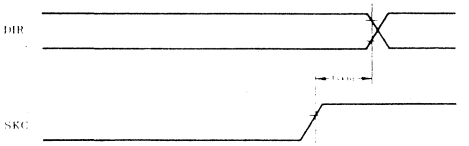
Buffered Step Mode (Hard Disk)



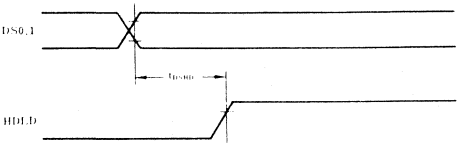
Write Operation (Hard Disk)



Seek Operation (Hard Disk)



Head Load Operation (Floppy Disk)



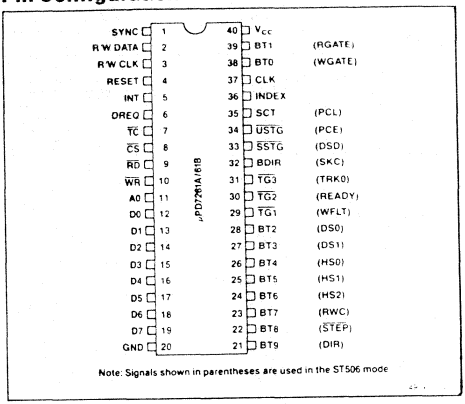
Description

The μPD7261A and μPD7261B hard-disk controllers are intelligent microprocessor peripherals designed to control a number of different types of disk drives. They are capable of supporting either hard-sector or soft-sector disks and provide all control signals that interface the controller with either SMD disk interfaces or ST506-type drives. The sophisticated instruction set minimizes the software overhead for the host microprocessor. By using the DMA controller, the microprocessor needs only to load a few command bytes into the μPD7261A/7261B and all the data transfers associated with read, write, or format operations are done by the μPD7261A/7261B and the DMA controller. Extensive error reporting, verify commands, ECC, and CRC data error checking assure reliable controller operation. The μPD7261A/7261B provides internal address mark detection, ID verification, and CRC or ECC checking and verification. An eight-byte FIFO is used for loading command parameters and obtaining command results. This makes the structuring of software drivers a simple task. The FIFO is also used for buffering data during DMA read/write operations.

Features

- Flexible interface to various types of hard disk drives
- Programmable track format
- Controls up to 8 drives
- Parallel seek operation capability
- Multi-sector and multi-track transfer capability
- Data scan and data verify capability
- High-level commands, including:
  Read Data, Read ID, Write Data, Format, Scan Data, Verify Data, Verify ID, Check, Seek (normal or buffered), Recalibrate (normal or buffered), Read Diagnostic (SMD only), Specify, Sense Interrupt Status, Sense Unit Status, and Detect Error
- NRZ or MFM data format
- Maximum R/W CLK frequency: 18 MHz (7261B)
  12 MHz (7261A)
- Error detection and correction capability
- Simple I/O structure: compatible with most microprocessors
- All inputs and outputs except clock pins are TTL-compatible (clock pins require pullup)
- Data transfers under DMA control
- NMOS
- Single +5 V power supply
- 40-pin dual-in-line package

Pin Configuration



Note: Signals shown in parentheses are used in the ST506 mode

Ordering Information

Device Number	Package Type	Max Freq. of Operation
μPD7261AD	40-pin ceramic DIP	12 MHz
μPD7261BD-18	40-pin ceramic DIP	18 MHz

Pin Identification

No.	Symbol	Function
Host Interface		
4	RESET	Reset input
5	INT	Interrupt request output
6	DREQ	DMA request output
7	$\overline{TC}$	Terminal count input
8	$\overline{CS}$	Chip select input
9	$\overline{RD}$	Read strobe input
10	$\overline{WR}$	Write strobe input
11	A_0	Register select input
12–19	D_0–D_7	Data I/O bus
20	GND	Ground
37	CLOCK	External clock input
40	V_{CC}	+5 V power supply
SMD Interface		
1	SYNC	PLL synchronization output
2	R/W DATA	Read/write data I/O
3	R/W CLK	Read/write clock input
21–28, 38, 39	BT9–BT0	Bit 9–0 outputs / Status inputs

Pin Identification (cont)

No.	Symbol	Function
SMD Interface (cont)		
29-31	$\overline{TG1}$-$\overline{TG3}$	Tag 1-3 output
32	BDIR	Bit direction output
33	$\overline{SSTG}$	SR select tag output
34	$\overline{USTG}$	Unit select tag output
35	SCT	Sector input
36	INDEX	Sector zero input
ST506-Type Interface		
1	SYNC	PLL lock / Read clock enable output
2	R/W DATA	Read / write data I / O
3	R/W CLK	Read / write clock input
21	DIR	Direction in output
22	$\overline{STEP}$	Step pulse output
23	RWC	Reduced write current output
24-26	HS2-HS0	Head select outputs 2-0
27, 28	DS1, DS0	Drive select outputs 1, 0
29	WFLT	Write fault input
30	READY	Ready input
31	TRK0	Track zero input
32	SKC	Seek complete input
33	DSD	Drive selected input
34	PCE	Precomp early output
35	PCL	Precomp late output
36	INDEX	Index input
38	WGATE	Write gate output
39	RGATE	Read gate output

Pin Functions—Host Interface

RESET (Reset)

When the RESET input is pulled high, it forces the device into an idle state. The device remains idle until a command is issued to the system.

INT (Interrupt Request)

The μPD7261A/7261B pulls the INT output high to request an interrupt.

DREQ (DMA Request)

The μPD7261A/7261B pulls the DREQ output high to request a DMA transfer between the disk controller and the memory.

$\overline{TC}$ (Terminal Count)

The $\overline{TC}$ input goes low to signal the final DMA transfer.

$\overline{CS}$ (Chip Select)

When the $\overline{CS}$ input is low, it enables reading from or writing to the register selected by A_0.

$\overline{RD}$ (Read Strobe)

When the $\overline{RD}$ strobe is low, data is read from the selected register.

$\overline{WR}$ (Write Strobe)

When the $\overline{WR}$ input is low, data is written to the selected register.

A_0 (Register Select)

The A_0 input is connected to a non-multiplexed address bus line. When A_0 is high, it selects the command or status register. When it is low, it selects the data buffer.

D_0-D_7 (Data Bus)

D_0-D_7 are connected to the system data bus.

CLOCK (Clock)

The CLOCK input is the timing clock for the on-chip processor.

Pin Functions—SMD Interface

SYNC (PLL Synchronization)

This output goes high after the read gate signal (BT1 when $\overline{TG3} = 0$) is high and a given number of bytes (GPL2-2) has elapsed.

R/W DATA (Read/Write Data)

The R/W DATA pin outputs the write data to the drive, and inputs the read data from the drive.

R/W CLK (Read/Write Clock)

R/W CLK is the input for the read and write clocks.

BT9-BT0 (Bit 9-0)

BT9-BT0 output the bit signals, bit 9-0. The bit 9-0 outputs send cylinder and unit addresses to the drives. BT9-BT2 also act as inputs for status signals from the drives as shown in table 1.

Table 1. Bit and Control Information

No.	Bit	Control
21	BT9	Unit Selected
22	BT8	Seek End
23	BT7	Write Protected
24	BT6	
25	BT5	Unit Ready
26	BT4	On Cylinder
27	BT3	Seek Error
28	BT2	Fault

BT7-BT2 also read the device status 2 (SR7-SR2) and device type (DT7-DT2). The index and SCT pins read SR0, SR1 and DT0, DT1.

BDIR (Bit Direction)

The BDIR output determines whether pins 28-21 will output BT2-BT9 or input drive status signals.

$\overline{TG3}$-$\overline{TG1}$ (Tag 3-1)

The $\overline{TG}$ outputs define the use of the BT pins. When $\overline{TG1}$ is low, BT9-BT0 output the cylinder address. When $\overline{TG2}$ is low, BT7-BT0 select a head address. When $\overline{TG3}$ is low, BT9-BT0 output control signals for the disk drive.

$\overline{SSTG}$ (SR Select Tag)

When the $\overline{SSTG}$ output is low, BT7-BT2, INDEX and SCT will be inputting SR7-SR0 or DT7-DT0.

$\overline{USTG}$ (Unit Select Tag)

When the $\overline{USTG}$ output is low, BT4-BT2 will be outputting a unit address.

INDEX (Index)

The INDEX input goes high when the drive detects an index mark. INDEX also acts as the SR0 and DT0 input pin.

SCT (Sector)

The SCT input goes high when the drive detects a sector mark. SCT also acts as the SR1 and DT1 input pin.

Pin Functions — ST506-Type Interface

SYNC (Read Clock Enable)

SYNC indicates that a sync pattern has been detected and that synchronization has been achieved.

R/W DATA (Read/Write Data)

The R/W DATA pin outputs the write data to the drive. and inputs the read data from the drive.

R/W CLK (Read/Write Clock)

R/W CLK is the input for the read and write clocks.

DIR (Direction In)

The DIR output determines the direction the read/write head will move in when it receives a step pulse. DIR high will cause the head to move inward, DIR low will move the head outward.

$\overline{STEP}$ (Step Pulse)

$\overline{STEP}$ outputs the head step pulses.

RWC (Reduced Write Current)

The RWC output signals that the read/write head of the disk drive has selected a cylinder address larger than that specified in the SPECIFY command. This signal is used to reduce the write current.

HS2-HS0 (Head Select 2-0)

The HS2-HS0 outputs select the head. Up to 8 read/write heads can be selected per drive.

DS1, DS0 (Drive Select 1,0)

The DS1 and DS0 outputs select one of up to 4 drives.

WFLT (Write Fault)

The WFLT input detects write faults.

READY (Ready)

The READY input detects the drive's ready state.

TRK0 (Track 0)

The TRK0 input signals that the head is at track 0.

SKC (Seek Complete)

The SKC input signals that a seek is complete.

DSD (Drive Selected)

The DSD input signals that the drive is selected.

PCE (Precomp Early)

When the PCE output is high, early write precompensation is required.

PCL (Precomp Late)

When the PCL output is high, late write precompensation is required.

INDEX (Index)

The INDEX input goes high when the drive detects the index mark.

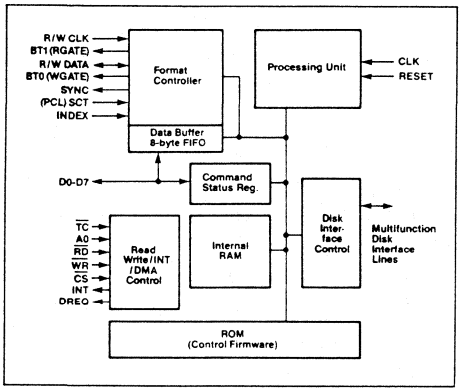
WGATE (Write Gate)

WGATE output goes high when the μPD7261A/7261B is writing data.

RGATE (Read Gate)

The RGATE output goes high when the μPD7261A/7261B is reading from the disk.

Block Diagram



Absolute Maximum Ratings

Operating temperature, T_{OPT}	0°C to +70°C
Storage temperature, T_{STG}	−65°C to +150°C
Voltage on any pin with respect to ground, V_{CC}	−0.5 to +7.0 V
Input voltage, V_I	−0.5 to +7.0 V
Output voltage, V_O	−0.5 to +7.0 V

Comment: Exposing the device to stresses above those listed in the Absolute Maximum Ratings could cause permanent damage. The device should not be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

*μPD7261B specifications are preliminary

T_A = 0 to +70°C, V_{CC} = +5.0 V ± 10% unless otherwise specified

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage low	V_{IL1}	−0.5		+0.8	V	All except CLK, R/W CLK
Input voltage low	V_{IL2}	−0.5		+0.6	V	CLK, R/W CLK
Input voltage high	V_{IH1}	+2.0		V_{CC}+0.5	V	All except CLK, R/W CLK
Input voltage high	V_{IH2}	+3.3		V_{CC}+0.5	V	CLK, R/W CLK
Output voltage low	V_{OL}			+0.45	V	I_{OL} = +2.0 mA
Output voltage high	V_{OH1}	+2.4			V	I_{OH} = −100 μA, all except pins 21-34
Output voltage high	V_{OH2}	+2.4			V	I_{OH} = −50 μA, pins 21-34
Input leakage current	I_{LI1}			±10	μA	V_{IN} = V_{CC} to 0.45 V, all except pins 21-34
Input leakage current	I_{LI2}			−500	μA	V_{IN} = V_{CC} to 0.45 V, pins 21-34
Output leakage current	I_{LO}			±10	μA	V_{OUT} = V_{CC} to 0.45 V
Supply current	I_{CC}		250	320	mA	

Capacitance

T_A = 25°C, V_{CC} = 0 V

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input capacitance	C_{IN}			15	pF	(Note 1)
Output capacitance	C_{OUT}			15	pF	(Note 1)
Input/Output capacitance	$C_{I/O}$			20	pF	(Note 1)

Note:

(1) f = 1 MHz, All unmeasured pins tied to GND.

AC Characteristics

μPD7261B specifications are preliminary.

T_A = 0°C to +70°C, V_{CC} = +5V ±10% unless otherwise specified

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Processor Interface						
Clock cycle	t_{CY}	83			ns	7261A only
		55			ns	7261B only
Clock time, low	t_{CL}	30			ns	
Clock time, high	t_{CH}	30			ns	
Clock rise time	t_{CR}			10	ns	
Clock fall time	t_{CF}			10	ns	
A_0, $\overline{CS}$ setup to $\overline{RD}$	t_{AR}	0			ns	
A_0, $\overline{CS}$ hold from $\overline{RD}$	t_{RA}	0			ns	
$\overline{RD}$ pulse width	t_{RR}	200			ns	
Data delay from $\overline{RD}$	t_{RD}			150	ns	
Output float delay	t_{RDF}	0		100	ns	
Data delay from A_0, $\overline{CS}$	t_{AD}			150	ns	
A_0, CS setup to $\overline{WR}$	t_{AW}	0			ns	
A_0, $\overline{CS}$ hold from $\overline{WR}$	t_{WA}	0			ns	
$\overline{WR}$ pulse width	t_{WW}	200			ns	
Data setup to $\overline{WR}$	t_{DW}	100			ns	
Data hold from $\overline{WR}$	t_{WD}	5			ns	
Recovery time from $\overline{RD}$, $\overline{WR}$	t_{RV}	200			ns	
Reset pulse width	t_{RES}	100			t_{CY}	
$\overline{TC}$ pulse width	t_{TC}	100			ns	
$\overline{INT}$ delay from $\overline{WR}$ ↑	t_{WI}			200	ns	
$\overline{DREQ}$ delay from $\overline{WR}$ ↑	t_{WRQ}			250	ns	
$\overline{DREQ}$ delay from $\overline{RD}$ ↑	t_{RRQ1}			250	ns	
$\overline{DREQ}$ delay from $\overline{RD}$ ↓	t_{RRQ2}			150	ns	
ST506-Type Interface						
R/W CLK cycle period	t_{RWCY}	83			ns	7261A
		55			ns	7261B
R/W CLK time, low	t_{RWCL}	30			ns	7261A
		20			ns	7261B
R/W CLK time, high	t_{RWCH}	30			ns	7261A
		20			ns	7261B

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
ST506-Type Interface (cont)						
R/W CLK rise time	t_{RWCR}			10	ns	
R/W CLK fall time	t_{RWCF}			10	ns	
R/W DATA setup to R/W CLK	t_{RDRC}	40			ns	
R/W DATA hold from R/W CLK	t_{RCRD}	5			ns	7261A
		0			ns	7261B
R/W DATA delay from R/W CLK	t_{WCWD}	35		90	ns	7261A
		0		55	ns	7261B
RGATE delay from R/W CLK	t_{RCRG}			300	ns	
WGATE delay from R/W CLK	t_{WCWG}			150	ns	
PCE / PCL delay from R/W CLK	t_{RWCPC}	35		110	ns	7261A
		0		55	ns	7261B
SYNC delay from R/W CLK	t_{RWCSY}			150	ns	
DS0, DS1 setup to $\overline{STEP}$	t_{DSST}	250			t_{CY}	Normal seek mode
DIR setup to $\overline{STEP}$	t_{DIST}	200			t_{CY}	Normal seek mode
$\overline{STEP}$ pulse width	t_{STEP}	69		85	t_{CY}	Normal seek mode
DS0, DS1 hold from $\overline{STEP}$	t_{STDS}	750			t_{CY}(1)	Normal seek mode
DIR hold from $\overline{STEP}$	t_{STDI}	750			t_{CY}(1)	Normal seek mode
DS0, DS1 hold from SKC	t_{SKDS}	100			t_{CY}(2)	Normal seek mode
DIR hold from SKC	t_{SKDI}	100			t_{CY}(2)	Normal seek mode
DS0, DS1 setup to $\overline{STEP}$	t_{DSSTB}	250			t_{CY}	Buffered seek mode
DIR setup to $\overline{STEP}$	t_{DISTB}	200			t_{CY}	Buffered seek mode
$\overline{STEP}$ pulse width	t_{STEPB}	69		85	t_{CY}	Buffered seek mode
$\overline{STEP}$ cycle period	t_{STCY}	570		660	t_{CY}	Buffered seek mode
DS0, DS1 hold from $\overline{STEP}$	t_{STDSB}	200			t_{CY}(1)	Buffered seek mode
DIR hold from $\overline{STEP}$	t_{STDIB}	200			t_{CY}(1)	Buffered seek mode

Note:

(1) Polling mode

(2) Nonpolling

(3) AC Characteristics are tested with C_L = 100 pF.

AC Characteristics (cont)

$T_A = 0°C$ to $+70°C$, $V_{CC} = +5V \pm 10\%$; $V_{SS} = 0V$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
ST506-Type Interface (cont)						
DS0, DS1 hold from SKC	t_{SKDSB}	100			$t_{CY}(2)$	Buffered seek mode
DIR hold from SKC	t_{SKDIB}	100			$t_{CY}(2)$	Buffered seek mode
Index pulse width	t_{IDXF}	8			t_{RWCY}	
SMD Interface						
R/W CLK cycle period	t_{RWCY}	83			ns	7261A
		55			ns	7261B
R/W CLK time, low	t_{RWCL}	30			ns	7261A
		20			ns	7261B
R/W CLK time, high	t_{RWCH}	30			ns	7261A
		20			ns	7261B
R/W CLK rise time	t_{RWCR}			10	ns	
R/W CLK fall time	t_{RWCF}			10	ns	
R/W DATA setup to R/W CLK	t_{RDRC}	40			ns	
R/W DATA hold from R/W CLK	t_{RCRD}	5			ns	7261A
		0			ns	7261B
R/W DATA delay from R/W CLK	t_{WCWD}	35		90	ns	7261A
		0		55	ns	7261B
BT1 delay from R/W CLK	t_{RCRG}			300	ns	
BT0 delay from R/W CLK	t_{WCWC}			150	ns	
SYNC delay from R/W CLK	t_{RWCSY}			150	ns	
$\overline{BDIR}$ setup to $\overline{USTG}$	t_{BDUT}	60			t_{CY}	Unit select operation
$\overline{BDIR}$ hold from $\overline{USTG}$	t_{UTBD}	15			t_{CY}	Unit select operation
Unit ADR setup to $\overline{USTG}$	t_{UAUT}	20		40	t_{CY}	Unit select operation
Unit ADR hold from $\overline{USTG}$	t_{UTUA}	15			t_{CY}	Unit select operation
$\overline{BDIR}$ setup to $\overline{TG1}$	t_{BDT1}	27		48	t_{CY}	Cylinder select operation
$\overline{BDIR}$ hold from $\overline{TG1}$	t_{T1BD}	60			t_{CY}	Cylinder select operation
CYL. ADR setup to $\overline{TG1}$	t_{CAT1}	27		48	t_{CY}	Cylinder select operation
CYL. ADR hold from $\overline{TG1}$	t_{T1CA}	60			t_{CY}	Cylinder select operation
$\overline{TG1}$ pulse width	t_{TG1}	24		36	t_{CY}	Cylinder select operation
$\overline{BDIR}$ setup to $\overline{TG2}$	t_{BDT2}	15			t_{CY}	Head select operation
$\overline{BDIR}$ hold from $\overline{TG2}$	t_{T2BD}	70			t_{CY}	Head select operation
HEAD ADR setup $\overline{TG2}$	t_{HAT2}	15		70	t_{CY}	Head select operation
HEAD ADR hold from $\overline{TG2}$	t_{T2HA}	70			t_{CY}	Head select operation
$\overline{TG2}$, pulse width	t_{TG2}	24		36	t_{CY}	Head select operation
$\overline{BDIR}$ setup to $\overline{TG3}$	t_{BDT3}	24			t_{CY}	(Note 4)
$\overline{BDIR}$ hold from $\overline{TG3}$	t_{T3BD}	24		36	t_{CY}	(Note 4)
$\overline{TG3}$, pulse width	t_{TG3}	56		66	t_{CY}	(Note 4)
BT2, 3, 4, 6, 7, 8 setup from $\overline{TG3}$	t_{BTT3}			56	t_{CY}	(Note 4)
BT4, 6 hold from $\overline{TG3}$	t_{T3BT1}	24			t_{CY}	(Note 4)
BT2, 3, 7, 8 hold from $\overline{TG3}$	t_{T3BT2}	75			t_{CY}	(Note 4)
$\overline{BDIR}$ delay from $\overline{SSTG}$	t_{STBD}	24			t_{CY}	(Note 5)
$\overline{BDIR}$ high time	t_{BDIR}	54		66	t_{CY}	(Note 5)
BT9 setup to $\overline{BDIR}$	t_{BTBD}	24		36	t_{CY}	(Note 5)
BT9 hold from $\overline{BDIR}$	t_{BDBT}	24		33	t_{CY}	(Note 5)
$\overline{SSTG}$ pulse width	t_{SSTG}			200	t_{CY}	(Note 5)
Index pulse width	t_{IDXH}	8			t_{RWCY}	
SCT pulse width	t_{SCT}	8			t_{RWCY}	

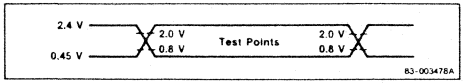
Note:

(4) RTZ, FAULT CLR, SERVO, DATA STB, control timing.

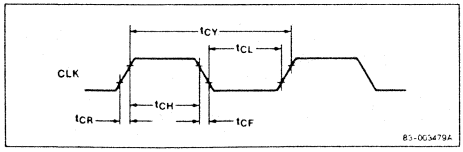
(5) Sense unit status timing.

Timing Waveforms — Host System Interface

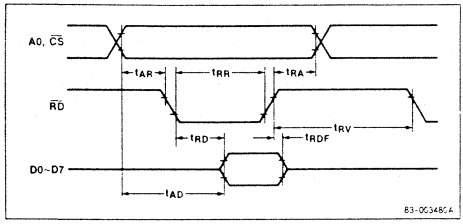
AC Test Points (Except R/W CLK, CLK)



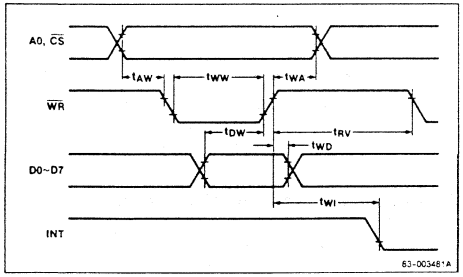
CLK Waveform



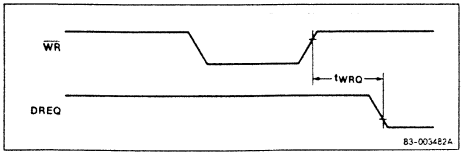
Read Timing



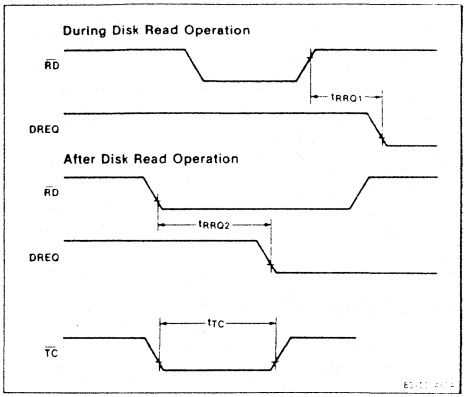
Write Timing



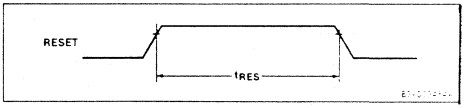
DMA Write Timing



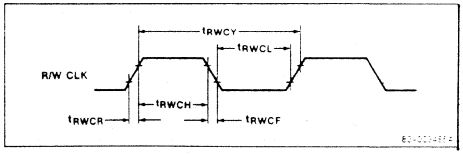
DMA Read Timing



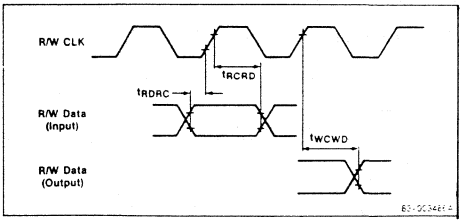
Reset Waveform



SMD Interface, R/W CLK Waveform

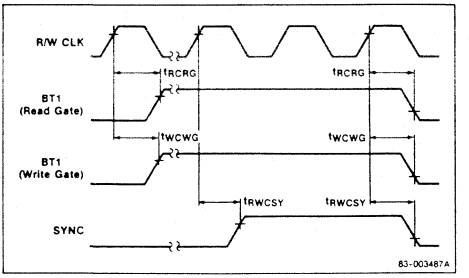


SMD Interface, Data Read/Write Timing

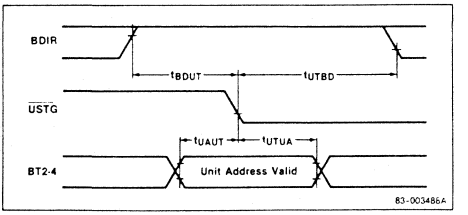


Timing Waveforms—Host System Interface (cont)

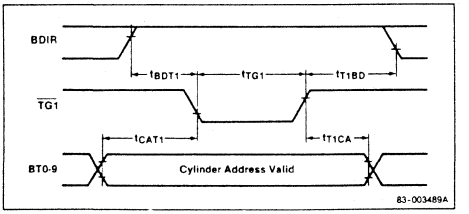
SMD Interface, Read/Write Timing



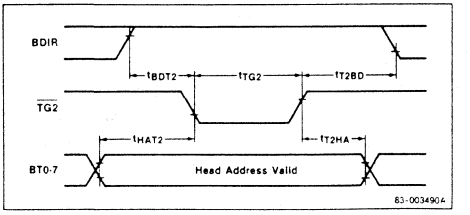
SMD Interface, Unit Select Timing



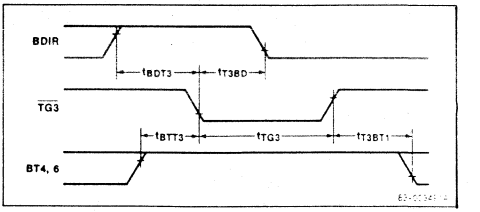
SMD Interface, Seek Timing



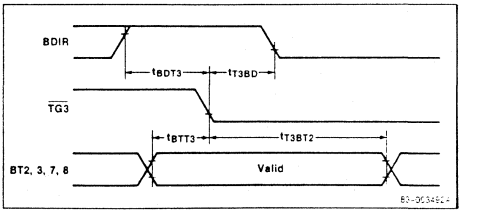
SMD Interface, Head Select Timing



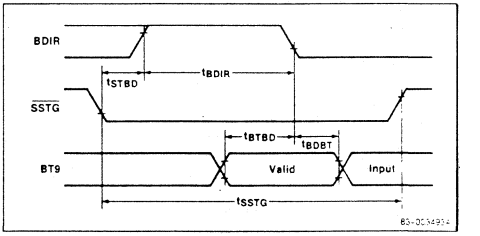
Bit Bus Timing, Fault Clear/Return-to-Zero



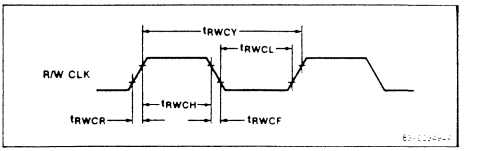
Bit Bus Timing, Servo Offset/Data Strobe



Bit Bus 9 Timing

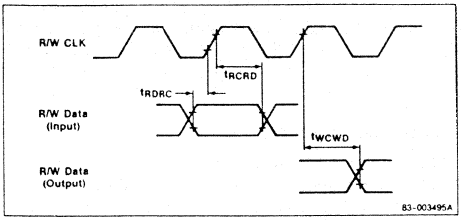


Floppy-Like Interface, R/W CLK Waveform

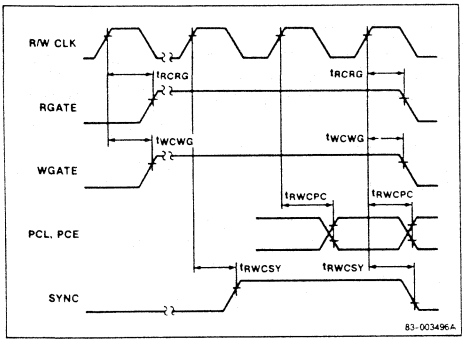


Timing Waveforms—Host System Interface (cont)

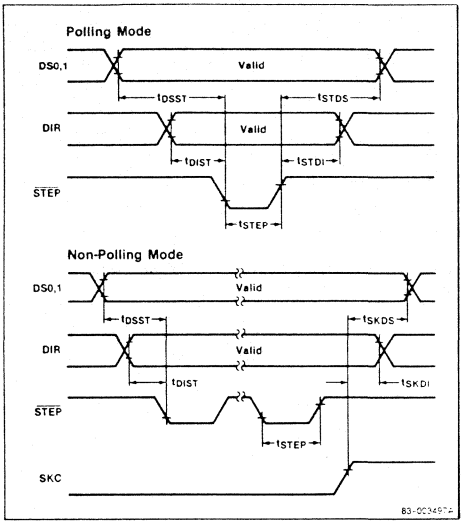
Floppy-Like Interface, Data Read/Write Operation



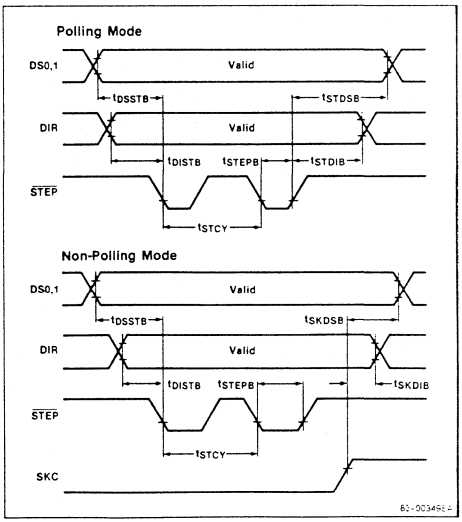
Floppy-Like Interface, Read/Write Operation



Normal Seek Operation

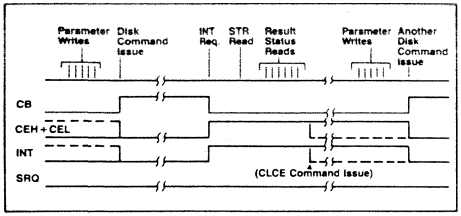


Buffered Seek Operation

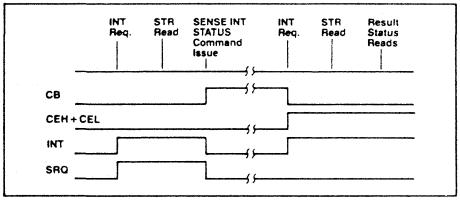


Timing Waveforms—Host System Interface (cont)

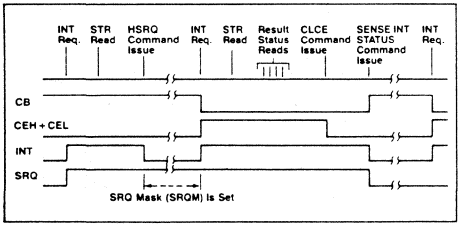
Read/Write Sequence (Disk Command Issue)



Sense Interrupt Status Request When Controller Not Busy



Sense Interrupt Status Request When Controller Busy



High-Level Commands

Specify

Allows user to select SMD or ST506-type mode data block length, ending track number, end sector number, gap length, track at which write current is reduced, ECC or CRC function, choice of polynomial, and polling mode enable.

Sense Interrupt Status

When a change of disk status occurs, the HDC will interrupt the host CPU. This command will reveal the cause of interrupt, such as seek end, disk ready change, seek error, or equipment check. The disk unit address is also supplied.

Sense Unit Status

The host CPU specifies the drive numbers and the HDC will return information such as write fault, ready, track 000, seek complete and drive selected, or for SMD units fault, seek error, on cylinder, unit ready, AM found, write protected, seek end, and unit selected.

Detect Error

Used after a read operation where ECC has been employed. The detect error command supplies the information needed to allow the host CPU to execute an error correction routine. (Only allowed when an actual correctable error is detected by the HDC.)

Recalibrate

Returns the disk drive heads to the home position or track 000 position. Has four modes of operation: SMD, normal, buffered, or nonpolling.

Seek

Moves the disk drive heads to the specified cylinder. As in recalibrate, seek has four modes of operation.

Format

This command is used to initialize the medium with the desired format which includes various gap lengths, data patterns, and CRC codes. This command is used in conjunction with the specify command.

Verify ID

Used to verify the ID bytes with data from memory. Performs the operation over a specified number of sectors.

Read ID

Used to verify the position of the read/write heads.

Read Diagnostic

Used in SMD mode only, the command allows the programmer to read a sector of data even if the ID portion of the sector is defective. Only one sector at a time can be read.

Read Data

Reads and transfers to the system memory the number of sectors specified. The HDC can read multiple sectors and multiple tracks with one instruction.

Scan

Compares a specified block of memory with specified sectors on the disk. The 7261A/7261B continues until a sector with matching data is found, until the sector count reaches zero, or the end of the cylinder is reached.

Verify Data

Makes a sector-by-sector comparison of data in the system memory by DMA transfer. As in read operation, multiple sectors and tracks may be verified with this commmand.

Write Data

Data from the system memory, transferred by DMA, is written onto the specified disk unit. As in the read command, data may be written onto successive sectors and tracks.

Auxiliary Command

Allows four additional functions to be executed: software reset, clear data buffer, mask interrupt request bit (masks interrupts caused by change of status of drives), and reset interrupt caused by command termination (used when no further disk commands will be issued, which would normally reset the interrupt).

Command Operation

There are three phases for most of the instructions that the μPD7261A/7261B can execute: command phase, execution phase, and result phase. During the command phase the host CPU loads preset parameters into the μPD7261A/7261B FIFO via the data bus and by successive write pulses to the part with A_0 and CS true low. Once the required parameter bytes are loaded the appropriate command is initiated by issuing a write pulse with A_0 high and CS low and the command code on the data bus.

The μPD7261A/7261B is now in the execution phase. This can be verified by examining the status register bit 7 (the controller busy bit). The execution phase is ended when a normal termination or an abnormal termination occurs. An abnormal termination can occur due to a read or write error, or a change of status in the addressed disk drive. A normal termination occurs when the command given is correctly completed. (This is indicated by bits in the status register.) The result phase is then entered. The host CPU may read various result parameters from the FIFO. These result parameters may be useful in determining the cause of an interrupt, or the location of a sector causing a read error, for example.

The chart shown in table 2 illustrates the preset parameters and result parameters that are associated with each command. The abbreviations are defined at the end of table 2.

Table 2. Preset Parameters and Result Status Byte

Disk Command	Command Code	Preset Parameters/Result Status							
		1st	2nd	3rd	4th	5th	6th	7th	8th
Detect error	0100X								
		EADH	EADL	EPT1	EPT2	EPT3			
Recalibrate	0101[B]								
		IST*							
Seek	0110[B]	PCNH	PCNL						
		IST*							
Format	0111(S)	PHN	(PSN)	SCNT	DPAT	GPL1	[GPL3]		
		EST	SCNT						
Verify ID	1000(S)	PHN	(PSN)	SCNT					
		EST	SCNT						
Read ID	1001(S)	PHN	(PSN)	SCNT					
		EST	SCNT						
(Read diagnostic)	1010X	PHN	PSN						
		EST							
Read data	1011X	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT	
		EST	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT
Check	1100X	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT	
		EST	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT
Scan	1101X	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT	
		EST	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT
Verify data	1110X	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT	
		EST	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT
Write data	1111X	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT	
		EST	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT
Sense interrupt status	0001X	IST							
Specify	0010X	MODE	DTLH	DTLL	ETN	ESN	GPL2	(MGPL1) [RWCH]	[RWCL]
Sense unit status	0011X								
		UST							

Note:
(): These are omitted for soft-sector disks.
[]: These are omitted for hard-sector disks.
*: IST available as a result byte only when in nonpolling mode.
B: Indicates buffered mode when set.
S: Indicates Skewed mode (SMD only) when set.
X: Indicates don't care.

Mnemonic Definitions

EADH Error address, high byte
EADL Error address, low byte
EPT1 Error pattern, byte one
EPT2 Error pattern, byte two
EPT3 Error pattern, byte three
PCNH Physical cylinder number, high byte

Mnemonic Definitions (cont)

PCNL Physical cylinder number, low byte
PHN Physical head number
PSN Physical sector number
SCNT Sector count
DPAT Data pattern
GPL1 Gap length one
GPL3 Gap length three
EST Error status byte
FLAG Flag byte
LCNH Logical cylinder number, high byte

Mnemonic Definitions (cont)

LCNL	Logical cylinder number, low byte
LHN	Logical head number
LSN	Logical sector number
IST	Interrupt status byte
MODE	Mode
DTLH	Data length, high byte
DTLL	Data length, low byte
ETN	Ending track number
ESN	Ending sector number
GPL2	Gap length two
RWCL	Write current cylinder, low byte
RWCH	Write current cylinder, high byte
UST	Unit status byte
MGPL1	Modified gap length 1

Status Register

This register is a read only register and may be read by asserting $\overline{RD}$ and $\overline{CS}$ with A_0 high. The status register may be read at any time. It is used to determine controller status and partial result status. See table 3.

Table 3. Status Register Bits

Pin No.	Pin Name	Function
D_7	CB (Controller busy)	Set by a disk command issue. Cleared when the command is completed. (This bit is also set by an external reset signal or an RST command, but will be cleared at the completion of the reset function.) When this bit is set, a new disk command will not be accepted.
D_6, D_5	CEH, CEL (Command end)	CEH = 0 and CEL = 0 A disk command is in process, or no disk command is issued after the last reset signal or the last CLCE auxiliary command. Both the CEH and CEL bits are cleared by a disk command, a CLCE auxiliary command, or a reset signal.
		CEH = 0 and CEL = 1 Abnormal termination of a disk command. Execution of a disk command was started, but was not successfully completed.
		CEH = 1 and CEL = 0 Normal termination of a disk command. The execution of a disk command was completed and properly executed.
		CEH = 1 and CEL = 1 Invalid command issue.

Table 3. Status Register Bits (cont)

Pin No.	Pin Name	Function
D_4	SRQ (Sense interrupt status request)	When a seek end, an equipment check condition, or a ready signal state change is detected, this bit is set requesting a sense interrupt status command be issued to take the detailed information. This bit is cleared by an issue of that command or by a reset signal.
D_3	RRQ (Reset request)	Set when controller has lost control of the format controller (missing address mark, for example). An auxiliary RST command or RESET signal will clear this bit.
D_2	IER (ID error)	Set when a CRC error is detected in the ID field. An auxiliary RST or another disk command will reset this bit.
D_1	NCI (Not coincident)	Set if the controller cannot find a sector on the cylinder which meets the comparison condition during the execution of a scan command. This bit is also set if data from the disk does not coincide with the data from the system during a verify ID or a verify data command. This bit is cleared by a disk command or a reset signal.
D_0	DRQ (Data request)	During execution of write ID, verify ID, scan, verify data, or a write data command, this bit is set to request that data be written into the data buffer. During execution of read ID, read diagnostic, or read data command, this bit is set to request that data be read from the data buffer.

Error Status Byte

This byte is available to the host at the termination of a read, write, or data verification command and provides additional error information to the host CPU. If the status register indicates a normal command termination, it can be assumed that the command was executed without error and it is not necessary to read this byte. When it is necessary to determine the cause of an error this byte may be read by issuing an $\overline{RD}$ pulse with $\overline{CS}$ and A_0 low. The remaining result bytes associated with a particular command may be read by issuing additional $\overline{RD}$ pulses. Data transfer from or to the FIFO is asynchronous and may occur at rates up to 2.5 Mbytes per second. See table 4.

Table 4. Error Status Bits

Pin No.	Pin Name	Function
D_7	ENC (End of cylinder)	Set when the controller tries to access a sector beyond the final sector of a cylinder. Cleared by a disk command or an auxiliary RST command.
D_6	OVR (Overrun)	When set, indicates that the FIFO became full during a read operation, or empty during a write operation.
D_5	DER (Data error)	A CRC or an ECC error was detected in the data field.
D_4	EQC (Equipment check)	A fault signal from the drive has been detected or a track 0 signal has not been returned within a certain time interval after the recalibrate command was issued.
D_3	NR (Not ready)	The drive is not in ready state.
D_2	ND (No data)	The sector specified by ID parameters was not found on the track.
D_1	NWR (Not writable)	Set if write protect signal is detected when the controller tries to write on the disk. It is cleared by a disk command or by an auxiliary RST command.
D_0	MAM (Missing address mark)	This bit is set if during execution of read data, check, scan, or verify data commands, no address mark was found in the data field or if during execution of a read ID or verify ID command, no address mark was detected in the ID field.

Interrupt Status Byte

This byte is made available to the host CPU by executing the Sense Interrupt Status command. This command should be issued only when the μPD7261A/7261B requests it, as indicated by bit D_4 of the status register. This byte reveals changes in disk drive status that have occurred. See table 5.

Table 5. Interrupt Status Bits

Pin No.	Pin Name	Function
D_7	SEN (Seek end)	A seek end or seek complete signal has been returned after a seek or a recalibrate command was issued.
D_6	RC (Ready change)	The state of the ready signal from the drives has changed. The state itself is indicated by the NR bit.
D_5	SER (Seek error)	Seek error has been detected on seek end.
D_4	EQC (Equipment check)	Identical to bit 4 of the error status byte.
D_3	NR (Not ready)	Identical to bit 3 of the error status byte.
D_2-D_0	UA_2-UA_0 (Unit address)	The unit address of the drive which caused an interrupt request on any of the above conditions.

Drive Interface

The μPD7261A/7261B has been designed to implement two of the more popular types of interfaces: the SMD (Storage Module Drive) and the floppy-like Winchester drive which has come to be known as the ST506 interface. The desired interface mode is selected by the Specify command.

ST506-Type Interface

In the ST506 mode the μPD7261A/7261B performs MFM encoding and decoding at data rates to 6 MHz and provides all necessary drive interface signals. Included internally is circuitry for address mark detection, sync area recognition, serial-to-parallel-to-serial conversion, an 8-byte FIFO for data buffering, and circuitry for logical addressing of the drives. External circuitry required consists of control signal buffering, a delay network for precompensation, a phase-lock loop, a write clock oscillator and a differential transceiver for drive data. The floppy-like interface can be implemented with as few as 7 IC's using NEC's hard-disk interface chip, the μPD9306A, or with 12 to 14 SSI ICs. See figure 1.

Figure 1. μPD7261A/7261B ST506-Type Interface

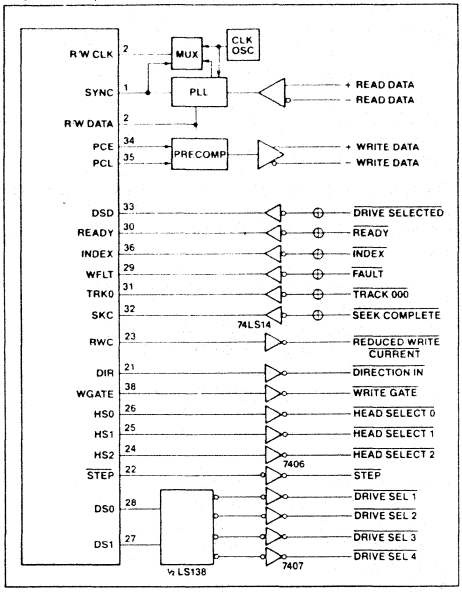
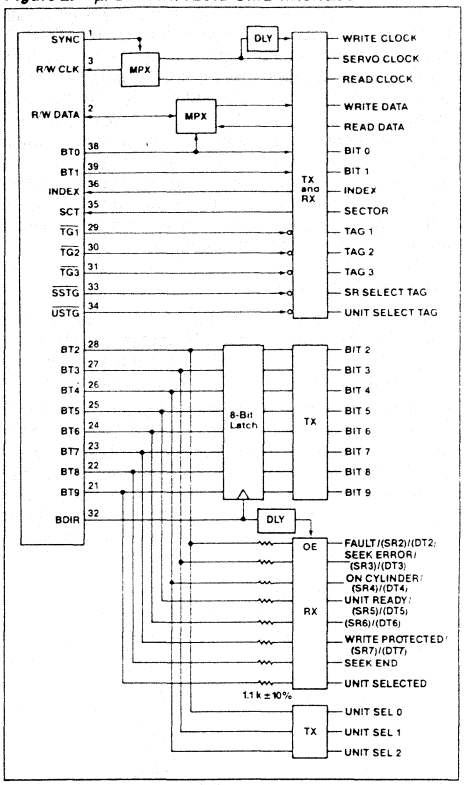


Figure 2. μPD7261A/7261B SMD Interface



SMD Interface

In the SMD mode the μPD7261A/7261B will support data rates to 10 MHz/15 MHz in the NRZ format. All control functions necessary for an SMD interface are implemented on-chip with de-multiplexing of 8 data lines performed externally by a single 8-bit latch. A small amount of logic is required to multiplex the data and clock lines, and differential drivers and receivers are required to implement the actual interface. Depending on individual logic design and the number of drives used, the SMD interface may be implemented with as few as 12 ICs. See figure 2.

Note:

CLK (pin 37) frequency must be a minimum of 1.1 × NRZ data rate.

Internal Architecture

The μPD7261A/7261B can be divided into three major internal logic blocks: command processor; format controller; microprocessor interface.

Command Processor

The command processor is an 8-bit microprocessor with its own instruction set, program ROM, scratchpad RAM, ALU, and I/O interface. Its major functions are:

- ☐ To decode the commands from the host microcomputer that are received through the 8-bit data bus
- ☐ To execute seek and recalibrate commands
- ☐ To interface to the drives and read the drive status lines
- ☐ To load the format controller with the appropriate microcode, enabling it to execute the various read/write data commands.

The command processor microprocessor is idle until it receives the command from the host microcomputer. It then reads the parameter bytes from the FIFO, and loads them into its RAM. The command byte is decoded and, depending on its opcode, the appropriate subroutine from the 2.6K internal ROM is selected and executed. Some of these commands are executed by the command processor without involvement of the format

controller. When data transfers to and from the disk are made, the command processor loads the appropriate microcode into the format controller, then relinquishes control. When the data transfer is complete, the command processor again takes control. One other important function that the command processor performs is managing the interface to the disk drives. The command processor contains an I/O port structure similar to many single-chip microcomputers in that the ports may be configured as input or output pins. Depending on the mode of operation selected by the Specify command, the command processor will use the bidirectional I/O lines for different functions.

Command Register

This register is a write only register. It is selected when the A_0 input is high and the $\overline{CS}$ input is low. There are two kinds of commands: disk commands and auxiliary commands. Each command format is shown in figure 3.

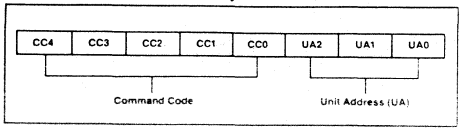
An auxiliary command is accepted at any time and is immediately executed, while a disk command is ignored if the on-chip processor is busy processing another disk command. A valid disk command causes the processor to begin execution using the parameters previously loaded into the data buffer. Disk commands and the parameters needed are described in the Microprocessor Interface section.

Command Codes

CC4	CC3	CC2	CC1	CC0		
0	0	0	0	X		(Auxiliary Command)
0	0	0	1	X		Sense int. status (Note 1)
0	0	1	0	X		Specify (Note 1)
0	0	1	1	X		Sense unit status
0	1	0	0	X		Detect error (Note 1)
0	1	0	1	[B]		Recalibrate
0	1	1	0	[B]		Seek
0	1	1	1	[S]		Format
1	0	0	0	[S]		Verify ID
1	0	0	1	[S]		Read ID
1	0	1	0	X		Read diagnostic
1	0	1	1	X		Read data
1	1	0	0	X		Check
1	1	0	1	X		Scan
1	1	1	0	X		Verify data
1	1	1	1	X		Write data

Note:
(1) The UA field is 000.
[B] Indicates buffered mode when set.
[S] Indicates skewed mode when set.

Figure 3. Disk Command Byte



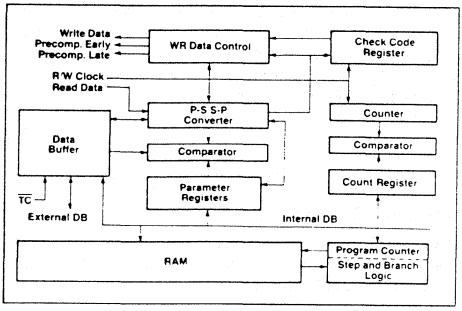
Format Controller

The format controller is built with logic that enables it to execute instructions at very high speed: one instruction per single clock cycle. The major functions it performs are:

- ☐ Serial-to-parallel and parallel-to-serial data conversion
- ☐ CRC and ECC generation and checking
- ☐ MFM data decoding and encoding
- ☐ Write precompensation
- ☐ Address mark detection and generation
- ☐ ID field search in soft-sector format
- ☐ DMA data transfer control during read/write operations.

The major blocks in the format controller are the sequencer and the serial/parallel data handler. The sequencer consists of a writable control store (32 words by 16 bits), a program counter, branch logic, and the parameter register. The serial/parallel logic consists of a parallel-to-serial converter for disk write operations, a serial-to-parallel converter for disk read operations, precompensation logic for writing MFM data, comparator logic that locates sync fields, address marks, and ID fields. There is also comparator logic that is used during Verify Data commands. See figure 4.

Figure 4. Block Diagram of the Format Controller



Microprocessor Interface

Read/Write Control. The internal registers are selected as shown in truth table 6.

Table 6. Register Selection Table

$\overline{CS}$	A_0	$\overline{RD}$	$\overline{WR}$	Selection
0	0	0	1	Data buffer register (Note 1)
0	0	1	0	Data buffer register (Note 1)
0	1	0	1	Status register
0	1	1	0	Command register
0	X	1	1	Don't care
1	X	X	X	Don't care
0	X	0	0	Inhibited

Note:
(1) Preset parameters and result status information are written and read from the result status register in the HDC through this data buffer register.

Interrupt. The interrupt request line is activated or inactivated according to the following equation:

$$INT = CEH + CEL + SRQ \bullet \overline{SRQM}$$

This means that if either of the command end bits is set or if the sense interrupt status request bit is set (and the SRQM mask is not set), then an interrupt will be generated. The command end bits, CEH and CEL, are set by command termination.

The SRQ bit is set when an equipment check condition or a state change of the ready signal from the disk drives is detected. It is also set when a seek operation is completed. Under these conditions the INT line is activated unless the SRQM mask is set.

Both of the CEH and CEL bits are cleared by a disk command, but both bits may be cleared before the next disk command by issuing a CLCE auxiliary command.

The interrupt caused by the SRQ bit indicates that a sense interrupt status command should be issued by the host microprocessor so that it can determine the exact cause of the interrupt. However, the μPD7261A/7261B may be processing a disk command when the interrupt occurs. Since it is not possible to issue a disk command while the μPD7261A/7261B is busy, an HSRQ auxiliary command can be issued to set the SRQM (sense interrupt request mask) and mask the interrupt. The SRQM is reset upon completion of the disk command in progress.

DMA Control. When true, the DREQ pin and the DRQ (data request) bit of the status register indicate a request for data transfer between the disk controller and external memory. These are activated during execution of the following disk commands:

HDC ← memory: Format, Verify ID, Scan, Verify Data, Write Data

HDC → memory: Read ID, Read Diagnostic, Read Data

Data being read from a disk or external memory is temporarily stored in the data buffer (8 bytes maximum), and is transferred to external memory or a disk, respectively.

Data transfers are terminated externally by a reset signal or by a read or a write data operation coinciding with an active terminal count ($\overline{TC}$) signal. They are also terminated internally when an abnormal condition is detected or all the data specified by the sector count parameter (SCNT) has been transferred.

Data transfers are accomplished by $\overline{RD}$ or $\overline{WR}$ signals to the μPD7261A/7261B when DREQ is active. During read operations, DREQ goes active when the FIFO contains three or more bytes. If the FIFO contains three bytes and an $\overline{RD}$ pulse is issued, DREQ goes low within t_{RRQ1}. DREQ will stay active on the final sector until the final byte is extracted. In this case, DREQ goes low within t_{RRQ2}. During write operations DREQ is asserted as soon as a Write Data command is accepted. DREQ remains high until the FIFO contains six bytes, at which time it goes low within t_{WAI}. DREQ corresponds to FIFO almost-full and FIFO almost-empty as implemented in the μPD7261A/7261B. This has been done so that a fast DMA controller may actually overrun the FIFO by one or two bytes without harm.

Commands

Recalibrate

0101B	
	IST*

The read/write heads of the specified drive are retracted to the cylinder 0 position. IST is available as a result byte only if polling mode is disabled. See Specify.

Hard-Sector. An RTZ (Return to Zero) signal is asserted on the bit-6 line with the TAG-3 bit being set. Then the CEH bit of the status register is set indicating a normal termination of the command.

After this command is given, the HDC checks the seek end, unit ready, and fault lines of the drive continually until an active signal is detected on these lines. Then the SRQ bit of the status register is set indicating that a sense interrupt status command should be performed. Each bit of the IST (interrupt status) byte is set according to the result, in anticipation of the sense interrupt status command.

Soft-Sector. There are four different ways to implement the Recalibrate command when the ST506 interface mode has been specified. Both polling and nonpolling modes of operation are provided, with both normal or buffered Recalibrate commands available in either mode.

Normal Mode with Polling. The CEH bit of EST is set to 1 immediately after the Recalibrate command is issued (a Recalibrate command may now be issued to another drive). The HDC now begins generating step pulses at the specified rate. The PCN for the drive is cleared and the TRK0 signal is checked while stepping pulses are sent to one or more drives. When TRK0 is asserted, the SEN (seek end) bit of the IST (interrupt status) byte is set and the SRQ bit of the status register is set. This causes an interrupt and requests that a sense interrupt status command be issued. If 1023 pulses have been sent and TRK0 is not asserted, then the SRQ bit is again set, but with the SER (seek error) and EQC (equipment check) bits of the IST byte set. The ready signal of each drive is checked before each step pulse is sent, and the Recalibrate command is terminated if the drive enters a not-ready state, whereby the NR bit of the IST byte is set to 1.

Normal Mode with Polling Disabled. Operation is similar to that in "Normal Mode with Polling", but the CEH and CEL bits of the status register are not set until either the SEN (seek end) or the SER (seek error) condition occurs. The SRQ bit is not set when polling is disabled, and the IST byte is now available as a result byte when the Recalibrate command is terminated (see "Preset Parameters and Result Status Bytes"). It is not possible to overlap Recalibrate operations in this mode.

Buffered Mode with Polling. This mode operates in a manner similar to that described as "Normal Mode with Polling", but with the following differences:

(1) 1023 step pulses are sent at a high rate of speed (approximately 50 μs between pulses)

(2) After the required number of pulses are sent, the CEH bit is set, and then additional Recalibrate or Seek commands will be accepted for other drives

(3) The SRQ bit is set when the drive asserts SKC, which causes the SEN bit of the IST byte to be set

(4) If SEN is not set within the time it takes to send 1023 "normal" pulses (i.e., when in normal stepping mode), then SER and EQC of the IST byte are set.

Buffered Mode with Polling Disabled. 1023 stepping pulses are immediately sent after the Recalibrate command is issued. CEH and/or CEL is set when SEN or SER occurs. SEN is set when TRK0 from the addressed drive is asserted. SER is set if TRK0 is not asserted within the time required to send 1023 "normal" pulses. The Recalibrate command will be terminated abnormally if a not-ready condition occurs prior to SEN being set. The SRQ bit of the status register is not set. The IST byte (interrupt status) is available as a result byte when either CEH or CEL is set.

Seek

01108	PCNH	PCNL
	IST*	

PCNH = Physical Cylinder Number, High Byte
PCNL = Physical Cylinder Number, Low Byte

The read/write heads of the specified drive are moved to the cylinder specified by PCNH and PCNL. IST is available as a result byte only if polling mode is disabled. See Specify.

Hard-Sector. The contents of PCNH and PCNL are asserted on the BIT0 through BIT9 output lines of the SMD interface with the TAG1 control line being set. (The most significant six bits of PCNH are not used.) The CEH bit of the status register is then set, and the command is terminated normally.

The HDC then checks the seek end, unit ready and fault lines of the drive continually until an active signal is detected on these lines. The SRQ bit of the status register is then set requesting that a Sense Interrupt Status command be performed. Each bit of the IST (interrupt status) byte is set appropriately in anticipation of the Sense Interrupt Status command.

Soft-Sector (Normal Stepping, Polling Enabled). In this mode, the CEH bit of the status register is set to 1 as soon as the Seek command is issued. This allows a Seek or Recalibrate command to be issued to another drive. The HDC now sends stepping pulses at the specified rate and monitors the ready signal. Should the drive enter a not-ready state, the SER bit of the IST byte is set and the SRQ bit of the status register is set, causing an interrupt and requesting a Sense Interrupt Status command. When the drive asserts the seek complete (SKC) signal, the SEN bit of the IST byte is set and the SRQ bit of the status register is set, again requesting service.

Soft-Sector (Normal Stepping, Polling Disabled). Stepping pulses to the drive begin as soon as the Seek command is accepted. The ready signal is checked prior to each step pulse. If the drive enters a not-ready state the seek command is terminated abnormally (CEL = 1), and SER of the IST byte is set. If the seek operation is successful, the seek command will be terminated normally (CEH = 1) when the drive asserts SKC (seek complete). The SEN (seek end) bit of the IST byte is set and the IST (interrupt status) byte is available as a result byte. The Sense Interrupt Status command is not allowed (SRQ is not set), nor can seek operations be overlapped in this mode.

Soft-Sector (Buffered Stepping, Polling Enabled). As soon as the Seek command is accepted by the HDC, high-speed stepping pulses are generated. As soon as the required number of pulses are sent, CEH is set to 1, indicating a normal termination. Another Seek command in the same mode may now be issued. The drive is now controlling its own head positioner and asserts SKC when the target cyclinder is reached.) If the drive has not asserted SKC (seek complete) within the time it takes to send the required number of pulses in normal stepping mode, or if the drive enters a not-ready state, then the SER bit of the IST byte and the SRQ bit of the status register are set. Otherwise, the SEN bit of the IST byte is set, along with SRQ of the status register.

Soft-Sector (Buffered Stepping, Polling Disabled). In this mode, the appropriate number of high-speed stepping pulses are sent as soon as the Seek command is issued. If the drive enters a not-ready state, or if SKC (seek complete) is not asserted within the time it takes to send the required number of pulses in normal stepping mode, then the Seek command is terminated normally (generating an interrupt). The IST byte is available as a result byte and the appropriate bit is set; i.e., SER and EQC or NR (not ready). If the seek operation is successful, the Seek command is terminated normally (CEH = 1) and the SEN bit of the IST byte is set. The IST byte is available as a result byte. The Sense Interrupt Status command is not allowed (SRQ is not set), nor can seek operations be overlapped in this mode.

Format

0111S	PHN	(PSN)	SCNT	DPAT	GPL1	(GPL3)	
	EST	SCNT					

PHN = Physical Head Number
PSN = Physical Sector Number
SCNT = Sector Count
DPAT = Data Pattern
GPL1 = Gap Length 1
GPL3 = Gap Length 3
EST = Error Status

This command is used to write the desired ID and data format on the disk.

(1) When using hard-sector drives, this command will begin format-writing at the sector specified by PHN and PSN, which are loaded during command phase.

When soft-sector drives are specified, this command will begin format-writing at the sector immediately following the index pulse on the track specified by PHN.

In either case, data transmitted from the local memory by DMA operation is written into the ID field, and the data field is filled with the data constant specified by DPAT until DTL (data length) is zero. DTL is established during the specify command with DTLH and DTTL. The sector count, SCNT, is decremented by one at the end of the Format operation on each sector. The following bytes are required by the HDC for each sector: (FLAG), LCNH, LCNL, LHN, and LSN. FLAG is omitted on soft sector drives. These bytes are transferred by DMA

The format operation produces the various gaps with length as specified by GPL1, GPL2 (See Specify), and GPL3 (For soft-sector only.)

Note:
GPL3 may not exceed decimal value of 44

(2) The above operation is repeated until SCNT is equal to zero. The execution of the command is terminated normally, when the content of SCNT is equal to zero and the second index pulse has occurred.

(3) When using a hard-sector drive, it is possible to write the ID field displaced from the normal position by 64 bytes by setting the skew bit of the command byte ((S) = 1). This is useful when defective media prevent writing in the normal area of the sector.

(4) Items 4, 5, and 8 of the Read Data and item 4 of the Write Data command are identical for this command. Refer to these items (which appear later in this section) for remaining format operation details.

Verify ID

1000S	PHN	(PSN)	SCNT	
	EST	SCNT		

PHN = Physical Head Number
PSN = Physical Sector Number
SCNT = Sector Count
EST = Error Status

ID bytes of specified sectors are read and compared with the data that are accessed from local memory via DMA control. The first sector that is verified is specified by PHN and PSN when a hard-sector disk is used. For soft-sector disks, only PHN is given and the Verify ID command begins comparisons with the first physical sector on the track.

Byte comparisons continue as long as successful or until the sector count is zero or a CRC error is found.

When using a hard-sector drive, it is possible to have the HDC verify a skewed ID field by setting the skew bit of the command byte. Refer to the Format section, given earlier, for details.

Read ID

1001S	PHN	PSN	SCNT	
	EST	SCNT		

PHN = Physical Head Number
PSN = Physical Sector Number
SCNT = Sector Count
EST = Error Status

ID bytes of specified sectors are read and transferred to local memory by DMA.

Hard-sector disks: Beginning with the sector specified by PHN and PSN, the ID bytes of each sector are read until an error is found or the SCNT has reached zero.

It is also possible to perform the above operation with skewed ID fields by setting the skew bit of the command byte. This will allow reading ID fields that have been shifted by 64 bytes by the Skewed Format command.

Soft-sector disks: This command will begin checking ID fields immediately following the index pulse and will continue until one valid ID field is read, or until the second index pulse is detected or SCNT = 0, whichever occurs first.

Read Diagnostic

1010X	PHN	PSN
	EST	

PHN = Physical Head Number
PSN = Physical Sector Number
EST = Error Status

This command is implemented only for hard-sector disks. The desired physical sector is specified, and the data field will be read even if the ID bytes of that sector contain a CRC error. Only one sector at a time may be read by this command.

Read Data

1011X	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT	
	EST	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT

PHN = Physical Head Number
FLAG = Flag Byte, Hard-Sector ID Field Only
LCNH = Logical Cylinder Number, High Byte
LCNL = Logical Cylinder Number, Low Byte
LHN = Logical Head Number
LSN = Logical Sector Number
SCNT = Sector Number
EST = Error Status

This command is used to read and transfer data via DMA from the disk to the local memory.

(1) The HDC reads data from the specified sector which is determined by the following preset parameters: FLAG (for hard-sector only), LCNH, LCNL, LHN, and LSN. The drive is selected by UA (unit address) in the command byte. The HDC then transfers the read data to the local memory via DMA operation.

(2) After reading each sector, the HDC updates the SCNT and LSN to point to the next sector, and repeats the above described operation until SCNT is equal to zero. During the above read operations, if LSN is equal to ESN, the HDC updates LSN, and continues the read operations after relocating the head (track) specified by LHN.

(3) The HDC abnormally terminates the execution of this command if SCNT is not equal to zero when the HDC reads out the data from the last sector (LSN = ESN and LHN = ETN). The ENC (end of cylinder) bit of EST (error status) is set to one in this situation.

(4) The HDC will terminate this command if a fault signal is detected while reading data. The HDC will set the EQC (equipment check) of the EST (error status) byte when this occurs.

(5) The HDC will terminate this command abnormally if the ready signal from the drive is not active or becomes not active while a Read Data command is being performed. The NR (not ready) bit of the EST (error status) register will be set to one in this case.

(6) The HDC will end this command abnormally if it cannot find an AM (address mark) (soft-sector mode) or a SYNC byte (hard-sector mode) of the ID field before four index pulses occur. Under these conditions, the RRQ (reset request) bit of the STR (status register) will be set. In order to perform further disk commands the HDC will have to be reset because the format controller is hung up looking for an AM or SYNC byte.

(7) ECC mode: If the HDC detects an ECC error during a read operation, it will execute the following operations: First, the HDC decides whether or not the error is correctable by checking the syndrome of the error pattern. If the error is correctable, the HDC terminates the command in the normal mode after setting the DER (data error) bit of EST register to one. The host system can input the error address and the error pattern information by issuing the Detect Error command. If it is not a correctable error, the HDC will terminate the command in the abnormal mode after setting the DER bit of the EST register to one.

CRC mode: If the HDC detects a CRC error on a sector during the read operation, the HDC will terminate the command in the abnormal mode after setting the DER bit of the EST register to one.

(8) If the HDC detects an overrun condition during a Read Data operation, the OVR (overrun) bit of the EST register is set. (An overrun condition occurs when the internal data FIFO is full, another data byte has been received from the disk drive, and a DMA service does not occur.) The command is then terminated in the abnormal mode.

(9) If the HDC cannot find the desired sector within the occurrence of three index pulses, the ND (no data) bit of the EST register is set to one and the command is terminated in the abnormal mode.

(10) If TC (terminal count) occurs during a Read Data command the DMA transfers to the local memory will stop. However, the HDC does continue the read operation until the end of the sector, if SCNT = 1.

If SCNT is 2 or more, DMA transfers restart when SCNT is updated to the next sector, and will continue until SCNT is zero.

(11) If the Read Data command has been successfully completed, the result status will be set indicating such, and the result status bytes will be updated according to the number of sectors that have been read. The logical disk parameters — LSN, LHN, and LCN — are incremented as follows:

LSN is incremented at the end of each sector until the value of ESN is reached. LSN is then set to 0 and LHN is incremented. If LHN reaches the value of ETN, then LHN is cleared and LCN is incremented.

In other words, if a Read or Write operation is terminated normally, the various parameters will point to the next logical sector.

If the command is terminated in the abnormal mode, the result status bytes will indicate on which sector, cylinder, and head the error occurred.

(12) If the HDC cannot detect the address mark (soft-sector) or SYNC bytes (hard-sector) immediately following the VFO sync in the data field, the HDC will set the MAM (missing address mark) bit of the EST register to one, and will terminate the command in the abnormal mode.

Check

1100X	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT	
	EST	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT

PHN = Physical Head Number
FLAG = Flag Byte, Hard-Sector ID Field Only
LCNH = Logical Cylinder Number, High Byte
LCNL = Logical Cylinder Number, Low Byte
LHN = Logical Head Number
LSN = Logical Sector Number
SCNT = Sector Number
EST = Error Status

This command is used to confirm that the data previously written to the medium by the Write Data command contains the correct CRC or ECC.

(1) The HDC reads the data in the sector specified by FLAG (hard-sector only), LCNH, LCNL, LHN, and LSN. The Check command differs from the Read Data command in that no DMA transfers occur.

With the exception of the ECC mode, the Check command is the same as the Read Data command. Please refer to items 2, 3, 4, 5, 6, 7, 8, 11, and 12 of Read Data command for details.

(2) If in the ECC mode, the HDC detects only ECC errors and does not execute any error correction operation even if the ECC errors are correctable. No data transfers have been made, and there is no data to correct.

Scan

1101X	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT	
	EST	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT

PHN = Physical Head Number
FLAG = Flag Byte, Hard-Sector ID Field Only
LCNH = Logical Cylinder Number, High Byte
LCNL = Logical Cylinder Number, Low Byte
LHN = Logical Head Number
LSN = Logical Sector Number
SCNT = Sector Number
EST = Error Status

(1) In executing the Scan command, the HDC reads the data from the sector specified by the preset parameters of the command phase. The HDC then compares this data with the data transmitted from the local memory. (The purpose of this command is to locate a sector that contains the same data as the local memory.)

This command will terminate successfully if the data from the disk and the data from the local memory are the same. If they are not, the HDC updates SCNT and LSN, and executes the abovementioned operation again.

If the HDC cannot locate a sector that satisfies the scan conditions, the NCI bit of the STR will be set. The HDC tries to compare data until the end of the cylinder has been reached, or until SCNT is zero.

(2) If the value of the LSN (logical sector number) is equal to that of ESN (ending sector number) after updating LSN, the HDC updates the contents of LHN (increasing by 1) and that of LSN (LSN = 0), and repeats the operation described in item 1 after selecting the next head.

(3) After comparing the data transferred from the host CPU with the data in the specified sectors, the result bytes (FLAG, which is only for hard-sector disks, LCNH, LCNL, LHN, and LSN) will be set equal to the sector location that satisfies the Scan command.

(4) The descriptions in 4, 5, 6, 8, and 9 of Read Data command, and items 3 and 4 of Verify Data command are identical for this command. Refer to these descriptions for additional details.

Verify Data

1110X	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT	
	EST	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT

PHN = Physical Head Number
FLAG = Flag Byte, Hard-Sector ID Field Only
LCNH = Logical Cylinder Number, High Byte
LCNL = Logical Cylinder Number, Low Byte
LHN = Logical Head Number
LSN = Logical Sector Number
SCNT = Sector Number
EST = Error Status

This command is used to verify data on the disk.

(1) The HDC reads the data from the specified sector, and compares the data transmitted from the local memory via DMA with the data from the disk.

The sector is specified by FLAG (hard-sector only), LCNH, LCNL, LHN, and LSN, and the drive is selected by UA. If the data transmitted from the local memory is the same as that read from the sector, the HDC updates the contents of LSN and SCNT, and continues the abovementioned operation. After updating SCNT, if the value of SCNT is equal to zero, the HDC ends the execution of the command in the normal mode. If the value of LSN is equal to that of ESN after updating LSN, the HDC updates the contents of LHN and LSN, and the HDC continues the verify data operation after selecting the head (track) specified by LHN.

If the data transmitted from the local memory is not the same as that read from the sector, the HDC ends the execution of the command in the abnormal mode after setting the NCI (not coincident) bit of STR to one.

(2) If, after verifying the data on the last sector, the contents of SCNT are not equal to zero, the HDC terminates execution of the command abnormally after setting the ENC (end of cylinder) bit of the EST register to one.

(3) After verifying the data read from a sector, the HDC checks the CRC bytes (CRC mode) or the ECC bytes (ECC mode).

If the HDC detects a CRC or an ECC error on a sector, the HDC terminates execution of the command abnormally after setting the DER bit of the EST register to a one.

(4) After detecting an active $\overline{TC}$ signal ($\overline{TC} = 0$), the HDC executes the above operation by comparing the read data from the disk drive with the data 00 instead of the data from the main system until the end of the sector.

In the case of SCNT greater than one, when SCNT is updated, DMA transfers restart and disk data is compared against host data until SCNT is zero.

(5) After verification of the data on all the sectors, FLAG (hard-sector only), LCNH, LCNL, LHN, and LSN are set to the values of FLAG, LCNH, LCNL, LHN, and LSN of the last verified sector.

(6) The descriptions in items 4, 5, 6, 8, 9, and 12 of the Read Data command are valid in this command. Please refer to these items for additional detail.

Write Data

1111X	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT	
	EST	PHN	(FLAG)	LCNH	LCNL	LHN	LSN	SCNT

PHN = Physical Head Number
FLAG = Flag Byte, Hard-Sector ID Field Only
LCNH = Logical Cylinder Number, High Byte
LCNL = Logical Cylinder Number, Low Byte
LHN = Logical Head Number
LSN = Logical Sector Number
SCNT = Sector Number
EST = Error Status

(1) This command is used to write data into the data field of the sectors specifed by FLAG (hard disks only), LCNH, LCNL, LHN, and LSN, and to write CRC bytes or ECC bytes according to each internally specified mode (CRC or ECC). The data is written to the disk via DMA transfer from the local memory.

(2) After writing data on a sector, the HDC updates the contents of SCNT and LSN, and repeats the above described Write Data operation until SCNT is equal to zero.

During the above Write Data operations, if LSN is equal to ESN, the HDC updates LHN and LSN, and continues the Write Data operations after selecting the new head (track) specified by LHN.

As described above, the HDC has the capability of multi-sector and multi-track write operations.

(3) The HDC abnormally terminates the execution of this command if the SCNT is not equal to zero when the HDC writes the data to the last sector (LSN = ESN and LHN = ETN). The ENC (end of cylinder) bit of EST (error status) register is set to one in this situation.

(4) If the write protected signal is active (high) at the beginning of the execution of this command, the HDC ends the execution of this command in the abnormal mode after setting the NWR (not writable) bit of the EST register to one.

(5) After detecting an active $\overline{TC}$ signal ($\overline{TC} = 0$), the HDC writes the data 00 to the sector, instead of the data from the host system.

In the case of SCNT of two or more, when SCNT is updated, the DMA transfers will restart and writing of host data will continue until SCNT = 0.

(6) In the ST506-type mode, the HDC will set the reduced write current output bit to a one when the cylinder number becomes greater than that specified by RWCH and RWCL. These parameters are loaded during execution of the Specify command.

The descriptions in items 4, 5, 6, 8, 9, and 11 of the Read Data command are applicable here also. Refer to these items for further detail.

Sense Interrupt Status

0001X	
	IST

IST = Interrupt Status

(1) The HDC transfers the new disk status to the host CPU at the end of a Seek or Recalibrate operation or the new disk status resulting from a change of state of the ready signal, which may occur at any time.

(2) If the Seek or Recalibrate command in progress is completed when this command is issued or if there has been no change of state of the ready signal from the drive, this command will be terminated abnormally.

Specify

0010X	MODE	DTLH	DTLL	ETN	ESN	GPL2	(MGPL1) [RWCH]	[RWCL]

MODE = Mode Byte; Selects Operation Mode
DTLH = Data Length, High Byte
DTLL = Data Length, Low Byte
ETN = Ending Track Number
ESN = Ending Sector Number
GPL2 = Gap Length 2
MGPL1 = Gap Length 1 (used in SMD mode only); Controls Read Gate Timing
RWCH = Reduced Write Current (Cylinder No.), High Byte
RWCL = Reduced Write Current (Cylinder No.), Low Byte

The Specify command is used to set the operational mode of the HDC by presetting various parameters. Parameters such as MODE (figure 5, table 7), DTLH (figure 6), DTLL, ETN, ESN, GPL2, MGPL1/RWCH, and RWCL may be programmed into the HDC. This allows for a high degree of versatility. Data record length is programmable from 128 to 4095 bytes in soft-sector mode and 256 to 4095 bytes in hard-sector mode.

Figure 5. Mode Byte

0	ECC	CRCS	SSEC	DSL/ STP3	DSE/ STP2	SOM/ STP1	SOP/ STP0

Figure 6. DTLH Byte

1	CRC	PAD	POL	DTL11	DTL10	DTL9	DTL8

CRC = Initial Value of Polynomial Counter, Either All Zeros or All Ones
PAD = Selects ID/Data pad of 00H if 0
= Selects ID/Data pad of 4EH if 1
POL = Polling Mode if 0
= Nonpolling Mode if 1

Table 7. Mode Byte Bits

Bit Name	Specified Mode
ECC	1 ECC is appended in data field $(x^{21}+1)(x^{11}+x^2+1)$
	0 CRC is appended in data field
CRCS	1 Generator polynomial: $(x^{16}+1)$
	0 Generator polynomial: $(x^{16}+x^{12}+x^5+1)$
SSEC	1 Soft-sector disk (floppy-like interface) MFM data
	0 Hard-sector disk (SMD interface) NRZ data

	SSEC = 0		SSEC = 1
DSL	Data strobe late	STP3	(Note 1)
DSE	Data strobe early	STP2	(Note 1)
SOM	Servo offset minus	STP1	(Note 1)
SOP	Servo offset plus	STP0	(Note 1)

Note:
(1) Stepping rate for ST506 mode = (16-STP) × 2110 × t_{CY}
Assuming a 10 MHz processor clock: F_H = 2.11 ms...O_H = 33.76 ms

Sense Unit Status

Soft-Sector Mode

0011X	
	UST

SMD Mode

0011X	1	2	5
	UST	DS	DT

The Sense Unit Status (SUS) command is used to transfer the Unit Status (UST) to the host. In the case of SMD mode the SUS command may also be used to transfer the Detail Status (DS) and Device Type (DT) by using the appropriate preset parameter value as shown above. No preset parameters are used in the soft-sector mode, although one is required in the SMD mode. Values other than 1, 2, or 5 do not produce valid results.

After result bytes are placed in FIFO, HDC generates a FAULT CLEAR when in SMD mode.

The DS and DT bytes are defined by the type of drives used. The UST is shown in table 8.

Table 8. Unit Status Byte

Bit No.	Interface Type: SMD	Interface Type: ST506
D_7	Unit selected	0
D_6	Seek end	0
D_5	Write protected	0
D_4	0	Drive selected
D_3	Unit ready	Seek complete
D_2	On cylinder	Track 000
D_1	Seek error	Ready
D_0	Fault	Write fault

Detect Error

0100X	EADH	EADL	EPT1	EPT2	EPT3

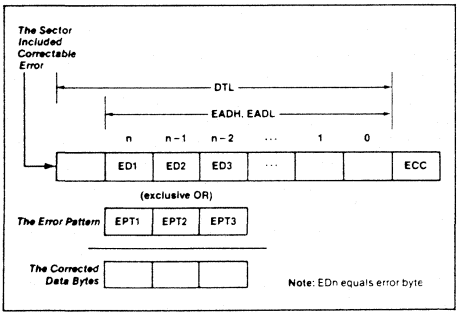
EADH = Error Address, High Byte
EADL = Error Address, Low Byte
EPT1 = Error Pattern, Byte 1
EPT2 = Error Pattern, Byte 2
EPT3 = Error Pattern, Byte 3

This command is used to transfer the error pattern and the error address to the host CPU, when correctable errors have occurred during the execution of a Read Data command with the ECC mode enabled.

The error address (EADH and EADL) is calculated from the last data byte of the sector that contained a correctable error which was indicated by the status bit of the previous Read Data command with the ECC mode enabled. The error pattern is used for correcting the error data at the location where the error occurred. After receiving the error address and the error pattern, the host CPU can correct the error data by performing an exclusive-OR of the error pattern and the error data. See figure 7.

The result bytes are available to the host CPU within 100μs.

Figure 7. Error Correction



Auxiliary Command

0000AAAA	

There are no preset parameters or result bytes associated with this command. The definitions of the 4 LSBs (AAAA) are given in figure 8 and table 9. The auxiliary command is accepted at any time and is immediately executed. The auxiliary command may be used to recover from certain types of error conditions, or to mask and clear interrupts.

Figure 8. Auxiliary Command

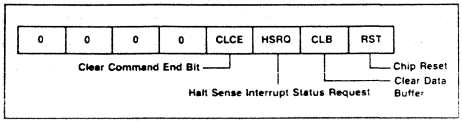


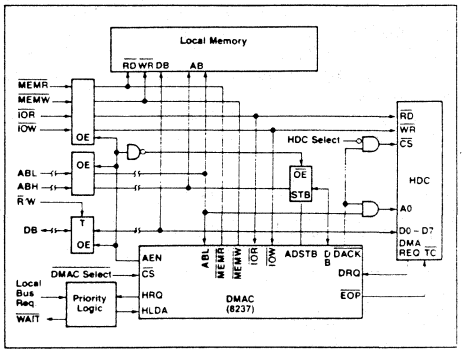
Table 9. Auxiliary Command Bits

Bit Name	Operation
CLCE	Clears the CE bits of the status register, inactivating the interrupt request output caused by Command End condition. This is used when no disk commands are going to be issued and it is desired to clear the interrupt.
HSRQ	Deactivates the interrupt request output caused by Sense Interrupt Status Request condition until a Command End occurs. However, this command has no effect on the SRQ bit of the status register.
CLB	Clears the data buffer.
RST	This has the same effect as a reset signal on the Reset input. This function is used whenever the RRQ bit in the status register is set (indicating the format controller is hung up), or when a software reset is needed.

System Example

Figure 9 shows an example of a local bus system.

Figure 9. Local Bus System



Track Format

Figure 10 shows track format for hard- and soft-sectored disks.

System Example Timing Diagrams

Figures 11 through 22 show the interface timing (soft-sector and hard-sector) required to interface the hard disk drive.

Figure 10. Track Format

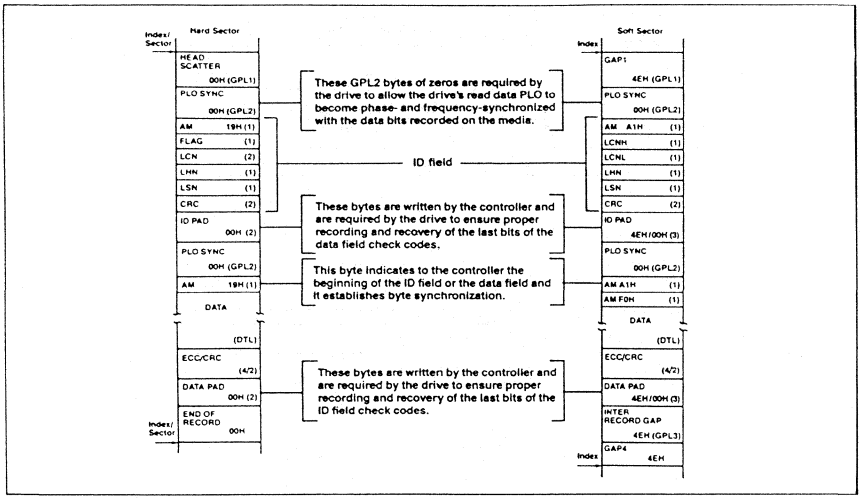


Figure 11. "Unit Selection" and "State Sense" Timing (Hard Sector)

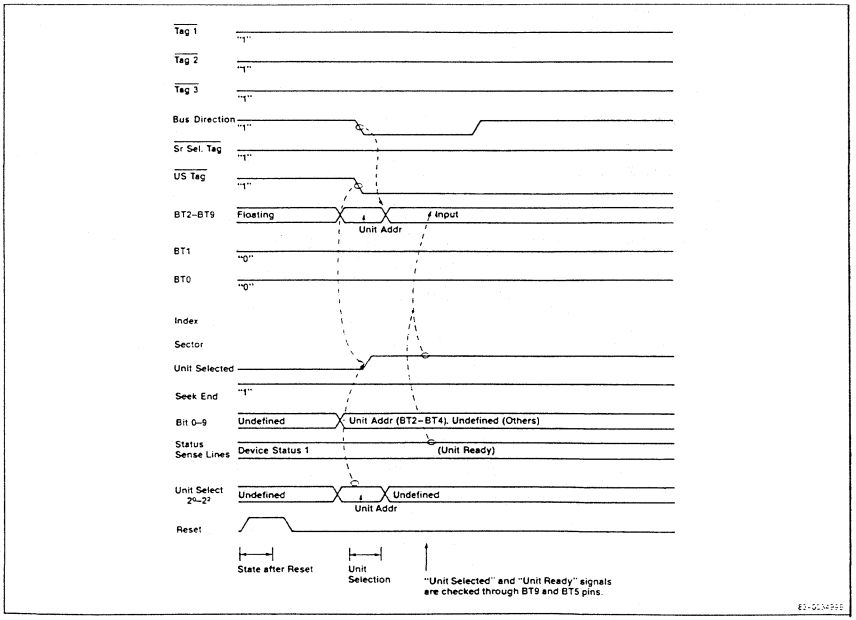


Figure 12. Return to Zero Timing (Hard Sector)

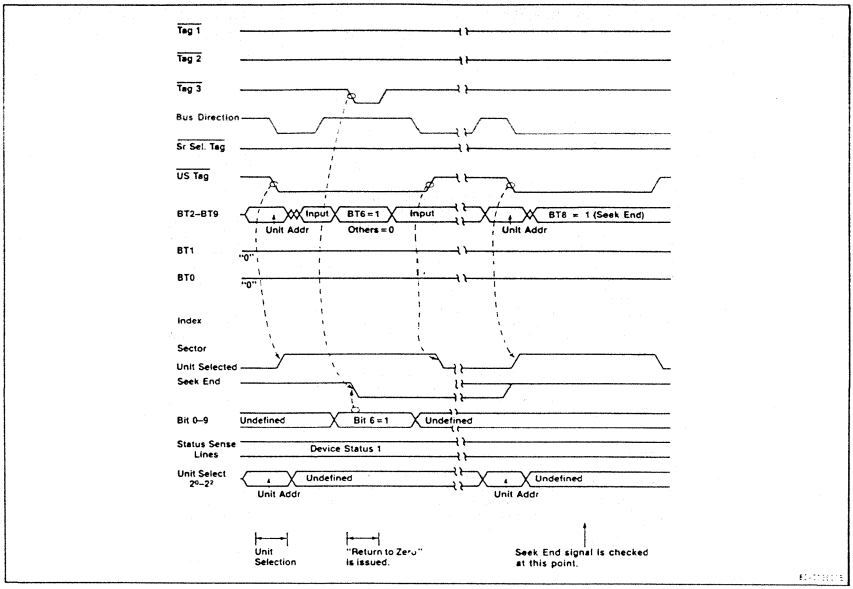


Figure 13. "Seek" Timing (Hard Sector)

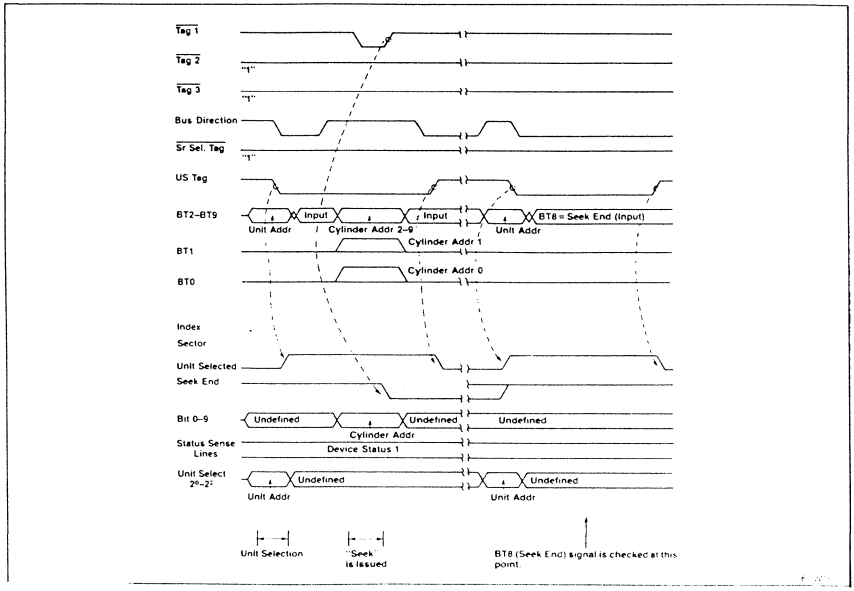


Figure 14. "Head Select" Timing (Hard Sector)

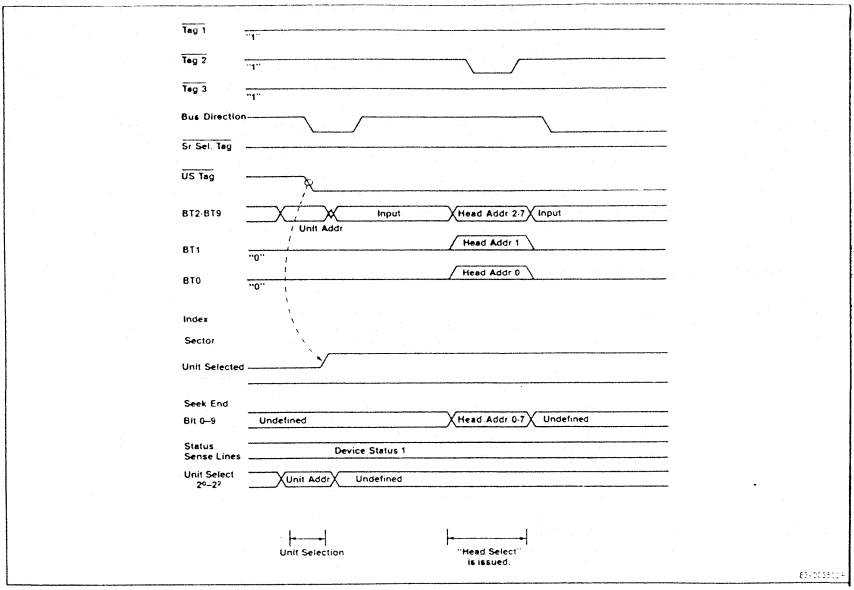


Figure 15. "Unit Status Sense' Timing (Hard Sector)

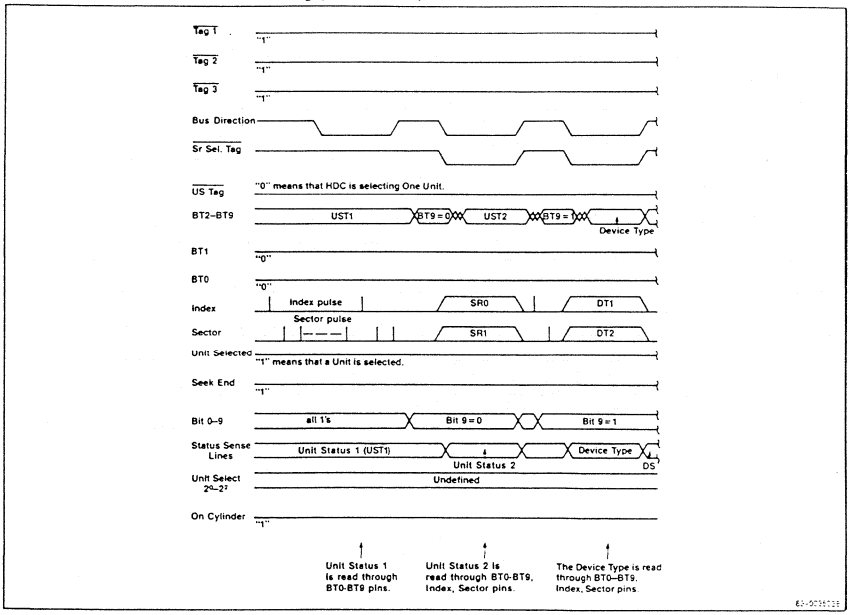


Figure 16. "Data Read" Timing (Hard Sector)

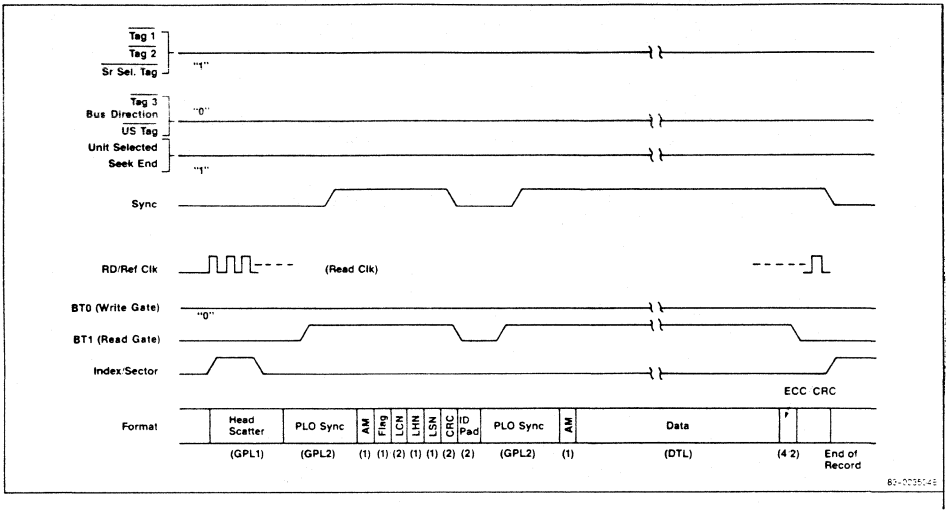


Figure 17. "Data Write" Timing (Hard Sector)

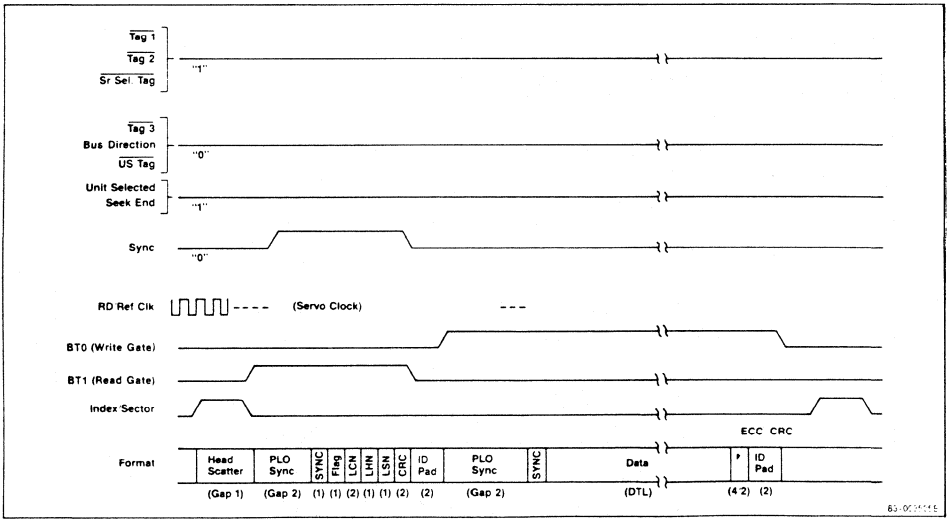


Figure 18. "Drive Select" and "Unit Status Sense" Timing (Soft Sector)

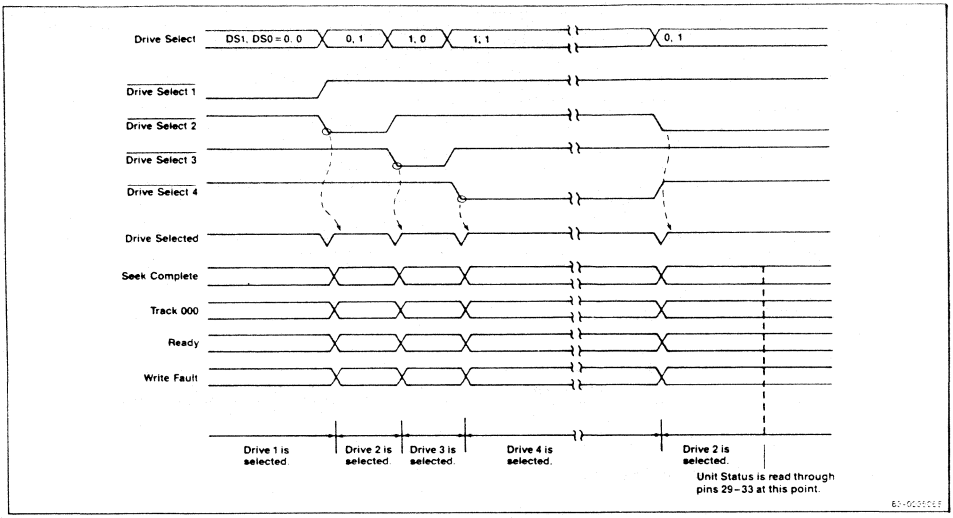


Figure 19. "Normal Seek" Timing (Soft Sector)

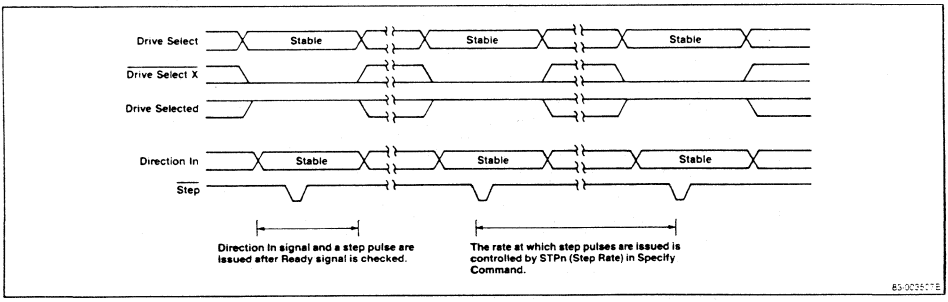


Figure 20. "Buffered Seek" Timing (Soft Sector)

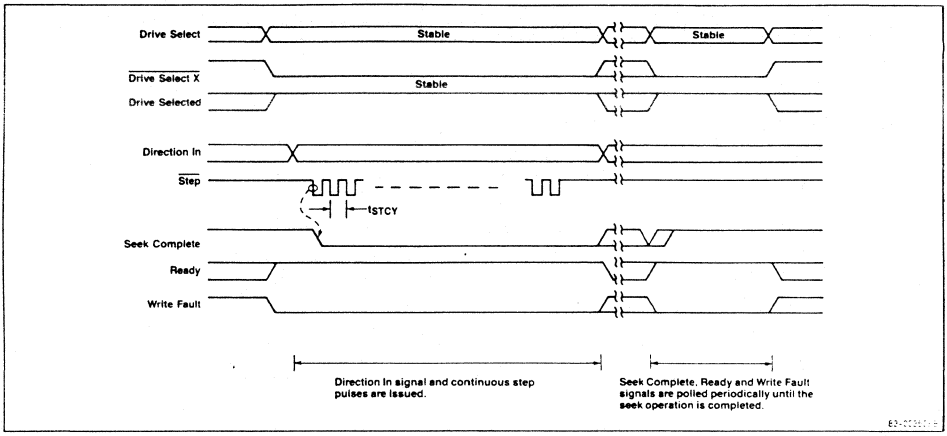


Figure 21. "Data Read" Timing (Soft Sector)

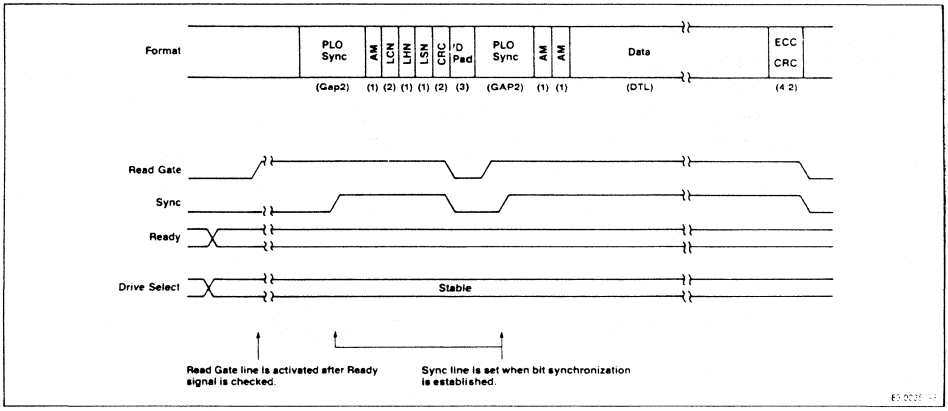
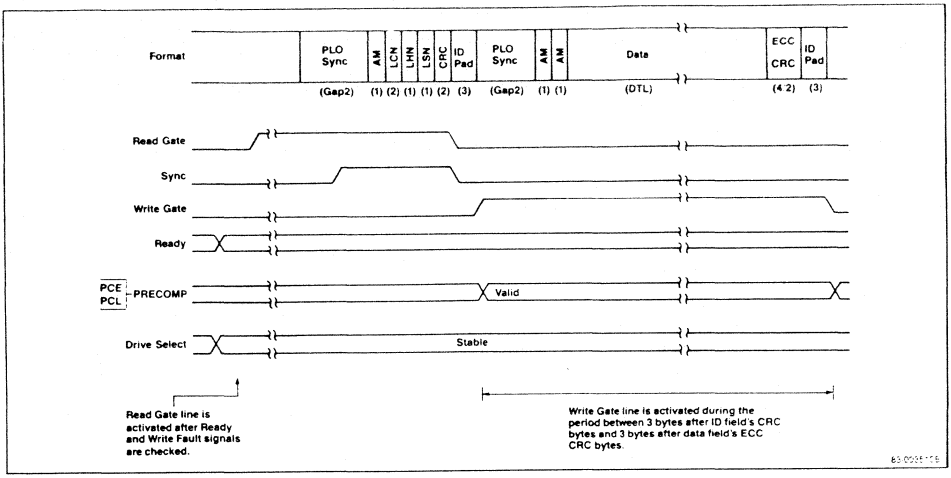


Figure 22. "Data Write" Timing (Soft Sector)



Description

The μPD9306A hard-disk interface (HDI) chips are unique CMOS single-chip support devices intended for use with the μPD7261A hard-disk controller. The μPD9306A includes a high-performance, digital phase-locked loop (DPLL), write precompensation logic, and μPD7261A CLK and R/W CLK generation. The μPD9306A requires only two inexpensive passive delay lines and a crystal for the self-contained oscillator. It provides a simple but effective solution to the design of support circuitry for typical hard-disk controllers utilizing the ST-506 type interface. Due to its fast acquisition time, the μPD9306A can actually provide increased storage by allowing for a size reduction in the sync field areas. The HDI also significantly reduces board area requirements and overall design time. The schematic examples included in this data sheet can be used to reduce the ST-506 interface design time to a few hours.

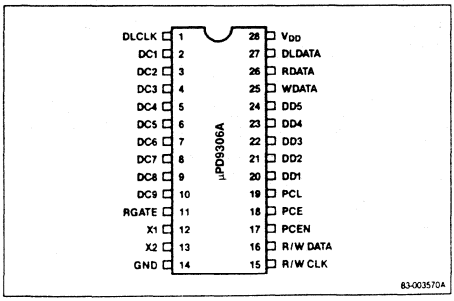
Features

- ☐ Unique digital phase-locked loop (no adjustments)
- ☐ Precompensation logic
- ☐ 5-MHz MFM data rate
- ☐ Internal crystal oscillator
- ☐ CMOS technology
- ☐ Single +5 V power supply

Ordering Information

Part Number	Package Type
μPD9306AC	28-pin plastic DIP

Pin Configuration



Pin Identification

No.	Symbol	Function
1	DLCLK	Delay line clock output
2-10	DC1-DC9	Delay clock inputs
11	RGATE	Read gate input
12	X1	Crystal clock input
13	X2	Crystal clock output
14	GND	Ground
15	R/W CLK	Read / write clock output
16	R/W DATA	Read / write data input / output
17	PCEN	Precompensation enable input
18	PCE	Precompensation early input
19	PCL	Precompensation late input
20-24	DD1-DD5	Delayed data inputs
25	WDATA	Write data output
26	RDATA	Read data input
27	DLDATA	Delay line data output
28	V_{DD}	+5 V power supply

Pin Functions

DC1-DC9 (Delayed Clock)

These nine inputs receive clock signals delayed relative to DLCLK. The delays for pins DC1-DC9 are 10 ns to 90 ns in 10 ns increments.

DD1-DD5 (Delayed Data)

These five inputs receive the input data signals, delayed relative to DLDATA. The delays for pins DD1-DD5 are 40, 60, 80, 90, and 100 ns respectively. As an option, DD1 and DD2 may be connected to the 30-ns and 70-ns taps, respectively, of delay line 1. Comparative performance data is shown in table 1.

DLDATA (Delay Line Data)

This output supplies the external delay line with processed read data from the disk or processed write data from the host.

DLCLK (Delay Line Clock)

This pin is used for the output clock of the on-chip oscillator and to supply clocks for both the delay line and the μPD7261A.

RGATE (Read Gate)

When this input is active, the digital phase-locked loop (DPLL) circuit generates a read/write clock that is synchronized to the phase of the read data from the disk.

R/W CLK (Read/Write Clock)

When RGATE is active, the DPLL selects one clock input from DLCLK or DC1-DC9. The clock input is synchronized with the read data at the R/W DATA pin and output via R/W CLK. When RGATE is inactive, the DPLL outputs the previously selected clock.

R/W DATA (Read/Write Data)

This pin outputs read data that has been synchronized with R/W CLK when RGATE is high. This pin inputs write data when RGATE is low.

RDATA (Read Data)

Input for read data from the hard-disk drive.

WDATA (Write Data)

Output for write data to the hard-disk drive. Precompensation is according to PCE, PCL, and PCEN states.

PCEN (Precompensation Enable)

Write precompensation is performed when this input signal is active.

PCE (Precompensation Early)

When PCE and PCEN are active, write data is advanced in phase from its nominal position and output on the WDATA pin. External delay lines determine the amount of time advance.

PCL (Precompensation Late)

When PCL and PCEN are active, write data is delayed in phase from its nominal position and output on the WDATA pin. External delay lines determine the amount of time delay.

X1, X2 (Crystal)

These two pins connect the crystal to the on-chip oscillator and clock generator.

V_{DD} (Power Supply)

+5 V power supply input.

GND (Ground)

Ground.

Absolute Maximum Ratings

$T_A = 25°C$

Power supply voltage, V_{DD}	−0.5 to +7.0 V (Note 1)
Input voltage, V_I	−0.5 to +7.0 V (Note 1)
Output current, I_O	10 mA
Operating temperature, T_{OPT}	0°C to +70°C
Storage temperature, T_{STG}	−65°C to +150°C

Note:
(1) With respect to ground.

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

$T_A = 0°C$ to +70°C, $V_{DD} = +5.0\,V \pm 10\%$ unless otherwise specified

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage high	V_{IH1}	2.0		$V_{DD}+0.5$	V	
	V_{IH2}	$0.7V_{DD}$		$V_{DD}+0.5$	V	
Input voltage low	V_{IL1}	−0.5		+0.8	V	(Note 3)
	V_{IL2}	0		$0.3V_{DD}$	V	(Note 4)
Output voltage high	V_{OH1}	$V_{DD}-0.4$			V	$I_{OH} = -1.0$ mA (Note 1)
	V_{OH2}	$V_{DD}-0.4$			V	$I_{OH} = -2.0$ mA (Note 2)
Output voltage low	V_{OL1}			+0.4	V	$I_{OL} = 3.2$ mA (Note 1)
	V_{OL2}			+0.4	V	$I_{OL} = 6.4$ mA (Note 2)
Input leakage current	I_{LI}			±10	μA	$0\,V \leq V_I \leq V_{DD}$
Output leakage current	I_{OL}			±10	μA	$0\,V \leq V_O \leq V_{DD}$
Supply current	I_{DD}		10	30	mA	

Note:
(1) All pins except DLCLK, DLDATA and R/W CLK.

(2) DLCLK, DLDATA, and R/W CLK pins only.

(3) all inputs except X1.

(4) X1 input.

Capacitance

$T_A = 25°C$, $f_C = 1MHz$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input capacitance	C_I			10	pF	(Note 1)
Output capacitance	C_O			15	pF	(Note 1)
I/O capacitance	C_{IO}			15	pF	(Note 1)

Note:
(1) All unmeasured pins returned to ground.

AC Characteristics

$T_A = 0°C$ to $+70°C$, $V_{DD} = +5.0V \pm 10\%$ (Note 1)

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
DLCLK, DLDATA rise time	t_{DLR}			20	ns	(Note 2)
DLCLK, DLDATA fall time	t_{DLF}			20	ns	(Note 2)
DLCLK cycle time	t_{CYDLK}		100		ns	
DLCLK high level width	t_{WDLKH}	40	50	60	ns	
DLCLK low level width	t_{WDLKL}	40	50	60	ns	
DLDATA high level width	t_{WDLH}	55	70	100	ns	
DC1–DC9, DD1–DD5 rise time	t_{DR}			30	ns	
DC1–DC9, DD1–DD5 fall time	t_{DF}			30	ns	
DC1–DC9 cycle time	t_{CYDC}		100		ns	
DC1–DC9 high level width	t_{WDCH}	40	50	60	ns	
DC1–DC9 low level width	t_{WDCL}	40	50	60	ns	
DD1–DD5 high level width	t_{WDH}	55	70	100	ns	
R/W CLK rise time	t_{RWR}			10	ns	
R/W CLK fall time	t_{RWF}			10	ns	
R/W CLK cycle time	t_{CYRW}	83	100		ns	
R/W CLK high level width	t_{WRWH}	30			ns	
R/W CLK low level width	t_{WRWL}	30			ns	

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Crystal frequency	f_{XTAL}		10	10.5	MHz	
DLCLK ↑ to DC9 ↑ delay time	t_{DDC1}	85	90	95	ns	(Note 3)
DCn ↑ to DCn+1 ↑ delay time (n=1, 2, ... 8)	t_{DDC2}	8	10	12	ns	(Note 3)
DLDATA ↑ to DD5 ↑ delay time	t_{DDD1}	95	100	105	ns	(Note 3)
DDn ↑ to DDn+1 ↑ delay time (n=2, 3, 4)	t_{DDD2}	8	10	12	ns	(Note 3)
R/W CLK ↑ to R/W DATA delay time	t_{DRW}	10	20	45	ns	RGATE = 1

Note:
(1) $C_{LOAD} = 30$ pF

(2) When delay line is driven

(3) Delay line specs used:
Delay time step = 10 ± 2 ns; total delay time = 100 ± 5 ns

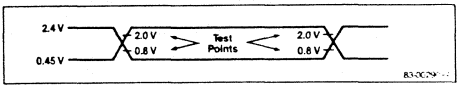
Table 1. μPD9306A Performance

Connection (Note 1)	Bit Jitter Margin	Speed Variation Tolerance
DD1 to 40-ns delay line tap and DD2 to 60-ns delay line tap	± 30 ns	± 2% (Note 2)
DD1 to 30-ns delay line tap and DD2 to 70-ns delay line tap	± 35 ns	± 1.5% (Note 2)

Note:
(1) Performance depends on precision of externally connected delay line.

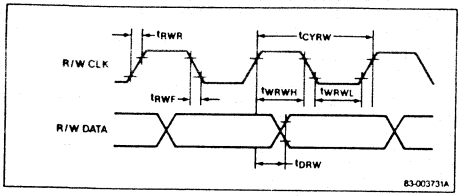
(2) Modern Winchester drives seldom exceed 0.5% speed variation.

AC Test Points

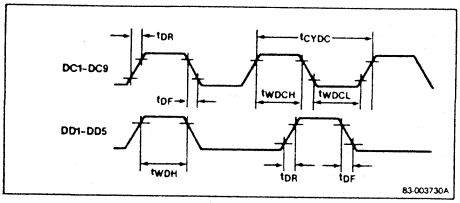


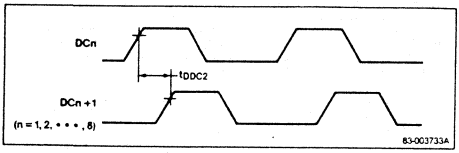
Timing Waveforms

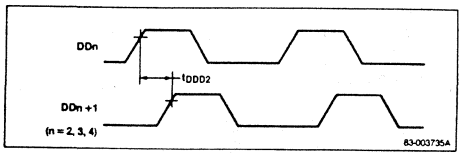
Controller Interface Timing (Read Operation Only)



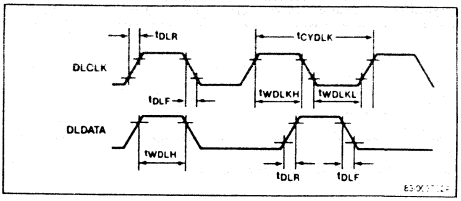
Delay Line Timing Requirements

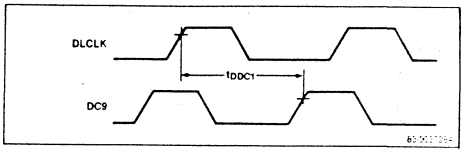


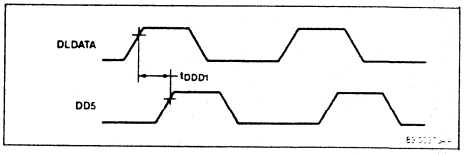




Delay Line Inputs





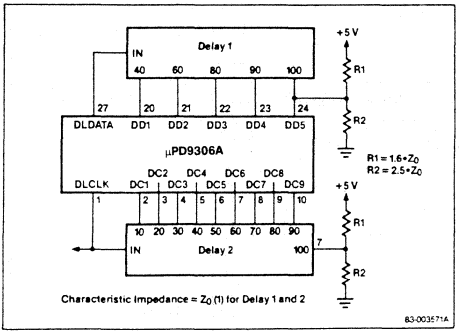


Functional Description

System Configuration

The schematic diagram in figure 1 illustrates the use of the μPD9306 A in conjunction with active delay lines. Active delay lines are the easiest to use in any application, but generally cost twice as much as the passive type. The μPD9306 A is capable of driving passive delay lines with 200 Ω or higher impedance. A circuit example is shown in figure 2. Passive delay lines will perform very well when provided with good grounds and proper termination.

Figure 1. System Configuration with Passive Delay Lines



Note:

(1) An internal terminating resistor provided with the delay line should not be used. The delay line should be terminated at the last stage output (100 ns) as shown.

Precompensation Circuit

Write precompensation is a technique that reduces the bit jitter present in read data, thereby increasing reliability. It is typically used only on the inner cylinders. When data is written to the disk, pulse crowding takes place on the higher-numbered inner cylinders where the same amount of data is compressed into less space than on the outer cylinders. A high percentage of the bit jitter present in the read data is due to magnetic effects causing flux transitions to occur displaced from their nominal position. These effects are predictable based on the pattern of data being recorded. Precompensation reduces bit jitter by writing the data slightly before or slightly after the nominal pulse transition time in a direction opposite to the expected jitter.

Various manufacturers of many ST-506 style Winchester disk drives use delay values of 10–12 ns. The μPD7261A generates the two precompensation control signals, precompensation early (PCE) and precompensation late (PCL), to direct the write data through one of three delay pathways. There is circuitry within the μPD9306A allowing it to operate with PCE/L and R/W DATA skewed from each other by as much as 50 ns. This eliminates the need for synchronizing the precompensation and write data signals externally.

The μPD9306 A utilizes the data path delay line for both the precompensation and the phase-comparator circuit. When RGATE is low, data appearing on the R/W DATA line is written to the drive. The write data is passed through delay line 1, and the 80-, 90- and 100-ns taps are used for the early, nominal and late signals.

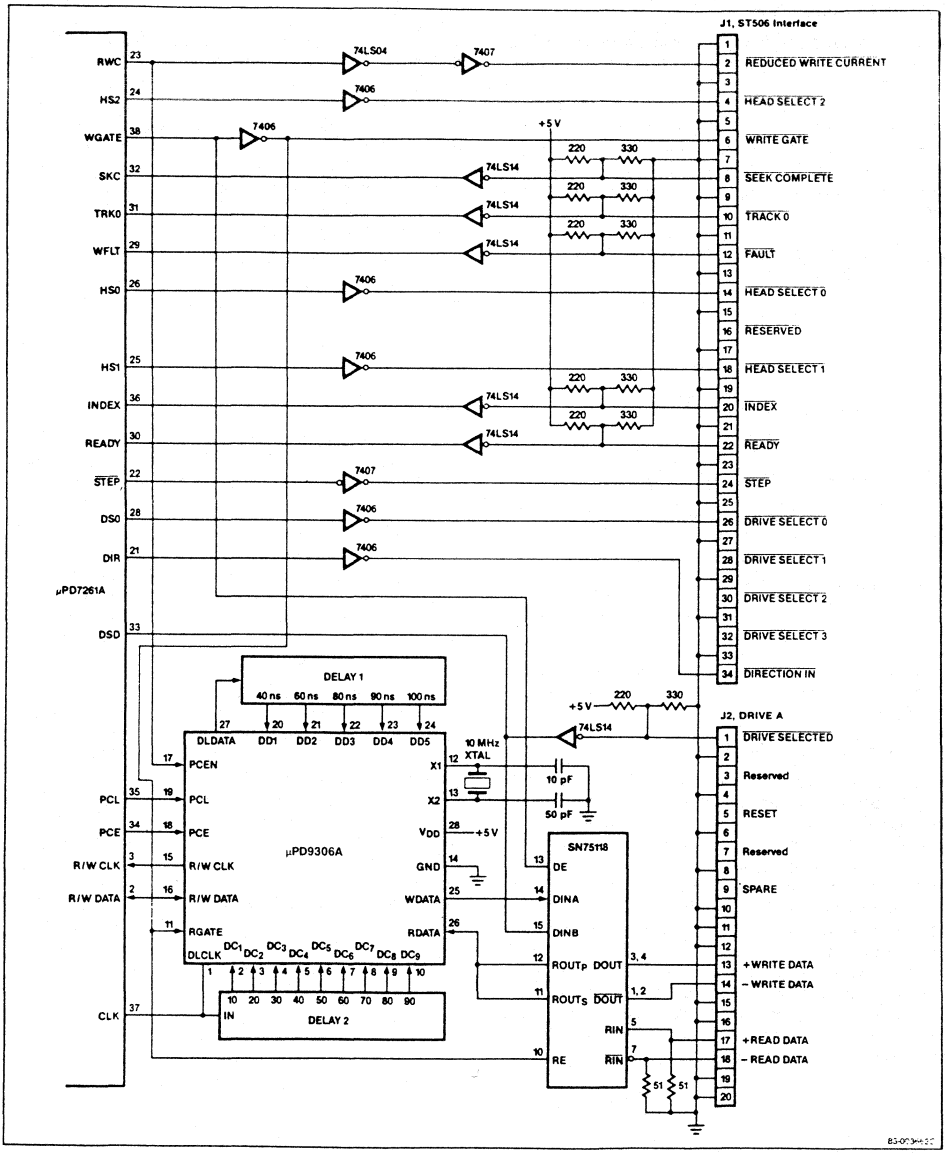
Digital Phase-Locked Loop

The μPD9306 A employs unique circuitry to accomplish the phase-locked loop (PLL) function, which simplifies the overall design and provides very low error rate data recovery.

The raw read data from the ST-506 Winchester is MFM encoded and consists of clock and data pulses. The data format on the disk is broken into sectors with each sector containing sync fields, address marks, ID fields, and data fields. The different fields each have specific functions. For an in-depth explanation of each of these, refer to the μPD7261A user's manual.

Typically, a Winchester controller will have a data separator that recovers data from the MFM data stream. Within the data separator are several functional blocks that include a sync field detector, phase-locked loop (consisting of a phase comparator, error amplifier, low-pass filter, voltage-controlled oscillator, and pulse synchronizing logic), reference oscillator, and address mark detector. The μPD9306 A eliminates the need for many of these functional blocks. It acquires "lock" within 4 bit times in a sync field, yet it is incapable of locking to a harmonic, as analog PLL circuits are prone to do. The μPD9306 A is also immune to the high-frequency bursts that may occur during the write splice areas of the disk.

Figure 2. ST 506 Interface Proposal



The μPD9306 A simulates the function of an analog VCO by using a digital phase-shift network. One of the external delay lines is used to generate ten phase-shifted reference clocks. These clocks have a frequency of 10 MHz and are phase shifted in equal degree increments. The total delay line time is 100 ns, which is the same as the period of the clock, providing a complete 360° phase shift. The μPD9306 A synthesizes the VCO signal by internally selecting one of the phase-shifted clock signals. The rate at which the clock is phase-shifted in one direction or the other corresponds to an increase or decrease in the resulting frequency.

The internal phase comparator uses the data delay line (Delay 1) to divide the data window into ten slices. Depending on where the sampling edge of the recovery clock falls within the data window, a proprietary algorithm changes the phase of the recovery clock. The μPD9306 A has the same jitter rejection abilities that you would expect from a well-designed analog PLL. It can accept disk data with jitter in excess of plus or minus 30 ns. As an option, delay line 1 taps DD1 and DD2 may be connected to the 30-ns and the 70-ns tap respectively. Due to this option, the μPD9306 A performance is affected by its immunity to bit jitter and its tolerance to speed variation as shown in table 1.

NEC

μPD7262
ENHANCED SMALL DEVICE INTERFACE CONTROLLER

PRELIMINARY INFORMATION

Description

The μPD7262 is a highly-integrated, single-chip controller for ESDI Winchester Disks. While conforming to the complete revision E of the ESDI specification, this device executes 22 high-level commands that provide flexibility and ease of usage. The μPD7262 is based on the proven μPD7261A/μPD7260 architecture but adapted to the special requirements of this disk interface. It eliminates numerous ICs and gives complete access to all of the features implemented by the ESDI disk drive manufacturers.

Features

- ☐ Controls ESDI serial mode disks
- ☐ Controls up to seven disk drives
- ☐ Programmable soft and hard sector formats
- ☐ 18-MHz data transfer rate
- ☐ Multi-sector, -track, and -cylinder transfer capability
- ☐ Implied seek and parallel seek capability
- ☐ 22 high level disk commands and 4 auxiliary commands
- ☐ CRC error detection
- ☐ ECC error detection and correction
- ☐ Single +5 volt supply
- ☐ NMOS 40-pin DIP

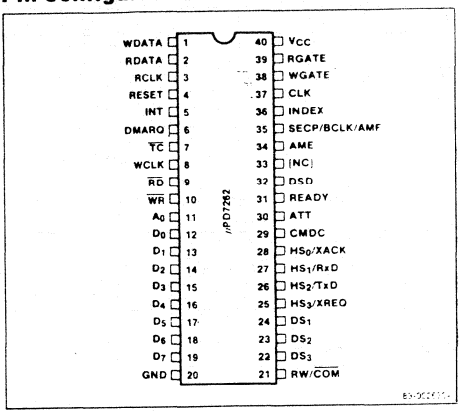
Disk Commands

Check	Read Diagnostic
Chip Reset	Read ID
Clear Command End Bit	Recalibrate
Clear Data FIFO	Scan
Detect Error	Send
Format Sector	Send Extended
Format Track	Sense Seek Status
Get Internal Information	Sense Unit Status
Group Assign	Specify1
Logical Seek	Specify2
Mask SRQ Interrupt	Verify Data
Physical Seek	Verify ID
Read Data	Write Data

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD7262D	40-pin ceramic DIP	18 MHz

Pin Configuration



Pin Identification

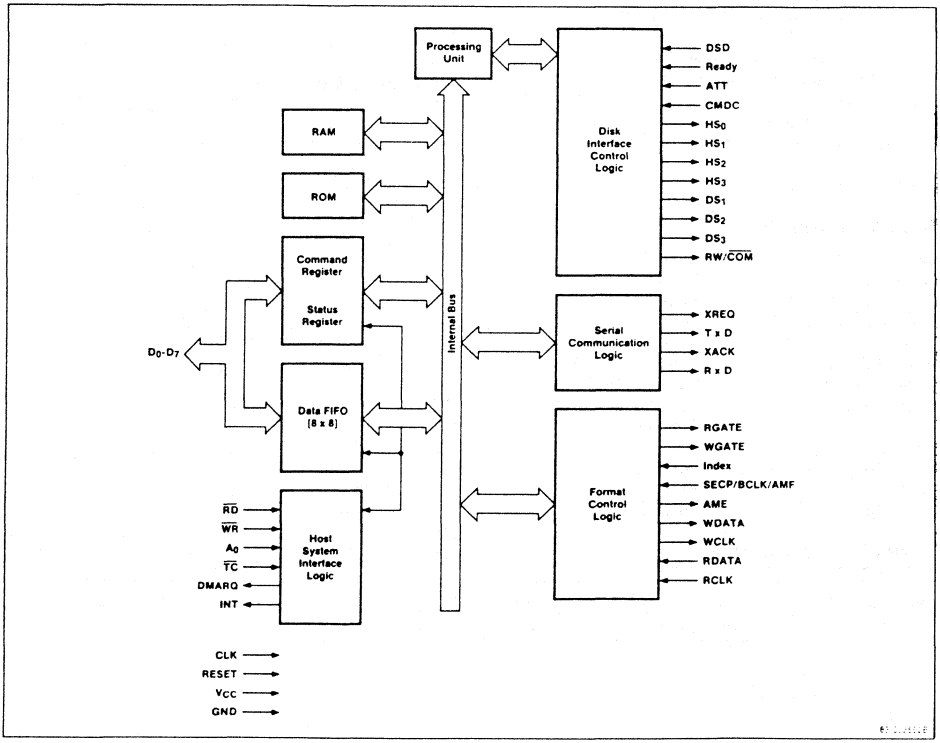
No.	Symbol	Function
1	WDATA	NRZ write data output to ESDI drive
2	RDATA	NRZ read data input from ESDI drive
3	RCLK	Read/reference clock input from ESDI drive
4	RESET	System reset input
5	INT	Interrupt request output
6	DMARQ	DMA request output
7	$\overline{TC}$	Terminal count input from DMAC
8	WCLK	Write clock output to ESDI drive
9	$\overline{RD}$	Read control input signal from host computer
10	$\overline{WR}$	Write control input signal from host computer
11	A_0	Address select input from host computer
12-19	D_0-D_7	Data bus from host computer
20	GND	System ground
21	RW/$\overline{COM}$	This output specifies the status of pins 25-28
22-24	DS_3-DS_1	Drive select outputs to ESDI drive

Pin Identification (cont)

No.	Symbol	Function
25 26 27 28	HS_3/XREQ HS_2/TxD HS_1/RxD HS_0/XACK	If RW/COM = 1: head select (HS) outputs to ESDI drive. If RW/COM = 0 for serial data transfer to ESDI drive: transfer request (XREQ) output, transmit data (TxD) output, receive data (RxD) input, and transfer acknowledge (XACK) input.
29	CMDC	Command complete input from ESDI drive
30	ATT	Attention input from ESDI drive
31	READY	Ready input from ESDI drive
32	DSD	Drive selected input from ESDI drive

No.	Symbol	Function
33	NC	Not connected; leave open
34	AME	Address mark enable output from ESDI drive
35	SECP/BCLK/AMF	Sector pulse or byte clock or address mark found; input from ESDI drive (mutually exclusive)
36	INDEX	Index detected input from ESDI drive
37	CLK	System clock input to μPD7262
38	WGATE	Write gate output to ESDI drive
39	RGATE	Read gate output to ESDI drive
40	V_{CC}	+5 V (Typical) input

Block Diagram



μPD7201A
MULTIPROTOCOL SERIAL COMMUNICATION CONTROLLER

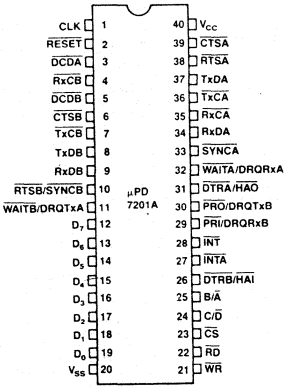
Description

The μPD7201A is a dual-channel multifunction peripheral communication controller designed to satisfy a wide variety of serial data communication requirements in computer systems. Its basic function is a serial-to-parallel, parallel-to-serial converter/controller and within that role it is configurable by systems software so its "personality" can be optimized for a given serial data communications application.

The μPD7201A is capable of handling asynchronous and synchronous byte-oriented protocols such as IBM Bisync, and synchronous bit-oriented protocols such as HDLC and IBM SDLC. This versatile device can also be used to support virtually any other serial protocol for applications other than data communications.

The μPD7201A can generate and check CRC codes in any synchronous mode and can be programmed to check data integrity in various modes. The device also has facilities for modem controls in both channels. In applications where these controls are not needed the modem controls can be used for general-purpose I/O.

Pin Configuration



Features

- ☐ Two fully independent duplex serial channels
- ☐ Four independent DMA channels for send/received data for both serial inputs/outputs
- ☐ Programmable interrupt vectors and interrupt priorities
- ☐ Modem controls signals
- ☐ Variable software programmable data rate, up to 1.1M baud at 5MHz clock
- ☐ Double buffered transmitter data and quadruply buffered received data
- ☐ Programmable CRC algorithm
- ☐ Selection of Interrupt, DMA or Polling mode of operation
- ☐ Asynchronous operation
  - Character length: 5, 6, 7, or 8 bits
  - Stop bits: 1, 1½, 2
  - Transmission speed: x1, x16, x32, or x64 clock frequency
  - Parity: odd, even, or disable
  - Break generation and detection
  - Interrupt on parity, overrun, or framing errors
- ☐ Monosync, bisync, and external sync operations
  - Software selectable sync characters
  - Automatic sync insertion
  - CRC generation and checking
- ☐ HDLC and SDLC operations
  - Abort sequence generation and detection
  - Automatic zero insertion and detection
  - Address field recognition
  - CRC generation and checking
  - I-field residue handling
- ☐ N-channel MOS technology
- ☐ Single +5V power supply; interface to most microprocessors including 8080, 8085, 8086, and others.
- ☐ Single-phase TTL clock
- ☐ Available in plastic and ceramic dual-in-line packages

Pin Identification

Pin No.	Symbol	Name	I/O	Description
1	CLK	System Clock	I	The μPD7201A uses a standard TTL clock.
2	RESET	Reset	I	A low RESET disables both receivers and transmitters, forces TxDA and TxDB marking, forces the modem controls high and disables all interrupts. The control registers must be rewritten after the μPD7201A is reset and before data is transmitted or received. RESET must be active for a minimum of one complete CLK cycle. (Active Low)
3, 5	DCDA, DCDB	Data Carrier Detect	I	These signals are similar to the CTS inputs except they can be used as receiver enables. (Active Low)
4, 35	RxCA, RxCB	Receiver Clocks	I	The receiver clocks may be 1, 16, 32, or 64 times the data rate in asynchronous modes. Receive data is sampled on the rising edge of RxC.
6, 39	CTSA, CTSB	Clear to Send	I	When programmed as auto enables, a low on these inputs enables the respective transmitter. If not programmed as auto enables, these inputs may be programmed as general-purpose inputs. Both inputs are Schmitt-trigger buffered to accommodate slow rise-time inputs. The μPD7201A detects pulses on these inputs and interrupts the processor on both logic level transitions. The Schmitt-trigger inputs do not guarantee a specified noise-level margin. (Active Low)
7, 36	TxCA, TxCB	Transmitter Clocks	I	In asynchronous modes, the transmitter clocks may be 1, 16, 32, or 64 times the data rate. The multiplier for the transmitter and the receiver must be the same. Both TxC and RxC inputs are Schmitt-trigger buffered for relaxed rise- and fall-time requirements (no noise margin is specified). TxD changes on the falling edge of TxC.
8, 37	TxDA, TxDB	Transmit Data	O	(Active High)
9, 34	RxDA, RxDB	Receive Data	I	(Active High)
10, 33	SYNCA, SYNCB	Synchronization	I/O	These pins can act either as inputs or outputs. In the asynchronous receive mode they are inputs similar to CTS and DCD. In this mode the transitions on these lines affect the state of the Sync/Hunt status bits in read register 0. In the external sync mode these lines also act as inputs. When external synchronization is achieved, SYNC must be driven low on the second rising edge of RxC after that rising edge of RxC on which the last bit of the sync character was received. In other words, after the sync pattern is detected, the external logic must wait for two full receive clock cycles to activate the SYNC input. Once SYNC is forced low it is wise to keep it low until the processor informs the external sync logic that synchronization has been lost or a new message is about to start. Character assembly begins on the rising edge of RxC that immediately precedes the falling edge of SYNC in the external sync mode. (Active Low) In the internal synchronization mode (monosync and bisync) these pins act as outputs that are active during the part of the receive clock (RxC) cycle in which sync characters are recognized. The sync condition is not latched.
10, 38	RTSA, RTSB	Request to Send	O	When the RTS bit is set, the RTS output goes low. When the RTS bit is reset in the asynchronous mode, the output goes high after the transmitter is empty. In synchronous modes, the RTS pin strictly follows the state of the RTS bit. Both pins can be used as general-purpose outputs. (Active Low)
11, 29, 30, 32	DRQTxA, DRQTxB DRQRxA, DRQRxB	DMA Request	O	These signals are generated by the receiver or transmitter of channel A and channel B. These signals can be connected to most DMA controllers directly and are used for handshaking during DMA transfer. (Active High)
11, 32	WAITA, WAITB	Wait	O	Wait lines for both channels that synchronize the processor to the μPD7201A data rate. The reset state is open drain.
12 –19	D_0–D_7	System Data Bus	I/O	The system data bus transfers data and commands between the processor and the μPD7201A. D_0 is the least significant bit. (Tristate)
20	V_{SS}	Ground		Ground.
21	WR	Write	I	The WR signal is used to control the transfer of either command or data from the processor or the memory to the μPD7201A. (Active Low)
22	RD	Read	I	If RD is active, a memory or I/O read operation is in progress. RD is used with C/D, B/A, and CS to transfer data from the μPD7201A to the processor or the memory. (Active Low)
23	CS	Chip Select	I	A low level at this input enables the μPD7201A to accept command or data inputs from the processor during a write cycle, or to transmit data to the processor during a read cycle. (Active Low)
24	C/D	Control or Data Select	I	This input defines the type of information transfer performed between the processor and the μPD7201A. A high at this input during a processor write to or read from the μPD7201A causes the information on the data bus to be interpreted as a command for the channel selected by B/A. A low at C/D means that the information on the data bus is data. (High selects Control)
25	B/A	Channel A or B Select	I	This input defines which channel is accessed during a data transfer between the processor and the μPD7201A. (High selects Channel B)
26	HAI①	DMA Acknowledge	I	Typically, the HLDA signal driven from the processor is input to the HAI terminal of the highest priority μPD7201A, and the HAO output of that μPD7201A is daisy-chained to the HAI input of the lower priority μPD7201A and propagated downstream. HAI and HAO signals provide acknowledgement for the highest priority outstanding DMA request. (Active Low)
26, 31	DTRA, DTRB	Data Terminal Ready	O	These outputs follow the state programmed into the DTR bit. They can also be programmed as general-purpose outputs. (Active Low)
27	INTA	Interrupt Acknowledge	I	This signal is generated by the processor and is sent to all peripheral devices. It serves to acknowledge the interrupt and to allow the highest priority interrupting device to put an 8-bit vector on the bus. INT and INTA are compatible with the fully nested option of the μPD8259A-5. (Active Low)
28	INT	Interrupt Request	O	When the μPD7201A is requesting an interrupt, it pulls INT low. (Open Collector, Active Low)
29	PRI	Priority In	I	PRI is used with PRO to form a priority daisy-chain when there is more than one interrupt-driven device. A low on this line indicates no other device of higher priority is being serviced by a processor interrupt service routine. (Active Low) PRO is low only if PRI is low and the processor is not servicing an interrupt from the μPD7201A. Thus, this signal blocks lower priority devices from interrupting while a higher priority device is being serviced by its processor interrupt service routine. (Active Low)
30	PRO	Priority Out	O	
31	HAO①	DMA Acknowledge	O	Typically, the HLDA signal driven from the processor is input to the HAI terminal of the highest priority μPD7201A, and the HAO output of that μPD7201A is daisy-chained to the HAI input of the lower priority μPD7201A and propagated downstream. HAI and HAO signals provide acknowledgement for the highest priority outstanding DMA request. (Active Low)

Note: ① The HAI HAO functions are only available in the DMA internal priority mode

Programming the MPSC²

The software operation of the MPSC² is very straightforward. Its consistent register organization and high-level command structure help minimize the number of operations required to implement complex protocol designs. Programming is further simplified by the MPSC²'s extensive interrupt and status reporting capabilities. This section is divided into two parts.

The MPSC² Registers

The MPSC² interfaces to the system software with a number of control and status registers associated with each channel. Commonly used commands and status bits are accessed directly through control and status registers 0. Other functions are accessed indirectly with a register pointer to minimize the address space that must be dedicated to the MPSC².

Control Register

Control Register	Function
0	Frequently used commands and register pointer control
1	Interrupt control
2	Processor/bus interface control
3	Receiver control
4	Mode control
5	Transmitter control
6	Sync/address character
7	Sync character

Status Register

Status Register	Function
0	Buffer and "external/status" status
1	Received character error and special condition status
2 (Channel B only)	Interrupt vector
3	Tx byte count register, low byte
4	Tx byte count register, high byte

All control and status registers except CR2 are separately maintained for each channel. Control and status registers 2 are linked with the overall operation of the MPSC² and have different meanings when addressed through different channels.

When initializing the MPSC² control register 2A (and 2B if desired) should be programmed first to establish the MPSC² processor/bus interface mode. Each channel may then be programmed to be used separately, beginning with control register 4 to set the protocol mode for that channel. The remaining registers may then be programmed in any order.

Control Register 0

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
CRC Control Command		Command			Register Pointer		

Register pointer ($D_0 - D_2$)

The register pointer specifies which register number is accessed at the next control register write or status register read. After a hardware or software reset the register pointer is set to zero. Therefore, the first control byte goes to control register 0. When the register pointer is set to a value other than zero the next control or status ($C/\overline{D} = 1$) access is to the specified register, after which the pointer is reset to zero. Other commands can be freely combined in control register 0 by setting the register pointer.

Commands ($D_3 - D_5$)

Commands commonly used during the operation of the MPSC² are grouped in control register 0. They include the following:

Null (000): This command has no effect and is used only to set the register pointer or issue a CRC command.

Send abort (001): When operating in the SDLC mode this command causes the MPSC² to transmit the SDLC abort code, issuing 8 to 13 consecutive ones. Any data currently in the transmitter or the transmitter buffer is destroyed. After sending the abort the transmitter reverts to the idle phase (flags). When using the Tx byte count mode enable (D_6 of CR1), and an underrun condition occurs, the μPD7201A will automatically issue the send abort command.

Reset external status interrupts (010): When the external/status change flag is set, the condition of bits $D_3 - D_7$ of status register 0 are latched to allow the capture of the short pulses that may occur. The reset external/status interrupts command reenables the latches so that new interrupts may be sensed.

Channel reset (011): This command has the same effect on a single channel as an external reset at pin 2. A channel reset command to channel A resets the internal interrupt prioritization logic. This does not occur when a channel reset command is issued to channel B. All control registers associated with the channel to be reset must be reinitialized. After a channel reset, wait at least four system clock cycles before writing new commands or controls to that channel.

Enable interrupt on next character (100): When operating the MPSC² in an interrupt on first received character mode this command may be issued at any time. This command must be issued at the end of a message to reenable the interrupt logic for the next received character (the first character of the next message).

Reset pending transmitter interrupt/DMA request (101): A pending transmitter buffer becoming empty interrupt or DMA request can be reset without sending another character by issuing this command (typically at the end of a message). A new transmitter buffer becoming empty interrupt or DMA request is not made until another character has been loaded and transferred to the transmitter shift register or when, if operating in the synchronous or SDLC modes, the first CRC character has been sent.

Error Reset (110): This command resets a special receive condition interrupt. It also reenables the parity and overrun error latches that allow errors at the end of a message to be checked.

End of interrupt (111) (channel A only): Once an interrupt request has been issued by the MPSC² all lower priority internal and external interrupts in the daisychain are held off to permit the current interrupt to be serviced while allowing higher priority interrupts to occur. At some point in the interrupt service routine (generally at the end), the end of interrupt command must be issued to channel A to reenable the daisychain and allow any pending lower priority internal interrupt requests to occur. The EOI command must be sent to channel A for interrupts that occurred on either channel.

CRC Control Commands ($D_6 - D_7$)
The following commands control the operation of the CRC generator/checker logic.

Null (00): This command has no effect and is used when issuing other commands or setting the register pointer.

Reset receiver CRC checker (01): This command resets the CRC checker to zero when the channel is in a synchronous mode and resets to all ones when in an SDLC mode.

Reset transmitter CRC generator (10): This command resets the CRC generator to zero when the channel is in a synchronous mode and resets to all ones when in an SDLC mode.

Reset idle/CRC latch (11): This command resets the idle/CRC latch so that when a transmitter underrun condition occurs (that is, the transmitter has no more characters to send), the transmitter enters the CRC phase of operation and begins to send the 16-bit CRC character calculated up to that point. The latch is then set so that if the underrun condition persists, idle characters are sent following the CRC. After a hardware or software reset the latch is in the set state. This latch is automatically reset after the first character has been loaded into the Tx buffer in the SDLC mode.

Control Register 1

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
Wait Function Enable	Tx Byte Count Mode Enable	Wait on Receiver Transmitter	Receiver Interrupt Mode		Condition Affects Vector	Transmitter Interrupt Enable	Ext/Status INT Enable

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
Low Byte							

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
High Byte							

External/status interrupt enable (D_0)
When this bit is set to one the MPSC² issues an interrupt whenever any of the following conditions occur:

- Transition of the $\overline{DCD}$ input pin
- Transition of the $\overline{CTS}$ input pin
- Transition of the $\overline{SYNC}$ input pin
- Entering or leaving synchronous hunt phase, break detection or termination
- SDLC abort detection or termination
- Idle/CRC latch becoming set (CRC being sent)
- After ending flag is sent in the SDLC mode

Transmitter interrupt enable (D_1)
When this bit is set to one the MPSC² issues an interrupt when:

1) The character currently in the transmitter buffer is transferred to the shift register (transmitter buffer becoming empty) or,
2) The transmitter enters the idle phase and begins transmitting sync or flag characters.
3) The Tx byte mode enable bit is set (CR1 – D6 = 1). The 7201A will automatically issue a Tx interrupt or DMA request when the transmitter becomes enabled (CR5 – D3 = 1).

Condition affects vector (D_2) (programmed in channel B for both channels)
When this bit is set to zero the fixed vector programmed in CR2B during MPSC² initialization is returned in an interrupt acknowledge sequence. When this bit is set to one the vector is modified to reflect the condition that caused the interrupt.

Receiver interrupt mode ($D_3 - D_4$)
This field controls how the MPSC²'s interrupt/DMA logic handles the character received condition.

Receiver interrupts/DMA request disabled (00)
The MPSC² does not issue an interrupt or a DMA request when a character has been received.

Interrupt/DMA on first received character only (01)
In this mode the MPSC² issues an interrupt only for the first character received after an enable interrupt/DMA on first character command (CR0) has been given. If the channel is in a DMA mode, a DMA request is issued for each character received including the first. This mode generally is used whenever the MPSC² is in a DMA or block transfer mode. This will signal the processor that the beginning of an incoming message has been received.

Interrupt (and issue a DMA request) on all received characters (10)
In this mode an interrupt (and DMA request if the DMA mode is selected) is issued whenever there is a character present in the receiver buffer. A parity error is considered a special receive condition.

Interrupt (and issue a DMA request) on all received characters (11)
This mode is the same as the one above except that a parity error is not considered a special receive condition. The following are considered special receive conditions:

- Receiver overrun factor
- Asynchronous framing error
- Parity error (if specified)
- SDLC end of message (final flag received)

Wait on receiver/transmitter (D_5)
If the wait function is enabled for block mode transfers, setting this bit to zero causes the MPSC² to issue a wait ($\overline{WAIT}$ output goes low) when the processor attempts to write a character to the transmitter while the transmitter buffer is full. Setting this bit to one causes the MPSC² to issue a wait when the processor attempts to read a character from the receiver while the receiver buffer is empty.

Tx byte count mode enable (D_6)

Each channel has a 16-bit Tx byte count register used for automatic transmit termination. When this bit is set to one the next two consecutive command cycle writes will be to the byte count register. The first byte is loaded into the lower 8 bits and the second to the upper 8 bits of the byte count register. The byte count register holds the number of transfers to be performed by the transmitter. A byte counter is incremented each time a transfer is performed until the value of the byte counter is equal to the value in the byte count register. When equal, interrupts or DMA requests will be stopped until the byte count enable bit is issued and a new byte count is loaded into the byte count register. If a transmit underrun occurs in the SDLC mode, and the byte count is not equal to the byte count register, the abort sequence will be sent automatically.

Also, when using the Tx byte count mode, a transmit interrupt or DMA request will automatically become active after issuing the Tx enable command to CR5.

The Tx byte count mode can be cleared by either a channel reset command or a hardware reset.

Wait function enable (D_7)

Setting this bit to one enables the wait function which is described in CR1.

Control Register 2 (Channel A)

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
Pin 10 SYNCB/RTSB	Rx INT Mask	Interrupt Vector Mode			Priority	DMA Mode Select	

DMA mode select ($D_0 - D_1$)

Setting this field determines whether channel A or B is used in a DMA mode (i.e., data transfers are performed by a DMA controller) or in a non-DMA mode where transfers are performed by the processor in either a polled, interrupt, or block transfer mode. The functions of some MPSC² pins are also controlled by this field.

DMA Mode Selection

		Channel		Pin Function					
D_1	D_0	A	B	11	26	29	30	31	32
0	0	Non-DMA	Non-DMA	WAITB	DTRB	PRI	PRO	DTRA	WAITA
0	1	DMA	Non-DMA	DRQTxA	HAI	PRI	PRO	HAO	DRQRxA
1	0	DMA	DMA	DRQTxA	HAI	DRQRxB	DRQTxB	HAO	DRQRxA
1	1	DMA	DMA	DRQTxA	DTRB	DRQRxB	DRQTxB	DTRA	DRQRxA

Priority (D_2)

This bit selects the relative priorities of the various interrupt and DMA conditions according to the application requirements.

DMA/Interrupt Priorities

D_2	Mode: Channel A	Mode: Channel B	DMA Priority Relation	Interrupt Priority Relation
0	INT	INT	—	SRxA, RxA > TxA > SRxB, RxB > TxB > ExTA > ExTB
1			—	SRxA, RxA > SRxB, RxB > TxA > TxB > ExTA > ExTB
0	DMA	INT	RxA > TxA	SRxA, RxA > SRxB, RxB > TxB > ExTA > ExTB
1			RxA > TxA	SRxA, RxA > SRxB, RxB > TxB > ExTA > ExTB
0	DMA	DMA	RxA > TxA > RxB > TxB	SRxA, RxA > SRxB, RxB > ExTA > ExTB
1			RxA > RxB > TxA > TxB	SRxA, RxA > SRxB, RxB > ExTA > ExTB

Interrupt vector mode ($D_3 - D_5$)

This field determines how the MPSC² responds to an interrupt acknowledge sequence from the processor.

Interrupt Acknowledge Sequence Response

D_5	D_4	D_3	Mode	Status Register 2B and Interrupt Vector Bits Affected When Condition Affects Vector is Enabled
0	0	0	Nonvectored	$D_4\ D_3\ D_2$
0	0	1	Nonvectored	$D_4\ D_3\ D_2$
0	1	0	Nonvectored	$D_2\ D_1\ D_0$
0	1	1	Illegal	—
1	0	0	8085 Master	$D_4\ D_3\ D_2$
1	0	1	8085 Slave	$D_4\ D_3\ D_2$
1	1	0	8086	$D_2\ D_1\ D_0$
1	1	1	8085/8259A Slave	$D_4\ D_3\ D_2$

Rx INT mask (D_6)

This option is generally used in the DMA modes. Enabling this bit inhibits the interrupt from occurring when the interrupt/DMA Request On First Received Character mode is selected. In other words, only a DMA request will be generated when the first character is received.

Pin 10 SYNCB/RTSB select (D_7)

Programming a zero into this bit selects RTSB as the function of pin 10. A one selects SYNCB as the function.

Control Register 2 (Channel B)

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
Interrupt Vector							

Interrupt vector ($D_0 - D_7$)

When the MPSC² is used in the vectored interrupt mode the contents of this register is placed on the bus during the appropriate portion of the interrupt acknowledge sequence. Its value is modified if status affects vector is enabled. The value of SR2B can be read at any time. This feature is particularly useful in determining the cause of an interrupt when using the MPSC² in a nonvectored interrupt mode.

Control Register 3

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
Number of Received Bits per Character		Auto Enables	Enter Hunt Phase	Receiver CRC Enable	Address Search Mode	Sync Character Load Inhibit	Receiver Enable

Receiver enable (D_0)

After the channel has been completely initialized, setting this bit to one allows the receiver to begin operation. This bit may be set to zero at any time to disable the receiver.

Sync character load inhibit (D_1)

In the character synchronous modes, this bit inhibits the transfer of sync characters to the receiver buffer thus performing a "sync-stripping" operation. When using the MPSC²'s CRC checking ability this feature should be used only to strip leading sync characters preceding a message since the load inhibit does not exclude sync characters embedded in the message from the CRC calculation. Synchronous protocols using other types of block checking such as checksum or LRC are free to strip embedded sync characters with this bit.

Address search mode (D_2)

In the SDLC mode, setting this bit places the MPSC² in an address search mode. Character assembly does not begin until the 8-bit character (secondary address field) following the starting flag of a message matches either the address programmed into CR6 or the global address 11111111.

Receiver CRC enable (D_3)

This bit enables and disables (1 = enable) the CRC checker in the COP mode allowing characters from the CRC calculation to be selectively included or excluded. The MPSC² features a one-character delay between the receiver shift register and the CRC checker so that the enabling or disabling takes effect with the last character transferred from the shift register to the receiver buffer. Therefore, there is one full character time in which to read the character and decide whether or not it should be included in the CRC calculation. In the SDLC mode, there is no 8-bit delay.

Enter hunt phase (D_4)

Although the MPSC² receiver automatically enters the sync hunt phase after a reset, there are times when reentry may be desired, such as when it has been determined that synchronization has been lost or, in an SDLC mode, to ignore the current incoming message. Writing a one into this bit at any time after initialization causes the MPSC² to reenter the hunt phase.

Auto enables (D_5)

Setting this bit to one causes the $\overline{DCD}$ and $\overline{CTS}$ inputs to act as enable inputs to the receiver and transmitter, respectively.

Number of received bits per character ($D_6 - D_7$)

This field specifies the number of data bits assembled to make each character. The value may be changed on the fly while a character is being assembled and, if the change is made before the new number of bits has been reached it affects that character. Otherwise the new specifications take effect on the next character received.

Received Bits per Character

D_7	D_6	Bits per Character
0	0	5
0	1	7
1	0	6
1	1	8

Control Register 4

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
Clock Rate		Sync Mode		Number of Stop Bits per Sync Mode		Parity Even/Odd	Parity Enable

Parity enable (D_0)

Setting this bit to one adds an extra data bit containing parity information to each transmitted character. Each received character is expected to contain this extra bit and the receiver parity checker is enabled.

Parity even/odd (D_1)

Programming a zero into this bit when parity is enabled causes the transmitted parity bit to take on the value required for odd parity. The received character is checked for odd parity. Conversely, a one in this bit signifies even parity generation and checking.

Number of stop bits per sync mode ($D_2 - D_3$)

This field specifies whether the channel is used in a synchronous (SDLC) or an asynchronous mode. In an asynchronous mode this field also specifies the number of bit times used as the stop bit length by the transmitter. The receiver always checks for one stop bit.

Stop Bits

D_3	D_2	Mode
0	0	Synchronous modes
0	1	Asynchronous 1-bit time (1 stop bit)
1	0	Asynchronous 1½ bit times (1½ stop bits)
1	1	Asynchronous 2-bit times (2 stop bits)

Sync mode ($D_4 - D_5$)

When the stop bits/sync mode field is programmed for synchronous modes (D_2, D_3 = 00), this field specifies the particular synchronous format to be used. This field is ignored in an asynchronous mode.

Synchronous Formats

Sync Mode 1	Sync Mode 2	
D_5	D_4	Mode
0	0	8-bit internal synchronization character (monosync)
0	1	16-bit internal synchronization character (bisync)
1	0	SDLC
1	1	External synchronization (SYNC pin becomes an input)

Clock rate ($D_6 - D_7$)

This field specifies the relationship between the transmitter and receiver clock inputs ($\overline{TxC}$, $\overline{RxC}$) and the actual data rates at TxD and RxD. When operating in a synchronous mode a 1x clock rate must be specified. In asynchronous modes any of the rates may be specified, however, with a 1x clock rate the receiver cannot determine the center of the start bit. In this mode, the sampling (rising) edge of $\overline{RxC}$ must be externally synchronized with the data.

Clock Rates

Clock Rate 1	Clock Rate 2	
D_7	D_6	Clock Rate
0	0	Clock Rate = 1x Data Rate
0	1	Clock Rate = 16x Data Rate
1	0	Clock Rate = 32x Data Rate
1	1	Clock Rate = 64x Data Rate

Control Register 5

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
DTR	Number of Transmitted Bits per Character		Send Break	Transmitter Enable	CRC Polynomial Select	$\overline{RTS}$	Transmitter CRC Enable

Transmitter CRC enable (D_0)

A one or a zero enables or disables respectively, the CR generator calculation. The enable or disable does not tak effect until the next character is transferred from the trans mitter buffer to the shift register, thus allowing specific characters to be included or excluded from the CRC calculation. By setting or resetting this bit just before loading

the next character, it and subsequent characters are included or excluded from the calculation. If this bit is zero when the transmitter becomes empty the MPSC² goes to the idle phase regardless of the state of the idle/CRC latch.

$\overline{RTS}$ (D_1)

In synchronous and SDLC modes setting this bit to one causes the $\overline{RTS}$ pin to go low while a zero causes it to go high. In an asynchronous mode setting this bit to zero does not cause $\overline{RTS}$ to go high until the transmitter is completely empty. This feature facilitates programming the MPSC² for use with asynchronous modems.

CRC polynomial select (D_2)

This bit selects the polynomial used by the transmitter and receiver for CRC generation and checking. A one selects the CRC-16 polynomial ($x^{16} + x^{15} + x^2 + 1$). A zero selects the CRC-CCITT polynomial ($x^{16} + x^{12} + x^5 + 1$). In an SDLC mode CRC-CCITT must be selected. Either polynomial may be used in other synchronous modes.

Transmitter enable (D_3)

After a reset the transmitted data output (TxD) is held high (marking) and the transmitter is disabled until this bit is set.

In an asynchronous mode TxD remains high until data is loaded for transmission.

In synchronous and SDLC modes the MPSC² automatically enters the idle phase and sends the programmed sync or flag characters.

When the transmitter is disabled in an asynchronous mode any character currently being sent is completed before TxD returns to the marking state.

If the transmitter is disabled during the data phase in a synchronous mode the current character is sent. TxD then goes high (marking). In an SDLC mode the current character is sent, but the marking line following is zero-inserted. That is, the line goes low for one bit time out of every five.

The transmitter should never be disabled during the SDLC data phase unless a reset is to follow immediately. In either case, any character in the buffer register is held.

Disabling the transmitter during the CRC phase causes the remainder of the CRC character to be bit-substituted with the sync (or flag). The total number of bits transmitted is correct and TxD goes high after they are sent.

If the transmitter is disabled during the idle phase the remainder of the sync (flag) character is sent. TxD then goes high.

Send break (D_4)

Setting this bit to one immediately forces the transmitter output (TxD) low (spacing). This function overrides the normal transmitter output and destroys any data being transmitted although the transmitter is still in operation. Resetting this bit releases the transmitter output.

Transmitted bits per character ($D_5 - D_6$)

This field controls the number of data bits transmitted in each character. The number of bits per character may be changed by rewriting this field just before the first character is loaded to use the new specification.

Transmitted Bits per Character

Transmitted Bits per Character 1	Transmitted Bits per Character	
D_6	D_5	Bits per Character
0	0	5 or less (see below)
0	1	7
1	0	6
1	1	8

Normally each character is sent to the MPSC² right-justified and the unused bits are ignored. However, when sending five bits or less the data should be formatted as shown below to inform the MPSC² of the precise number of bits to be sent.

Transmitted Bits per Character for 5 Characters or Less

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Number of Bits per Character
1	1	1	1	0	0	0	D_0	1
1	1	1	0	0	0	D_1	D_0	2
1	1	0	0	0	D_2	D_1	D_0	3
1	0	0	0	D_3	D_2	D_1	D_0	4
0	0	0	D_4	D_3	D_2	D_1	D_0	5

$\overline{DTR}$ (data terminal ready) (D_7)

When this bit is one the $\overline{DTR}$ output is low (active). Conversely, when this bit is zero $\overline{DTR}$ is high.

Control Register 6

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
Sync Byte 1							

Sync byte 1 ($D_0 - D_7$)

Sync byte 1 is used in the following modes:

Monosync	8-bit sync character transmitted during the idle phase
Bisync	Least significant (first) 8 bits of the 16-bit transmit and receive sync character
External Sync	Sync character transmitted during the idle phase
SDLC	Secondary address value matched to secondary address field of the SDLC frame when the MPSC² is in the address search mode

Control Register 7

D_7	D_6	D_5	D_4		D_2	D_1	D_0
Sync Byte 2							

Sync byte 2 ($D_0 - D_7$)

Sync byte 2 is used in the following modes:

Monosync	8-bit sync character matched by the receiver
Bisync	Most significant (second) 8 bits of the 16-bit transmit and receive sync characters
SDLC	The flag character, 01111110, must be programmed into control register 7 for flag matching by the MPSC² receiver

Status Register 0

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
Break/ Abort	Idle/CRC	CTS	Sync Status	DCD	Transmitter Buffer Empty	Interrupt Pending	Received Character Available

Received character available (D_0)

When this bit is set it indicates that one or more characters in the receiver buffer is available for the processor to read. Once all the available characters have been read the MPSC² resets this bit until a new character is received.

Interrupt pending (D_1 — channel A only)

The interrupt pending bit is used with the interrupt vector register (status register 2) to make it easier to determine the MPSC²'s interrupt status, particularly in a nonvectored interrupt mode where the processor must poll each device to determine the interrupt source. In this mode interrupt pending is set when status register 2B is read, the $\overline{PRI}$ input is active (low), and the MPSC² is requesting interrupt service.

The status registers of both channels need not be analyzed to determine if an interrupt is pending. If the status affects vector is enabled and the interrupt pending is set the vector read from SR2 contains valid condition information.

In a vectored interrupt mode interrupt pending is set during the interrupt acknowledge cycle (on the leading edge of the second $\overline{INTA}$ pulse) when the MPSC² is the highest priority device requesting interrupt service ($\overline{PRI}$ is active). In either mode if there are no other pending interrupt requests interrupt pending is reset when the end of the interrupt command is issued.

Transmitter buffer empty (D_2)

This bit is set whenever the transmitter buffer is empty except during the transmission of CRC. (The MPSC² uses the buffer to facilitate this function.) After a reset the buffer is considered empty and transmit buffer empty is set.

External/status flags (D_3–D_7)

The following status bits reflect the state of the various conditions that cause an external/status interrupt. The MPSC² latches all external/status bits whenever a change occurs that would cause an external/status interrupt (regardless of whether this interrupt is enabled). This allows transient status changes on these lines to be captured with relaxed software timing requirements.

When the MPSC² is operated in an interrupt-driven mode for external/status interrupts, status register 0 should be read when this interrupt occurs and a reset external/status interrupt command issued to reenable the interrupt and the latches. To poll these bits without interrupts, the reset external/status interrupt command can be issued to first update the status to reflect the current values.

$\overline{DCD}$ (D_3): This bit reflects the inverted state of the $\overline{DCD}$ input. When $\overline{DCD}$ is low the $\overline{DCD}$ status bit is high. Any transition on this bit causes an external/status interrupt request.

Sync status (D_4): The meaning of this bit depends on the operating mode of the MPSC².

Asynchronous mode: Sync status reflects the inverted state of the $\overline{SYNC}$ input. When $\overline{SYNC}$ is low, sync status is high. Any transition on this bit causes an external/status interrupt request.

External synchronization mode: Sync status operates in the same manner as an asynchronous mode. The MPSC²'s receiver synchronization logic is also tied to the sync status bit in an external synchronization mode and a low-to-high transition ($\overline{SYNC}$ input going low) informs the receiver that synchronization has been achieved and character assembly begins.

A low-to-high transition on the $\overline{SYNC}$ input indicates that synchronization has been lost and is reflected both in the sync status becoming zero and the generation of an external/status interrupt. The receiver remains in the receive data phase until the enter hunt phase bit in control register 3 is set.

Monosync, bisync, SDLC modes: In these modes, sync status indicates whether the MPSC² receiver is in the sync hunt or receive data phase of operation. A zero indicates that the MPSC² is in the receive data phase and a one indicates that the MPSC² is in the sync hunt phase (as after a reset or a setting of the enter sync hunt phase bit). As in the other modes a transition on this bit causes an external/status interrupt to be issued. It should be noted that entering a sync hunt phase after either a reset or when programmed causes an external/status interrupt request which may be cleared immediately with a reset external/status interrupt command.

$\overline{CTS}$ (D_5): This bit reflects the inverted state of the $\overline{CTS}$ input. When $\overline{CTS}$ is low, the $\overline{CTS}$ status bit is high. Any transition on this bit causes an external/status interrupt request.

Idle/CRC (D_6) (Tx underrun/EOM): This bit indicates the state of the idle/CRC latch used in the synchronous and SDLC modes. After a hardware reset this bit is set to one, indicating that the transmitter is completely empty. When the MPSC² enters idle phase it automatically transmits sync or flag characters.

In the SDLC mode the MPSC² automatically resets this latch after the first byte of a frame is written to the Tx buffer.

When the transmitter is completely empty, the MPSC² sends the 16-bit CRC character and sets the latch again. An external/status interrupt is issued when the latch is set, indicating that CRC is being sent. No interrupt is issued when the latch is reset.

Break/abort (D_7): In the asynchronous mode this bit indicates the detection of a break sequence (a null character plus framing error that occurs when the RxD input is held low, spacing, for more than one character time). Break/abort is reset when RxD returns high (marking).

In the SDLC mode, Break/abort indicates the detection of an abort sequence when seven or more ones are received in sequence. It is reset when a zero is received.

Any transition of the break/abort bit causes an external/status interrupt.

Status Register 1

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
End of SDLC Frame	CRC Framing Error	Overrun Error	Parity Error	SDLC Residue Code			All Sent

All sent (D_0)

This bit is set when the transmitter is empty and reset when a character is present in the transmitter buffer or shift register. This feature simplifies the modem control software routines. In the bit synchronous mode, this bit will be set when the ending flag pattern is sent.

SDLC residue code ($D_1 - D_3$)

Since the data portion of an SDLC message can consist of any number of bits and not necessarily an integral number of characters, the MPSC² features special logic to determine and report when the end of frame flag has been received, the boundary between the data field and the CRC character in the last few data characters that were just read.

When the end of frame condition is indicated, that is, status register 1 $D_7 = 1$ and special receive condition interrupt (if enabled), the last bits of the CRC character are in the receiver buffer. The residue code for the frame is valid in the status register 1 byte associated with that data character. (SR1 tracks the received data in its own buffer.)

The meaning of the residue code depends upon the number of bits per character specified for the receiver. The previous character refers to the last character read before the end of frame, and so forth.

Residue Codes

8 Bits per Character

D_3	D_2	D_1	Previous Character	2nd Previous Character	
1	0	0	CCCCCCCC	CCCCCDDD	
0	1	0	CCCCCCCC	CCCCDDDD	
1	1	0	CCCCCCCC	CCCDDDDD	
0	0	1	CCCCCCCC	CCDDDDDD	
1	0	1	CCCCCCCC	CDDDDDDD	
0	1	1	CCCCCCCC	DDDDDDDD	(no residue)
1	1	1	CCCCCCCD	DDDDDDDD	
0	0	0	CCCCCCDD	DDDDDDDD	

7 Bits per Character

D_3	D_2	D_1	Previous Character	2nd Previous Character	
1	0	0	CCCCCCC	CCCCCDD	
0	1	0	CCCCCCC	CCCCDDD	
1	1	0	CCCCCCC	CCCDDDD	
0	0	1	CCCCCCC	CCDDDDD	
1	0	1	CCCCCCC	CDDDDDD	
0	1	1	CCCCCCC	DDDDDDD	(no residue)
0	0	0	CCCCCCD	DDDDDDD	

6 Bits per Character

D_3	D_2	D_1	Previous Character	2nd Previous Character	
1	0	0	CCCCCC	CCCCCD	
0	1	0	CCCCCC	CCCCDD	
1	1	0	CCCCCC	CCCDDD	
0	0	1	CCCCCC	CCDDDD	
1	0	1	CCCCCC	CDDDDD	
0	0	0	CCCCCC	DDDDDD	(no residue)

5 Bits per Character

D_3	D_2	D_1	2nd Previous Character	3rd Previous Character	
1	0	0	CCCCC	DDDDD	(no residue)
0	1	0	CCCCD	DDDDD	
1	1	0	CCCDD	DDDDD	
0	0	1	CCDDD	DDDDD	
0	0	0	CDDDD	DDDDD	

Special receive condition flags

The status bits described below — parity error (if parity as a special receive condition is enabled), receiver overrun error, CRC/framing error, and end of SDLC frame — all represent special receive conditions.

When any of these conditions occur and interrupts are enabled, the MPSC² issues an interrupt request. In addition, if a condition affects vector mode is enabled, the vector generated (and the contents of SR2B for nonvectored interrupts) is different from that of a received character available condition. Thus, it is not necessary to analyze SR1 with each character to determine if an error has occurred.

As a further convenience, the parity error and receiver overrun error flags are latched. That is, once one of these errors occurs, the flag remains set for all subsequent characters until reset by the error reset command. With this facility SR1 need only be read at the end of a message to determine if either of these errors occurred anywhere in the message. The other flags are not latched and follow each character available in the receiver buffer.

Parity error (D_4): This bit is set and latched when parity is enabled and the received parity bit does not match the sense (odd or even) calculated from the data bits.

Receiver overrun error (D_5): This error occurs and is latched when the receiver buffer already contains three characters and a fourth character is completely received, overwriting the last character in the buffer.

CRC/framing error (D_6): In the asynchronous mode a framing error is flagged (but not latched) when no stop bit is detected at the end of a character (i.e., RxD is low one bit time after the center of the last data or parity bit). When this condition occurs, the MPSC² waits an additional one-half bit time before sampling again so that the framing error is not interpreted as a new start bit.

In the synchronous and SDLC modes this bit indicates the result of the comparison between the current CRC result and the appropriate check value and is usually set to one since a message rarely indicates a correct CRC result until correctly completed with the CRC check character. Note that a CRC error does not result in a special receive condition interrupt.

End of SDLC frame (EOF) (D_7): This status bit is used only in the bit synchronous mode to indicate that the end of frame flag has been received and that the CRC error flag and residue code are valid. This flag can be reset at any time by issuing an error reset command. The MPSC² also automatically resets this bit when the first character of the next message frame is sent.

Status Register 2B

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
Interrupt Vector							

Interrupt vector ($D_0 - D_7$ — channel B only)

Reading status register 2B returns the interrupt vector that is programmed into control register 2B. If a condition affects vector mode is enabled the value of the vector is modified as shown in the following table.

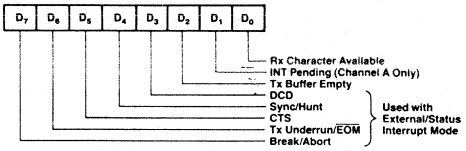
Condition Affects Vector Modifications

Interrupt Pending (SR0, D_1 Channel A)	8085 Modes D_4 D_3 D_2 / 8086 Modes D_2 D_1 D_0	Condition
0	1 1 1	No interrupt pending
1	0 0 0	Channel B transmitter buffer empty
1	0 0 1	Channel B external/status change
1	0 1 0	Channel B received character available
1	0 1 1	Channel B special receive condition
1	1 0 0	Channel A transmitter buffer empty
1	1 0 1	Channel A external/status change
1	1 1 0	Channel A received character available
1	1 1 1	Channel A special receive condition

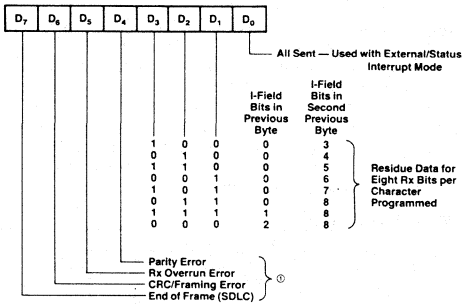
As can be seen code 111 can mean either channel A special receive condition or no interrupt pending. They can be easily distinguished by examining the interrupt pending bit (D_1) of status register 0, channel A. In a nonvectored interrupt mode the vector register must be read first for the interrupt pending to be valid.

Read Register Bit Functions

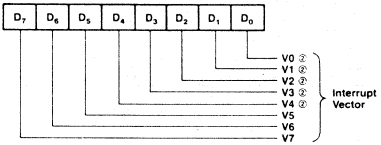
Read Register 0



*Read Register 1*①



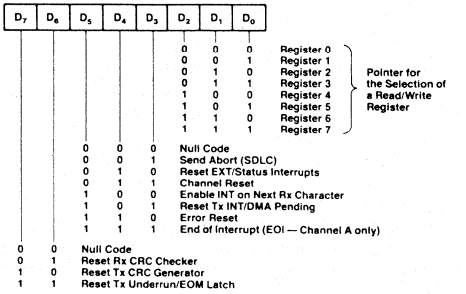
Read Register 2



Notes: ① Used with special receive condition mode.
② Variable if Status Affects Vector is programmed.

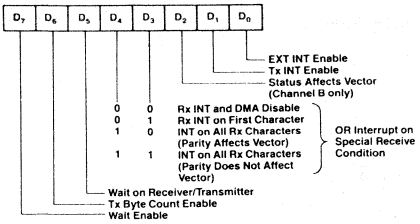
Write Register Bit Functions

Write Register 0

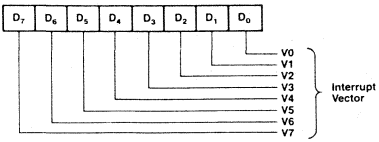


Write Register Bit Functions (Cont.)

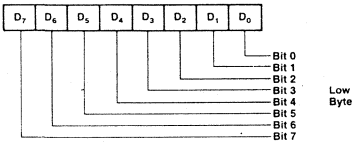
Write Register 1



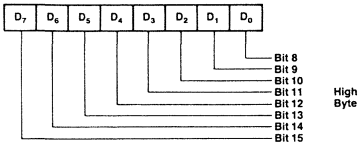
Write Register 2 (Channel B)



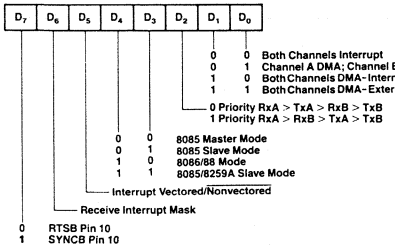
Tx Byte Count Register



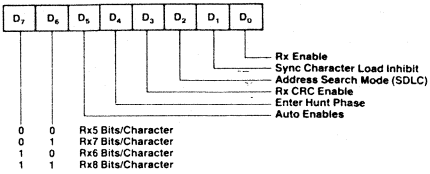
Tx Byte Count Register



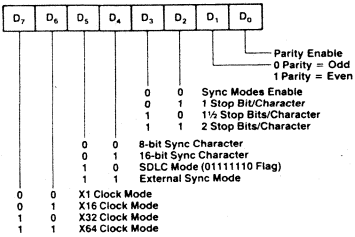
Write Register 2 (Channel A)



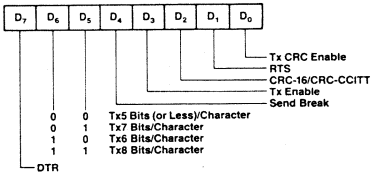
Write Register 3



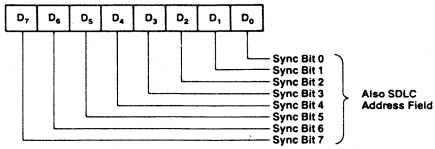
Write Register 4



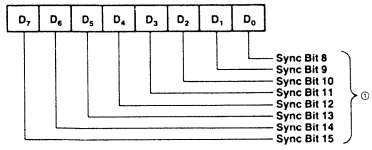
Write Register 5



Write Register 6



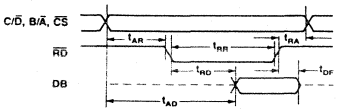
Write Register 7



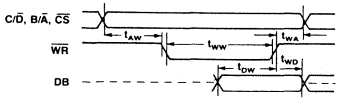
Note: ① For SDLC it must be programmed to 01111110 for flag recognition.

Timing Waveforms

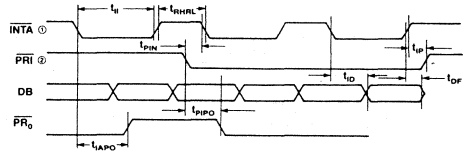
Read Cycle



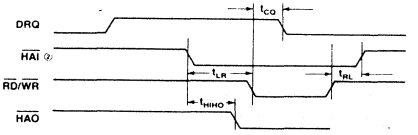
Write Cycle



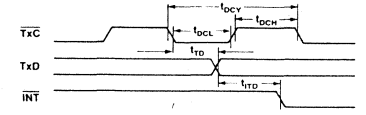
INTA Cycle



DMA Cycle

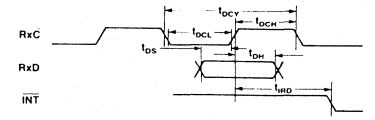


Transmit Data Cycle

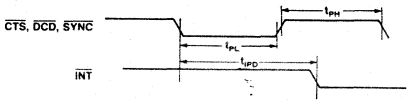


Notes: ① $\overline{\text{INTA}}$ signal acts as $\overline{\text{RD}}$ signal.
② $\overline{\text{PRI}}$ and $\overline{\text{HAI}}$ signals act as $\overline{\text{CS}}$ signal.

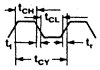
Receive Data Cycle



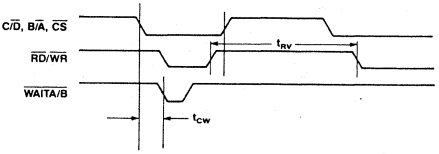
Other Timing



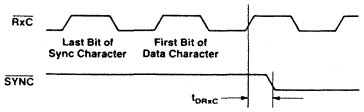
Clock



Read/Write Cycle (Software Block Transfer Mode)



Sync Pulse Generation (External Sync Mode)



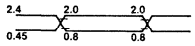
AC Characteristics

T_a = 0°C to +70°C; V_{CC} = +5V ± 10%

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Clock Cycle	t_{CY}	200		4000	ns	
Clock High Width	t_{CH}	70		2000	ns	
Clock Low Width	t_{CL}	70		2000	ns	
Clock Rise Time	t_r	0		30	ns	
Clock Fall Time	t_f	0		30	ns	
Address Setup to RD	t_{AR}	0			ns	
Address Hold from RD	t_{RA}	0			ns	
RD Pulse Width	t_{RR}	200			ns	
Data Output Delay from Address	t_{AD}			200	ns	
Data Output Delay from RD	t_{RD}			200	ns	
Data Float Delay from RD	t_{DF}	10		100	ns	
Address Setup to WR	t_{AW}	0			ns	
Address Hold from WR	t_{WA}	0			ns	
WR Pulse Width	t_{WW}	200			ns	
Data Setup to WR	t_{DW}	130			ns	
Data Hold from WR	t_{WD}	0			ns	
PRO Delay from PRI	t_{PIPO}			100	ns	
PRO Delay from INTA	t_{IAPO}			200	ns	
PRI Setup to INTA	t_{PIN}	0			ns	
PRI Hold from INTA	t_{IP}	20			ns	
INTA Pulse Width	t_{II}	200			ns	
Data Output Delay from INTA	t_{ID}			200	ns	
Data Float Delay from INTA	t_{DF}	10		100	ns	
Request Hold from RD/WR	t_{CQ}			150	ns	
HAI Setup to RD/WR	t_{LR}	300			ns	
HAI Hold from RD/WR	t_{RL}	0			ns	
HAO Delay from HAI	t_{HIHO}			100	ns	
Data Clock Cycle	t_{DCY}	400			ns	RxC, TxC
Data Clock High Width	t_{DCH}	180			ns	RxC, TxC
Data Clock Low Width	t_{DCL}	180			ns	RxC, TxC
Tx Data Delay from TxC	t_{TD}			300	ns	x1 Mode
				1000		x16, 32, 64
Rx Data Setup to RxC	t_{DS}	0			ns	
Rx Data Hold from RxC	t_{DH}	140			ns	
INT Delay Time from Tx Data	t_{ITD}			4–6	t_{CY}	
INT Delay Time from RxC	t_{IRD}			7–11	t_{CY}	
CTS, DCD, SYNC High Pulse Width	t_{PH}	200			ns	
CTS, DCD, SYNC Low Pulse Width	t_{PL}	200			ns	
External INT from CTS, DCD, SYNC	t_{IPD}			500	ns	
Recovery Time Between Controls	t_{RV}	300			ns	
WAIT Delay Time from Address	t_{CW}			120	ns	
SYNC Setup to RxC	t_{DRxC}			100	ns	

Notes: 1: $\overline{RESET}$ must be active for a minimum of one complete CLK cycle.
2: In all modes system clock rate must be 4.5 times data rate.

AC Waveform Measurement Points



μPD7201A Target Specifications

Absolute Maximum Ratings

T_a = 25°C	
Power Supply, V_{CC}	−0.5V to +7.0V
Input Voltages, V_I	−0.5V to +7.0V
Output Voltages, V_O	−0.5V to +7.0V
Operating Temperature, T_{OPT}	0°C to +70°C
Storage Temperature, T_{STG}	−65°C to +125°C

*COMMENT: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

T_a = 0°C to +70°C; V_{CC} = +5V ± 10%

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input Low Voltage	V_{IL}	−0.5		+0.8	V	
Input High Voltage	V_{IH}	+2.0		V_{CC} + 0.5	V	
Output Low Voltage	V_{OL}			+0.45	V	I_{OL} = +2.0mA
Output High Voltage	V_{OH}	+2.4			V	I_{OH} = 200μA
Input Leakage Current	I_{IL}			±10	μA	V_{IN} = V_{CC} to 0V
Output Leakage Current	I_{OL}			±10	μA	V_{OUT} = V_{CC} to 0V
V_{CC} Supply Current	I_{CC}			230	mA	

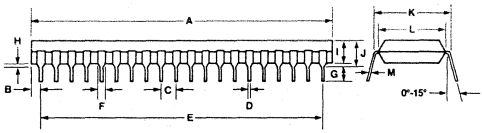
Capacitance

T_a = 25°C; V_{CC} = GND = 0V

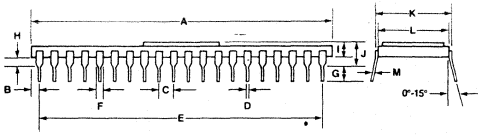
Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input Capacitance	C_{IN}			10	pF	fc = 1MHz
Output Capacitance	C_{OUT}			15	pF	Unmeasured pins
I/O Capacitance	$C_{I/O}$			20	pF	returned to GND.

Package Outlines

μPD7201AC (Plastic)



μPD7201AD (Ceramic)



Plastic

Item	Millimeters	Inches
A	51.5 Max	2.028 Max
B	1.62	0.064
C	2.54 ± 0.1	0.10 ± 0.004
D	0.5 ± 0.1	0.019 ± 0.004
E	48.26	1.9
F	1.2 Min	0.047 Min
G	2.54 Min	0.10 Min
H	0.5 Min	0.019 Min
I	5.22 Max	0.206 Max
J	5.72 Max	0.225 Max
K	15.24	0.600
L	13.2	0.520
M	$0.25^{+0.1}_{-0.05}$	$0.010^{+0.004}_{-0.002}$

Ceramic

Item	Millimeters	Inches
A	51.5 Max	2.03 Max
B	1.62 Max	0.06 Max
C	2.54 ± 0.1	0.10 ± 0.004
D	0.5 ± 0.1	0.02 ± 0.004
E	48.26 ± 0.1	1.9 ± 0.004
F	1.02 Min	0.04 Min
G	3.2 Min	0.13 Min
H	1.0 Min	0.04 Min
I	3.5 Max	0.14 Max
J	4.5 Max	0.18 Max
K	15.24 Typ	0.6 Typ
L	14.93 Typ	0.59 Typ
M	0.25 ± 0.05	0.01 ± 0.0019

PRELIMINARY INFORMATION

Description

The μPD72001 is an advanced multiprotocol serial controller (AMPSC) designed to meet a wide variety of communications needs. This 40-pin device contains two independent full-duplex channels which can be configured to transmit and receive data in either asynchronous character-oriented (BISYNC) or bit-oriented (SDLC/HDLC) protocols, including CRC generation and checking-in synchronous modes.

The AMPSC can handle several modes of interrupt operation including vectored and non-vectored modes. Separate DMA requests are available for the transmitter and receiver on each channel, allowing operation at speeds up to 1.6 Mb/s in synchronous modes. The AMPSC is easily interfaced to most microprocessors with a minimum of logic.

The AMPSC is an upgraded CMOS version of the μPD7201A, adding internal baud rate generators, a digital phase lock loop (DPLL), and a crystal oscillator. The μPD72001 also adds the capability of SDLC loop operation. These added features further simplify the design requirements while maintaining the flexible architecture of the μPD7201A.

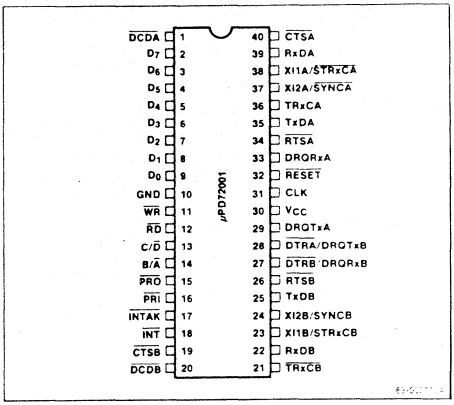
Features

- ☐ Upgraded version of the μPD7201A
- ☐ Multiprotocol:
  - — Asynchronous, character-oriented (BISYNC)
  - — Bit-oriented (SDLC/HDLC)
- ☐ Two independent full-duplex channels
- ☐ Versatile host-system interface:
  - — Software polling
  - — Wait
  - — Interrupt
  - — DMA
- ☐ DC to 1.6-Mb/s data rate
- ☐ Modem control signals
- ☐ NRZ, NRZI, and FM encoding/decoding
- ☐ Digital phase lock loop
- ☐ Two baud rate generators per channel (receive and transmit)
- ☐ Crystal oscillator
- ☐ Test loop mode
- ☐ SDLC loop mode
- ☐ Mark idle detection
- ☐ Short frame detection
- ☐ Single +5 V power supply
- ☐ CMOS technology

Ordering Information

Part No.	Package Type
μPD72001C	40-pin plastic DIP
μPD72001L	44-pin PLCC

Pin Configuration



Pin Identification

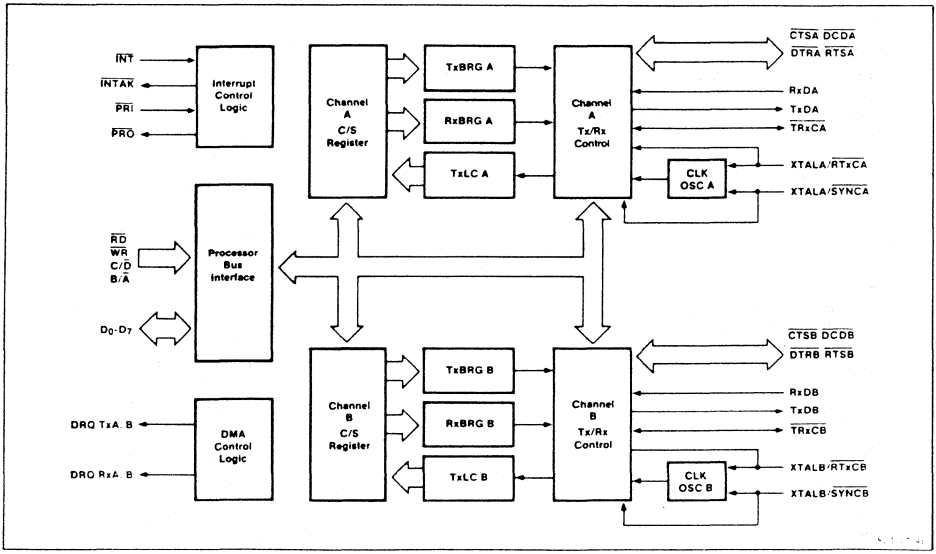
No.	Symbol	Function
1	$\overline{DCDA}$	Data carrier detect input for channel A
2-9	D_7-D_0	System data bus
10	GND	System ground
11	$\overline{WR}$	Write control input from host computer
12	$\overline{RD}$	Read control input from host computer
13	C/$\overline{D}$	Control/data input select from host computer
14	B/A	Channel B or channel A select input from host computer
15	$\overline{PRO}$	Priority output, interrupt daisy chain control
16	PRI	Priority input, interrupt daisy chain control
17	$\overline{INTAK}$	Interrupt acknowledge input from host computer
18	$\overline{INT}$	Interrupt request output to host computer

Pin Identification (cont)

No.	Symbol	Function
19	$\overline{CTSB}$	Clear to send input for channel B
20	$\overline{DCDB}$	Data carrier detect input for channel B
21	$\overline{TRxCB}$	Transmit/receive clock input/output for channel B
22	RxDB	Receive data input for channel B
23 24	XI1B/$\overline{STRxCB}$ XI2B/$\overline{SYNCB}$	Crystal inputs for channel B; or synchronization and source of transmit/receive clock for channel B. Function depends on control register 15.
25	TxDB	Transmit data output for channel B
26	RTSB	Request to send output for channel B
27	DTRB/ DRQRxB	Data terminal ready output for channel B or DMA request output for receive channel B; determined by control register 2A.
28	DTRA/ DRQTxB	Data terminal ready output for channel A or DMA request output for transmit channel B; determined by control register 2A

No.	Symbol	Function
29	DRQTxA	DMA request for transmit channel A
30	V_{CC}	+5 V (typical)
31	CLK	System clock input from host computer
32	$\overline{RESET}$	System reset input from host computer
33	DRQRxA	DMA request output for receive channel A
34	$\overline{RTSA}$	Request-to-send output for channel A
35	TxDA	Transmit data output for channel A
36	TRxCA	Transmit/receive clock input for channel A
37 38	XI2A/$\overline{SYNCA}$ XI1A/$\overline{STRxCA}$	Crystal inputs for channel A; or synchronization input and source of transmit/receive clock for channel A. Functions depend on control register 15.
39	RxDA	Receive data input for channel A
40	$\overline{CTSA}$	Clear-to-send input for channel A

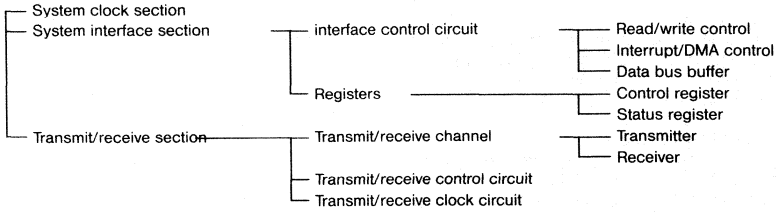
Block Diagram



CONFIGURATION

The basic function of the AMPSC is to control serial data transmission/reception with other serial data communication devices. The AMPSC contains a flexible architecture to efficiently implement this function.

The internal logics of the AMPSC can be divided into system clock, system interface, and transmit/receive blocks. The system clock section supplies the system clock which is the base used to control the whole operation of the AMPSC's other internal circuits. The system interface block controls interfacing with its host system. The transmit/receive block controls data transmit/receive sequences. Fig. 2-1 shows the internal circuit configuration of the AMPSC.



AMPSC Internal Circuit Configuration

System Interface Block

The system interface block consists of an interface control logic and registers. The interface control logic contains a read/write controller, an interrupt/DMA controller, and a data bus buffer. The registers consist of control and status registers.

Interface control circuit

The interface control circuit controls interfacing between the AMPSC and its host system. Data transfer between a device and host system is controlled by the read/write controller and interrupt/DMA controller via an 8-bit data bus buffer. The type of data on the data bus, channel selection, and direction of data transfer are controlled by control inputs. Table 2 shows combinations of control input signals and corresponding selections.

Table 2 Control Inputs Versus Selected Functions

B/$\overline{A}$	C/$\overline{D}$	$\overline{RD}$	$\overline{WR}$	$\overline{INTAK}$	$\overline{PRI}$	Function
L	L	L	H	H	X (1)	Channel A — Reads receive data
H						Channel B
L	L	H	L	H	X	Channel A — Writes transmit data
H						Channel B
L	H	L	H	H	X	Channel A — Reads status register
H						Channel B (SR)
L	H	H	L	H	X	Channel A — Writes data to control
H						Channel B register (CR)
X	X	H	H	L / L	L / H	Interrupt aknowledge sequence (2)

Notes: 1. X denotes "Don't care".
2. Data to be output differs depending on vector type.

Registers

The registers within the AMPSC are used to set AMPSC operation or to indicate the device status. Each channel of the AMPSC has 20 control registers (CRs) for setting operation mode and operation control, and 12 types of status registers (SRs) for status indication.

Control words are written into these registers by the host processor. The status registers hold device status information. The status of the AMPSC can be determined by reading these registers.

Transmitter/Receiver Block

The transmitter/receiver block consists of two independent full-duplex channels, its control circuit and transmit/receive clock circuits. The operation of each transmit/receive channel is selectable from asynchronous, COP (bisync. etc.), and BOP (HDLC, SDLC, etc.) protocols, and is controlled by the transmit/receive control circuit. This block also contains a baud rate generator and digital PLL to supply clocks for serial data transmission and reception.

System Clock Section

The system clock block generates an internal reference clock based on the system clock applied to the CLK pin. This reference clock is supplied to other internal blocks to synchronize device operations.

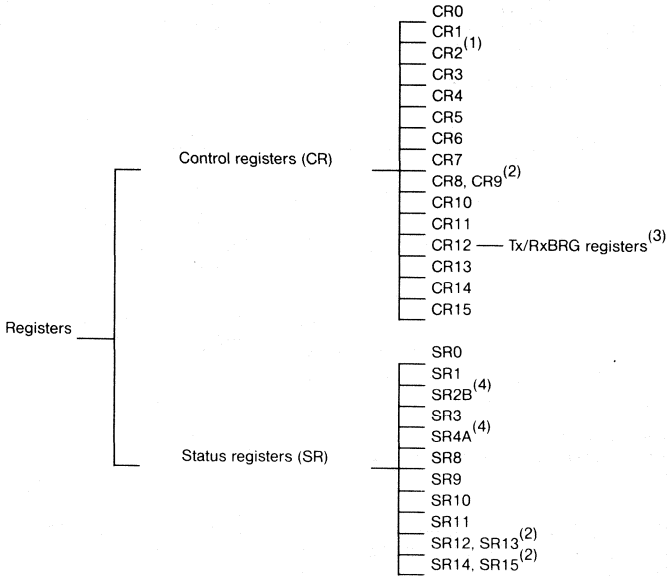
REGISTER CONFIGURATION

To implement operations under different communication protocols, the AMPSC contains a large group of registers. This section details the register configuration within the AMPSC and the function of each register.

The descriptions in this section assume that the reader already has some basic knowledge about each communication protocol. For details of communication protocols, refer to the respective standards for protocols. Unless otherwise stated, the following descriptions assume that relevant interrupts are enabled.

3.1 Outline of Registers

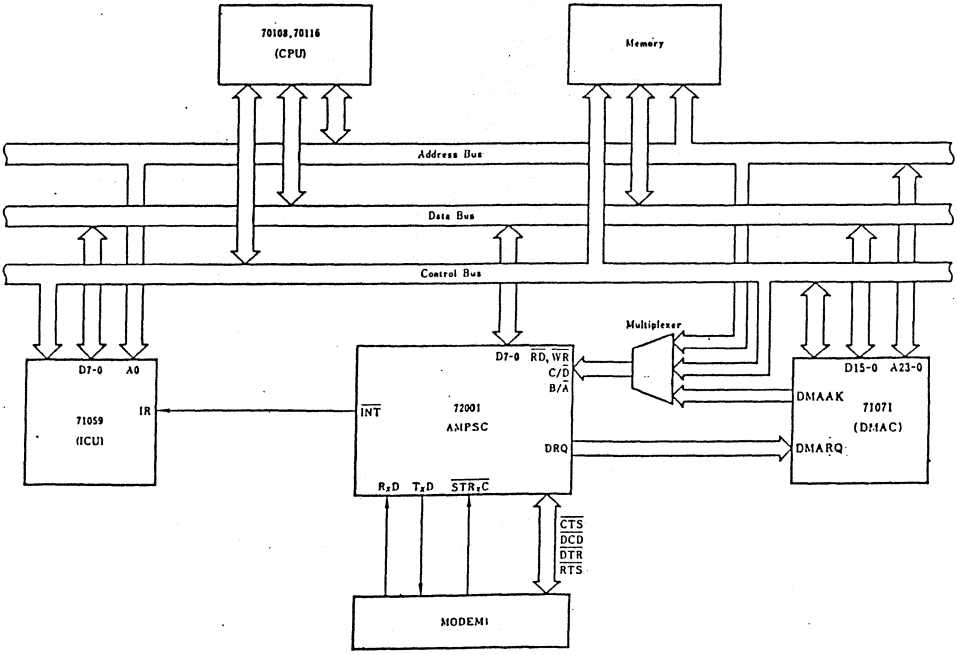
The AMPSC's internal registers are divided into control registers (CR) and status registers (SR). Control registers are used to set up the device operation mode or to control device operations. Control words are written into these registers by the host processor. Status registers hold device status information. The host processor can monitor the AMPSC's status by reading these status registers.



Note: 1. Shared with both channels, though the function of this register differs on each channel.
2. These registers are used in pairs.
3. These registers are made available by setting CR12.
4. These registers do not exist on other channels.
5. The registers listed above are provided on each channel, with some exceptions.

SYSTEM CONFIGURATION EXAMPLE

The following figure shows a system configuration example in which the μPD72001 is interfaced with a modem, with both channels placed in the DMA mode.



Type	Reg. Name	Channel	Description
Control registers	CR0	A, B	Register selection pointer, control commands, or initialize commands
	CR1	A, B	Interrupt/DMA control, received data transfer mode
	CR2	A	System Interface mode, Interrupt/DMA mode, Vector mode
		B	Initial value of interrupt vector
	CR3	A, B	Receive control and Auto Enable control
	CR4	A, B	Operation protocol mode, parity control
	CR5	A, B	Transmission control
	CR6	A, B	SYNC character/address
	CR7	A, B	SYNC character/flag pattern
	CR8	A, B	Tramsmit data count (lower 8 bits) (TxDL-L)
	CR9	A, B	Transmit data count (higher 8 bits) (TxDL-H)
	CR10	A, B	Data format, loop mode control, SYNC character bit length
	CR11	A, B	E/S interrupt control
	CR12	A, B	$\overline{TRxC}$ pin/DPLL source selection, Tx/RxBRG interrupt control, Tx/RxBRG register control
	RxBRG-L	A, B	RxBRG count value (lower 8 bits)
	RxBRG-H	A, B	RxBRG count value (higher 8 bits)
	TxBRG-L	A, B	TxBRG count value (lower 8 bits)
	TxBRG-H	A, B	TxBRG count value (higher 8 bits)
	CR13	A, B	TxDLC control, standby mode control
	CR14	A, B	DPLL control, test mode control, Tx/Rx BRG control
	CR15	A, B	Crystal oscillator control, Tx/Rx CLK source selection, $\overline{TRxC}$ pin control
Status registers	SR0	A, B	Transmit/receive buffer status, Special Rx Condition status
	SR1	A, B	E/S bit
	SR2	B	Interrupt vector
	SR3	A, B	Residue Code, Tx/Rx BRG Zero Count
	SR4	A	INT Pending bit
	SR8	A, B	TxDLC-L (lower 8 bits)
	SR9	A, B	TxDLC-H (higher 8 bits)
	SR10	A, B	DPLL CLK Missing status, Loop status
	SR11	A, B	Interrupt Enable status (contents of CR11)
	SR12	A, B	RxBRG count value (lower 8 bits)
	SR13	A, B	RxBRG count value (higher 8 bits)
	SR14	A, B	TxBRG count value (lower 8 bits)
	SR15	A, B	TxBRG count value (higher 8 bits)

μPD72001 Target Electrical Spec.

Absolute Maximum Ratings (Ta = 25 °C)

Parameter	Symbol	Test Condition	Limits	Unit
Power Supply			VSS-0.3～+0.7	V
Opening Temperature	TOPT		−40～+85	℃
Storange Temperature	TSTG		−65～+150	℃
Input Voltages	VI		VSS-0.3 ～VCC+0.3	V
Output Voltages	VO		VSS-0.3 ～VCC+0.3	V

DC Characteristics (Ta = −40 ～ +85 °C, VCC = ± 10%, VSS = 0V)

Parameter	Symbol	Test Condition	Min.	TYP.	Max.	Unit
Input Low Voltage	VIL		-0.5		+0.8	V
Input High Voltage	VIH		2.2		VCC+0.5	V
Output Low Voltage	VOL	IOL = 2.5mA			+0.4	V
Output High Voltage	VOH	IOM = -400uA	0.7VCC			V
Output Leakage Current	IOL	0V≦Vout≦VCC			±10	uA
Input Leakage Current	IIL	0V≦Vin ≦VCC			±10	uA
VCC Supply Current	ICC	All Output at High Level, TCY=0.125us		20	40	mA
Stand-by Current	ICCI	FRx=FTx= Fφ=DC		1	20	uA
		Stand-by Mode		1	2	mA

AC Characteristics (Ta = −40 ~ +85 °C, VCC = +5V ± 10%)

Parameter	Symbol	Test Condition	Limits		Unit
			Max.	Min.	
Clock Cycle	TCY		125		ns
Clock High Width	TCH		50		ns
Clock Low Width	TCL		50		ns
Clock Rise Time	TR		0	10	ns
Clock Fall Time	TF		0	10	ns
Address Setup to $\overline{RD}$	TAR		0		ns
Address Hold from $\overline{RD}$	TRA		0		ns
$\overline{RD}$ Pulse Width	TRR		150		ns
Data Output Delay from Address	TAD			120	ns
Data Output Delay from $\overline{RD}$	TRD			120	ns
Data Float Delay from $\overline{RD}$	TDF		10	85	ns
Address Setup to $\overline{WR}$	TAW		0		ns
Address Hold from $\overline{WR}$	TWA		0		ns
$\overline{WR}$ Pulse Width	TWW		150		ns
Data Setup to $\overline{WR}$	TDW		120		ns
Data Hold from $\overline{WR}$	TWD		0		ns
$\overline{PRO}$ Delay from $\overline{PRI}$	TPIPO			100	ns
$\overline{PRO}$ Delay from $\overline{INTA}$	TIAPO			200	ns
PRI Setup to $\overline{INTA}$	TPIIA		0		ns
$\overline{PRI}$ Hold from $\overline{INTA}$	TIAPI		20		ns
$\overline{INTA}$ Pulse Width	TIAIA		150		ns
Data Output Delay from $\overline{INTA}$	TIAD1			120	ns
Data Float Delay from $\overline{INTA}$	TDF		10	85	ns
Request Hold from $\overline{RD}$/$\overline{WR}$	TCQ			120	ns

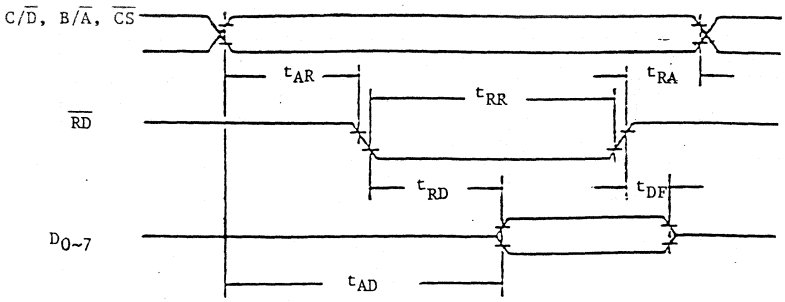
Parameter	Symbol		Test Condition	Limits		UNIT
				Max.	Min.	
Data Clock Cycle	TDCY		$\overline{STRxC}$ $\overline{RTxC}$	200		ns
Data Clock High Width	TDCH		$\overline{STRxC}$ $\overline{RTxC}$	90		ns
Data Clock Low Width	TDCL		$\overline{STRxC}$ $\overline{RTxC}$	90		ns
Tx Data Delay from TxC	TTCTD 1		x 1 Mode		300	ns
			x16,32,64 Mode		1000	
Rx Data Setup to $\overline{RTxC}$, STRxC	TRDRC	1	NRZ, NRZI	0		ns
		2	FM0, 1			
Rx Data Hold from $\overline{RTxC}$, STRxC	TRCRD	1	NRZ, NRZI	140		ns
		2	FM0, 1			
$\overline{INT}$ Delay Time from Tx Data	TTDI				4~6	tcy
$\overline{INT}$ Delay Time from $\overline{RxC}$	TRCI				7~11	tcy
Tx Data Delay from TxC	TTCTD2		x 1, FM0, 1		300	ns
$\overline{CTS}$, $\overline{DCD}$, $\overline{SYNC}$ High Pulse Width	TMH			200		ns
$\overline{CTS}$, $\overline{DCD}$, $\overline{SYNC}$ Low Pulse Width	TML			200		ns
$\overline{INT}$ Delay Time from $\overline{CTS}$, $\overline{DCD}$, $\overline{SYNC}$	TMI				500	ns
XTAL Input Pulse Width	TXTAL			125	1000	ns
$\overline{RD}$, $\overline{WR}$ Recovery Time	TRV			300		ns
DRQTx Delay Time from Tx Data	TTDD					
DRQRx Delay Time from $\overline{RxC}$	TRID					
$\overline{SYNC}$ Setup Time to $\overline{RTxC}$, STRxC	TRCS				100	ns

Note 1: $\overline{RESET}$ must be active for a minimum of 2 system clock cycle.

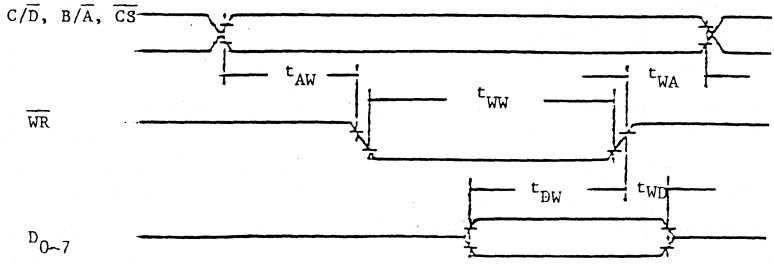
2: In all modes system clock rate must be 5 times data rate.

TIMING WAVEFORMS

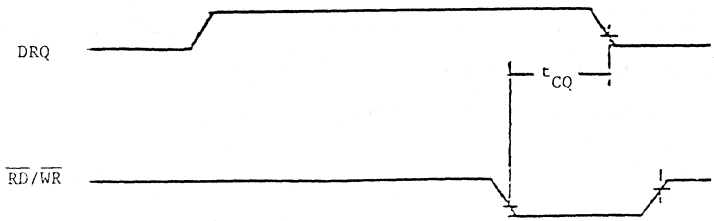
Read Cycle Timing



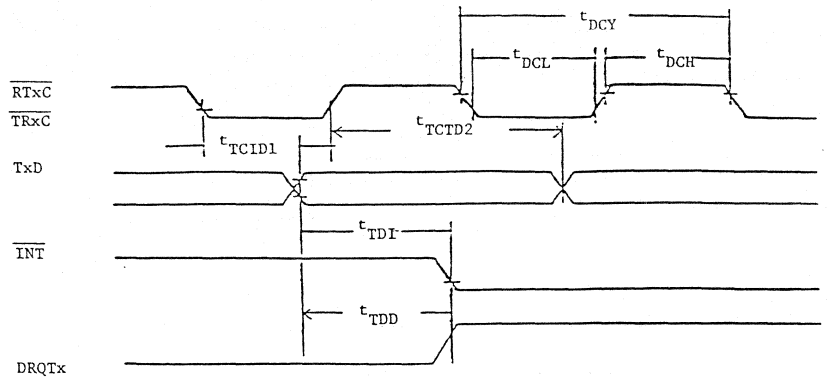
Write Cycle Timing



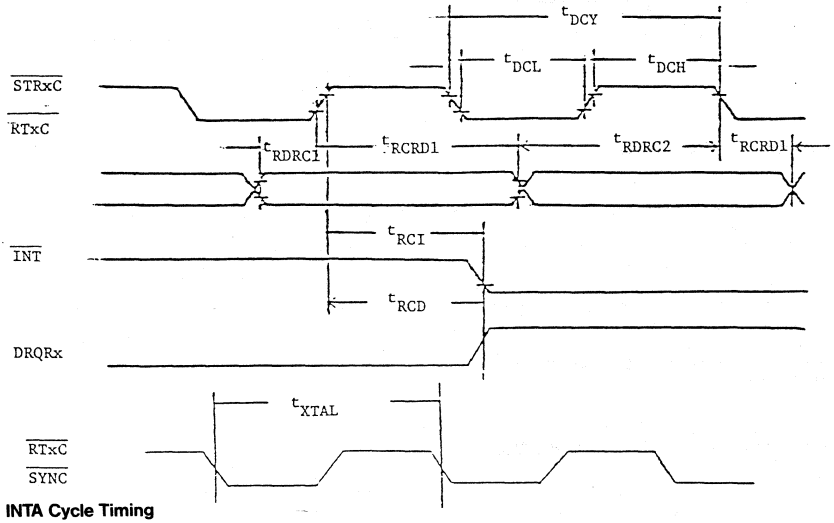
DMA Cycle Timing



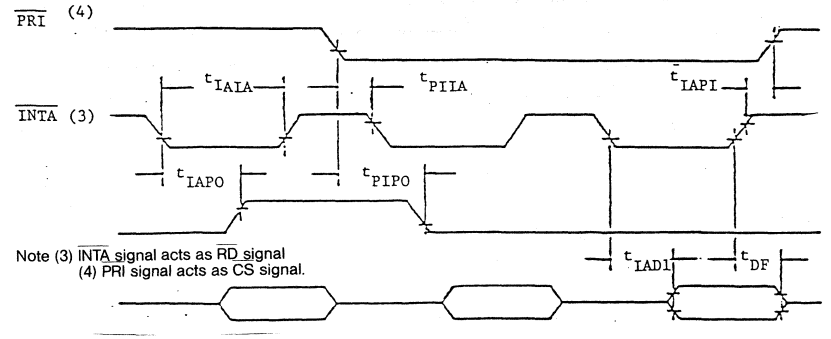
Transmit Cycle Timing



Receive Cycle Timing

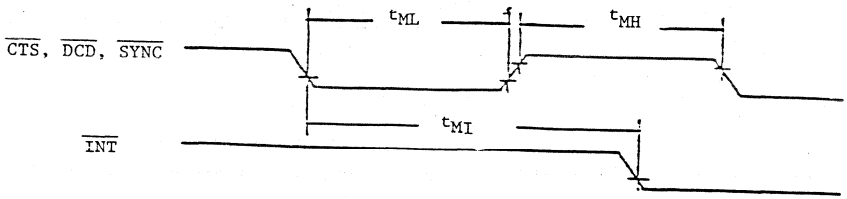


INTA Cycle Timing

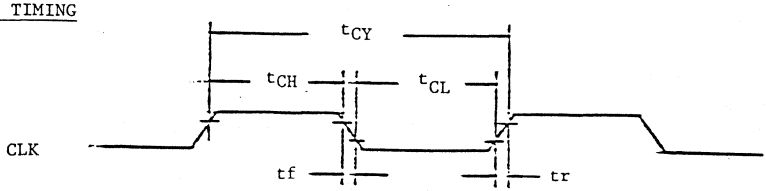


Note (3) INTA signal acts as RD signal
(4) PRI signal acts as CS signal.

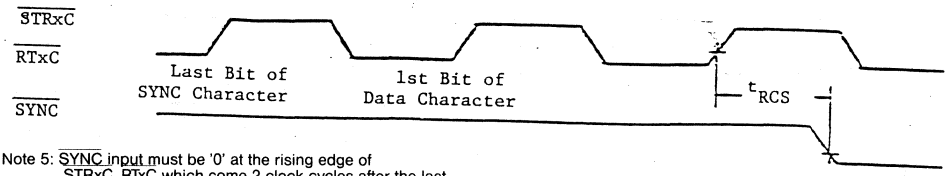
E/S TIMING



CLOCK TIMING

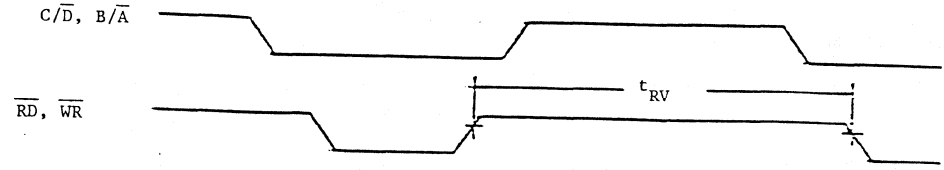


SYNC Input Timing (External Sync Mode)



Note 5: SYNC input must be '0' at the rising edge of STRxC, RTxC which come 2 clock cycles after the last bit of SYNC character.

Read/Write Cycle Timing (Software Block Transfer Mode)



Description

The μPD72105 provides local area network (LAN) communications implementing the OMNINET® I and II protocols in a single CMOS 48-pin DIP. The device can transmit data at a rate of up to 4 Mb/s using RS-422 bus transmitters and receivers. The controller responds to 17 OMNINET commands using the on-chip CPU.

The chip also contains a DMA controller with four independent channels for use with an 8- or 16-bit data bus, and can address a 16M-byte address space. The transmit section contains a 12-byte FIFO and the receiver contains a 20-byte FIFO to accommodate the high data rate. The OMNINET controller provides network diagnostics capability as well as CRC generation and checking using a 16- or 32-bit CRC for data reliability.

The μPD72105 provides a single chip solution to LAN implementation. The excellent memory addressing and data handling capability of this controller can significantly reduce the overhead on the system CPU.

OMNINET is a registered trademark of Corvus Systems.

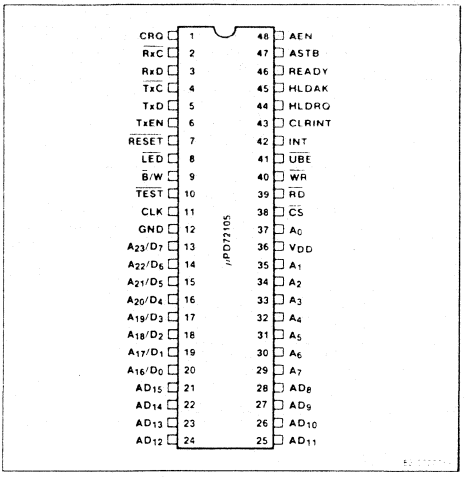
Features

- ☐ Fully implements OMNINET I and II protocols
- ☐ Data rates up to 4 Mbps
- ☐ 17 OMNINET commands
- ☐ On-chip CPU
- ☐ On-chip DMAC with four independent channels
- ☐ 8- or 16-bit data bus
- ☐ 16M-byte (2^{24}) address space for dual-ported local or global memory
- ☐ 12-byte transmitter FIFO
- ☐ 20-byte receiver FIFO
- ☐ 16- or 32-bit CRC
- ☐ On-chip 40-MHz DPLL
- ☐ Network diagnostics
- ☐ 8-MHz system clock input, independent of serial clock
- ☐ CMOS technology

Ordering Information

Part No.	Package Type
μPD72105C	48-pin plastic DIP
μPD72105L	52-pin PLCC

Pin Configuration



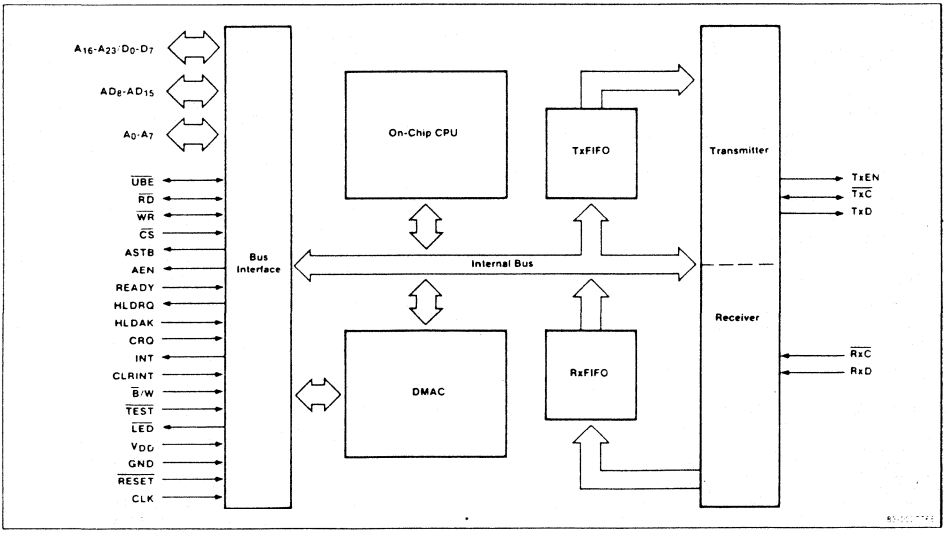
Pin Identification

No.	Symbol	Function
1	CRQ	Command request input
2	$\overline{RxC}$	Receive clock input
3	RxD	Receive data input
4	$\overline{TxC}$	Transmit clock input/output
5	TxD	Transmit data output
6	TxEN	Transmit enable output
7	$\overline{RESET}$	System reset from host computer
8	$\overline{LED}$	LED drive output, general purpose output
9	$\overline{B}$/W	Byte/word mode select input
10	$\overline{TEST}$	Test input, must be held high for normal operation
11	CLK	System clock input
12	GND	System ground
13-20	A_{23}/D_7 to A_{16}/D_0	Multiplexed address bits 16-23 and data bus bits 0-7. These signals are bidirectional.
21-28	AD_{15}/AD_8	Multiplexed address bits 8-15 and data bus bits 8-15. These signals are bidirectional.
29-35	A_7-A_1	Address bits 1 to 7; bit 1 is an input/output, bits 2-7 are output only.

Pin Identification (cont)

No.	Symbol	Function
36	V_{DD}	+5 V (typical)
37	A_0	Address bit 0, input/output
38	$\overline{CS}$	Chip select input from host computer; input
39	$\overline{RD}$	Read control signal from host computer; input
40	$\overline{WR}$	Write control signal from host computer; input
41	$\overline{UBE}$	Upper byte enable input/output
42	INT	Interrupt request output
43	CLRINT	Clear interrupt request input
44	HLDRQ	Hold request output
45	HLDAK	Hold acknowledge input
46	READY	Ready input
47	ASTB	Address strobe output
48	AEN	Address enable output

Block Diagram



INTERNAL CONFIGURATION

The μPD72105 has a transmitter and a receiver that transmits/ receives serial data as well as TxFIFO and RxFIFO buffers that respectively hold parallel data for the transmitter and receiver. In addition, it has a system interface to transfer data to and from the host system, a DMA controller to control data transfer, and an internal controller to control operation of each block.

Internal Controller

The internal controller interprets the commands sent from the host processor and controls the serial section and DMA controller. It also generated results which are to be transmitted to the host system after command execution has been completed.

System Interface

This is hardware for interfacing with the host system to process the I/O access and DMA transfer initiated by the host system.

DMA controller

The DMA controller processes the information (such as commands, data, and results) transferred between the host system and μPD72105 on a memory basis, using DMA. The transfer is performed in units of 4-byte blocks. Each time the transmitter or receiver processes the 4-byte data, the DMA controller issues a HLDRQ signal.

RxFIFO

This is a 20-byte receive buffer.

TxFIFO

This is a 12-byte transmit buffer.

Receiver

The receiver receives packets via the RxD pin and stores them in RxFIFO.

Transmitter

The transmitter transmits the contents of TxFIFO via the TxD pin.

INTERFACING WITH HOST SYSTEM

The host system can access three registers in the μPD72105: the control, status, and address FIFO registers. The control and status registers are used to control the μPD72105 without using the CRQ, INT, and CLRINT pins. The address FIFO is used to provide command addresses to the μPD72105.

Register Selection (x : Don't Care)

$\overline{CS}$	$\overline{WR}$	$\overline{RD}$	A1	A0	Operation
0	0	1	0	0	Writes to the control register
	1	0			Reads from the status register
	0	1	0	1	Specifies the address FIFO
	0	1	1	1	Writes to the address FIFO
	All others				Use prohibited
1	x				Not selected

Control Register

D7	D6	D5	D4	D3	D2	D1	D0	
X	X	X	MIRQ	CIRQ	0	0	CMDRQ	(X: Don't Care)

CMDRQ (Command Request)

This bit has the same functions as the CRQ pin. The host system can issue a command request to the μPD72105 by setting this bit to 1. This bit is automatically reset when the command is executed.

CIRQ (Clear Interrupt Request):
This bit has the same functions as the CLRINT pin. The host system can clear the INT signal of the μPD72105 by setting this bit to 1. When the INT signal is cleared, this bit is automatically reset.

Status Register

D7	D6	D5	D4	D3	D2	D1	D0	
–	–	–	IRQ	–	–	WNR	–	(–: Undefined)

WNE (Write Not Ready):
This bit indicates that the μPD72105 is not ready when the host system is preparing to write a command address to the address FIFO. The host system must wait for this bit to become 0 before writing the next byte.

IRQ (Interrupt Request):
This bit indicates the status of the INT pin. The host system can detect an interrupt from the μPD72105 by bolling this bit.

Address FIFO
This is a register that receives the memory address to which the host system has written a command and then issues a command request. The μPD72105 then receives a command from the memory area indicated by the address in the address FIFO and executes it.
When the host system issues a command request without writing an address in the address FIFO, the μPD72105 fetches a command from the memory area indicated by the default address (see NEW DEFLT ADDR command) and executes it.

COMMANDS

Types of Commands

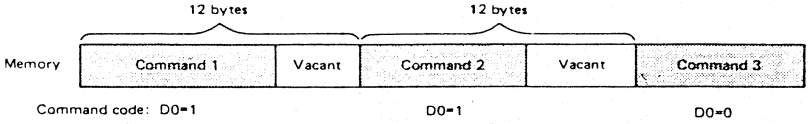
The μPD72105 is provided with the following commands:

Command name	Description
INIT (Initialize)	Initializes the μPD72105.
SEND (Send)	Transmits a message to the other nodes through the network.
SETUP RCV (Setup Receive)	Activates a socket for receive.
END RCV (End Receive)	Inactivates the set-up socket.
WAIT RCV (Wait receive)	Directs a particular socket to await reception for a specific period of time.
RCV LIST (Receive List)	Sets up a list of the receive buffers.
ECHO (Echo)	Transmits an ECHO packet to the other transporter on the network.
LOOP BACK (Loop Back)	Transfers data stored in a particular buffer in the node an other buffer via the μPD72105.
INIT MONIT (Initialize Monitor)	Starts the network monitor.
MONIT OFF (Monitor OFF)	Suspends transfer during network monitoring.
MONIT ON (Monitor ON)	Resumes suspended transfer during network monitoring.
SET PARM (Set Parameters)	Sets the internal parameters of the μPD72105.
GET PARM (Get Parameters)	Reads the internal parameters of μPD72105.
NEW CHAIN (New Chain)	Specifies a command address to execute the command stored there.
NEW DEFLT ADDR (New Default Address)	Sets the default value of a command address to execute the command stored there.
CLR STAT (clear Statistics)	Clears the Tx / Rx statistics of the μPD72105.
GET STAT (Get statistics)	Reads the Tx / Rx statistics of the μPD72105.

Note: INIT MONIT, MONIT OFF and MONIT ON commands don't start operation without setting the μPD72105 in a state. The setting way will be informed to the licensees of corvus systems Inc.

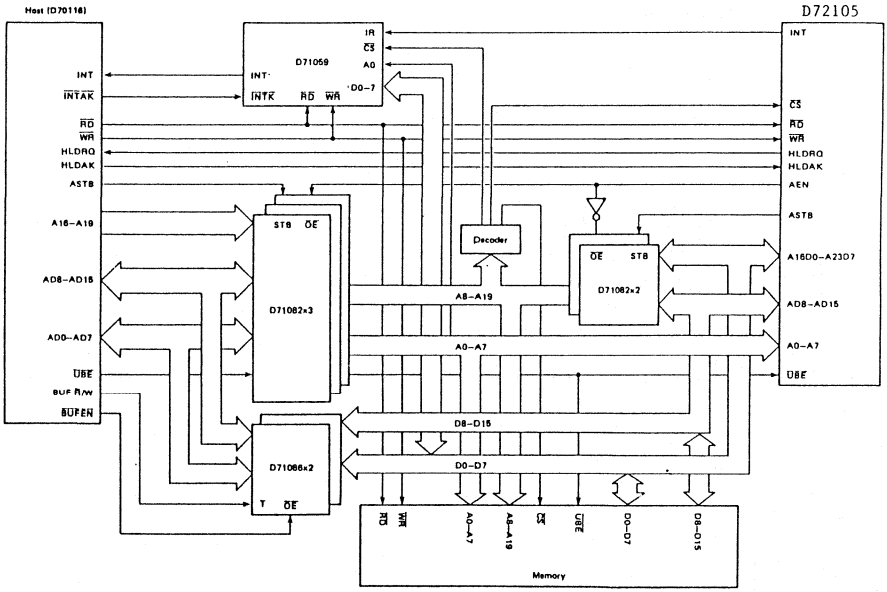
Command Functions

μPD72105 fetches 12-byte data as a command and processes valid data only. Command codes are even values and when they are changed into odd values by setting to D0 bit to 1, the "command chaining function" of the μPD 72105 is enabled. This function allows the μPD72105 to execute a sequence of commands on memory when the host system issues a single command request. When the μPD72105 receives a command whose command code has the D0 bit set to 1, it executes the command then the next one automatically. In this case, however, commands must continuosly exist in every 12-byte area in memory.

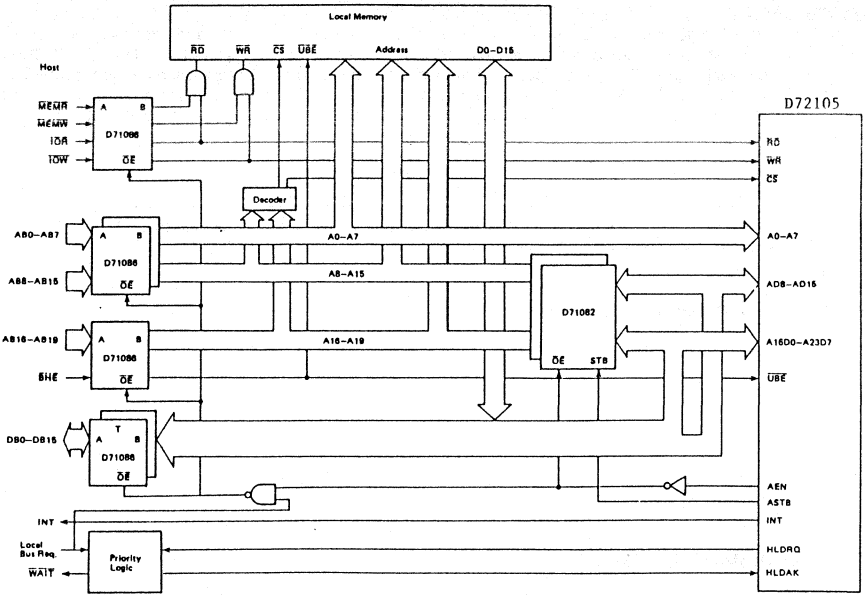


Example of Command Chaining (3 commands)

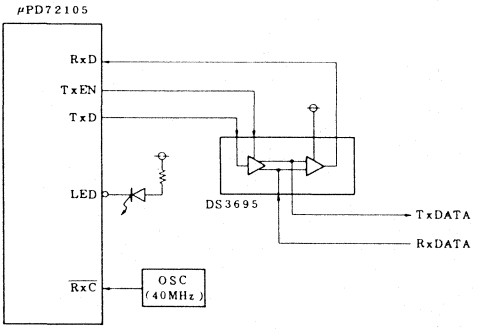
SYSTEM CONFIGURATION EXAMPLES



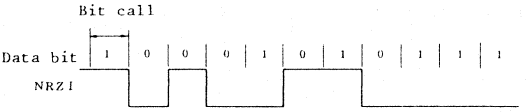
System Configuration Example I (Memory Mapped I/O)



System Configuration Example II

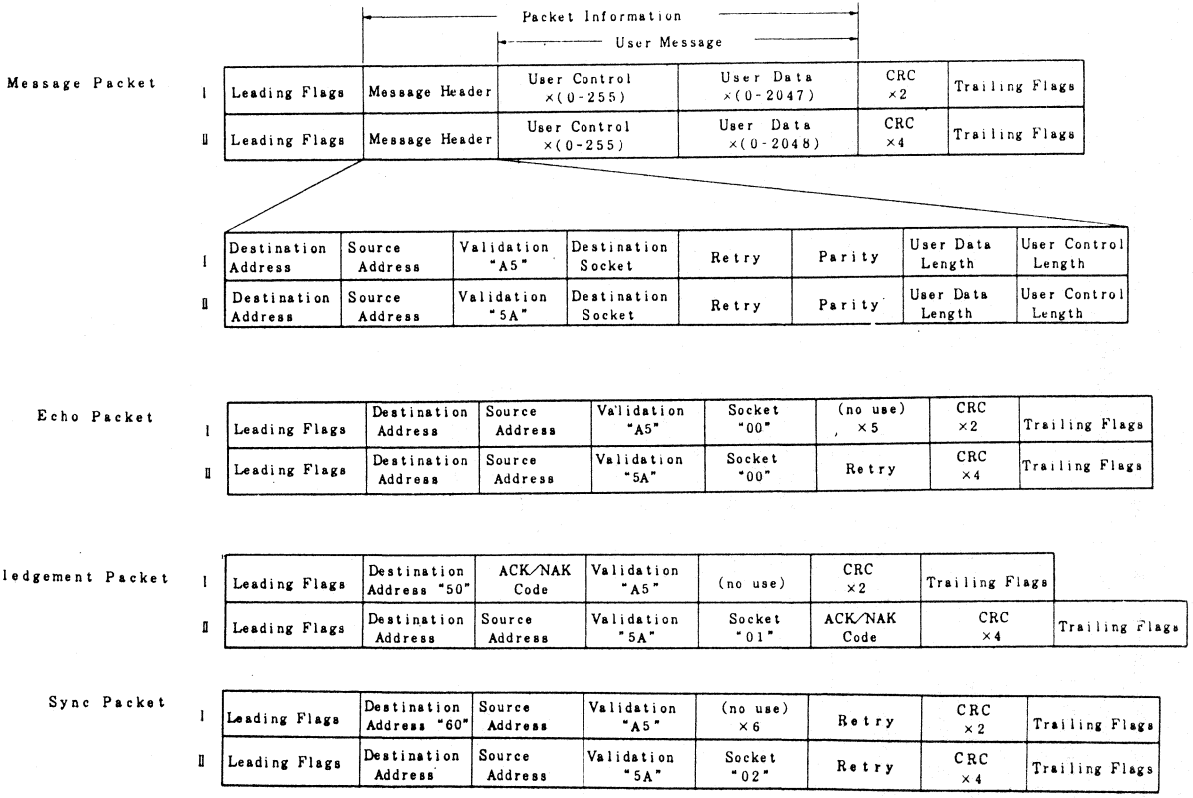


NRZI Data Format



Example for serial interface

Packet Format



I = OMNINET I protocol, II = OMNINET II protocol

AC/DC Target spec.

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Parameter	Symbol	Test Conditions	Ratings	Units
Power Supply Voltage	VDD		−0.5 ~ +7.0	V
Input Voltage	VI		−0.5 ~ VDD +0.3	V
Output Voltage	VO		−0.5 ~ VDD + 0.3	V
Operating Temperature	Topt		−40 ~ +85	°C
Storage Temperature	Tstg		−40 ~ +125	°C

DC CHARACTERISTICS (Ta = −40 ~ +85 °C, VDD = 5V ± 10%)

Parameter	Symbol	Test Conditions	MIN	TYP	MAX	Units
Input Low Voltege	VILC	CLK Pin	−0.5		+0.8	V
	VILR	$\overline{RXC}$ when using on-chip DPLL	−0.5		+0.4	V
	VIL	Others	−0.5		+0.8	V
Input High Voltage	VIHC	CLK Pin	+3.3		VDD+0.5	V
	VIHR	RXC when using on-chip DPLL	+2.4		VDD+0.5	V
	VIH	Others	+2.2		VDD+0.5	V
Output Voltage Low	VOL	IOL = 2.5 mA			+0.4	V
Output Voltage High	VOH	IOIl = −400uA	0.7*VDD			V
Supply Current	IDDI	When operating		50		mA
Input Leakage Current	ILI	0V ≦ VIN ≦ VDD			± 10	uA
Output leakage Current	ILO	OV ≦ VOUT ≦ VDD			± 10	uA

AC CHARACTERISTIC (Ta = −40 ~ +85 °C, VDD = 5V ± 10%)

BUS-MASTER MODE

Parameter	Symbol	Test Conditions	MIN	MAX	Unit
CLK Cycle Time	TCYK		125	1000	nS
CLK Active Low	TKKL		50		nS
CLK Active High	TKKH		50		nS
CLK Rise Time	TKR	1.5–3.0V		10	nS
CLK Fall Time	TKF	3.0–1.5V		10	nS
HLDRQ↑ Delay Time from CLK↓	TDHQH			100	nS
HLDRQ↓ Delay Time from CLK↑	TDHQL			100	nS
HLDAK Setup Time to CLK↑	TSHA		35		nS
AEN↑ Delay Time from CLK↓	TDAEH			100	nS
AEN↓ Delay Time from CLK↑	TDAEL			100	nS
ASTB↑ Delay Time from CLK↑	TDSTH			70	nS
ASTB Pulse Width	TSTSTH		TKKH-15		nS
ASTB↓ Delay Time from CLK↓	TDSTL			100	nS
ADR/$\overline{UBE}$/$\overline{RD}$/$\overline{WR}$ Delay Time from CLK↑	TDA			100	nS
ADR/$\overline{UBE}$/$\overline{RD}$/$\overline{WR}$ Float Delay from CLK↓	TFA			70	nS
ADR Setup Time to ASTB↓	TSAST		TKKH-35		nS
ADR Hold Time from ASTB	THSTA		TKKL-20		nS
$\overline{RD}$↓ Delay Time from ADR Float	TDAR		TKKH-30		nS
$\overline{RD}$↓ Delay Time from CLK↓	TDRL			70	nS
$\overline{RD}$ Pulse Width	TRRL2		1.5TCYK −50		nS
$\overline{RD}$↑ Delay Time from CLK↑	TDRH			100	nS
DATA Setup Time to $\overline{RD}$↑	TSDR		70		nS
DATA Hold Time from $\overline{RD}$↑	THRD		0		nS
$\overline{WR}$↓ Delay Time from CLK↓	TDWL			70	nS
$\overline{WR}$ Pulse Width	†WWL2		1.5TCYK −50		nS
$\overline{WR}$↑ Delay Time from CLK↑	TDWH			80	nS
READY Setup Time to CLK↑	TSRY		35		nS
READY Hold Time from CLK↑	THRY		20		nS

Parameter	Symbol	Test Conditions	MIN	MAX	Units
CLRINT Pulse Width	TCLCLH		100		nS
INT↑ Delay Time from CLK↑	TDIH			100	nS
INT↓ Delay Time from CLRINT↑	TDIL			100	nS
$\overline{LED}$↓ Delay Time from CLK↑	TDLL			100	nS
$\overline{LED}$↑ Delay Time from CLK↑	TDLH			100	nS
CRQ Pulse Width	TCRCRH		100		nS

BUS-SLAVE MODE

Parameter	Symbol	Test Conditions	MIN	MAX	Units
$\overline{WR}$ Pulse Width	TWWL		100		nS
$\overline{CS}$ Hold Time from $\overline{WR}$↑	THWCS		0		nS
ADR/$\overline{UBE}$/$\overline{CS}$ Setup Time to $\overline{WR}$↓	TSAW		0		nS
ADR/$\overline{UBE}$ Hold Time from $\overline{WR}$	THWA		0		nS
DATA Setup Time to $\overline{WR}$↑	TSDW		100		nS
DATA Hold Time from $\overline{WR}$↑	THWD		0		nS
$\overline{RD}$ Pulse Width	TRRL		150		nS
ADR/$\overline{CS}$ Setup Time to $\overline{RD}$↓	TSAR		35		nS
ADR/$\overline{CS}$ Hold Time from $\overline{RD}$↑	THRA		0		nS
DATA Delay Time from $\overline{RD}$↓	TDRD			120	nS
DATA Float Delay from $\overline{RD}$↑	TFRD		10	100	nS
$\overline{RESET}$ Pulse Width	TRSTL		7TGYK		nS
VDD Setup Time to $\overline{RESET}$↑	TSVDD		1000		nS
1st $\overline{WR}$/$\overline{RD}$ from $\overline{RESET}$↑	TSYWR		2TCYK		nS
Recovery Time from $\overline{WR}$/$\overline{RD}$	TRVWR		200		nS
High Setup Time to HLDAK↑	TSWR		−20		nS
High Hold Time from AEN↓	THWR		100		nS

* 1 Input levels for AC test are
  2.4V (as "1") and
  0.4V (as "0").

  Test points are
  2.2V (as "1„) and
  0.8V (as "0").

* 2 Fix B/W pin to "1" or "0"

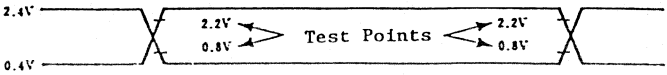
Serial Part

Parameter	Symbol	Test Conditions	MIN	MAX	Units
TXC/RXC Cycle Time	TCYS		250	2000	nS
TXC/RXC Active Low	TSSL		110		nS
TXC/RXC Active High	TSSH		110		nS
TXC/RXC Rise Time	TSR			20	nS
TXC/RXC Fall Time	TSF			12	nS
TXD Delay Time from $\overline{TCX}\downarrow$	TDTXD			100	nS
TXEN↑ Delay Time from $\overline{TXC}\downarrow$	TDTEH			100	nS
TXEN↓ Delay Time from $\overline{TCX}\downarrow$	TDTEL			100	nS
RXD Setup Time to $\overline{RXC}\uparrow$	TSRXD		50		nS
RXD Hold Time from $\overline{RXC}\uparrow$	THRXD		70		nS
$\overline{RXC}$ Cycle Time *3	TCYH	When using on-chip DPLL	25	200	nS
$\overline{RXC}$ Active Low	THHL	When using on-chip DPLL	5		nS
$\overline{RXC}$ Active High	THHH	When using on-chip DPLL	5		nS
$\overline{RXC}$ Rise Time	THR	When using on-chip DPLL		5	nS
$\overline{RXC}$ Fall Time	THF	When using on-chip DPLL		5	nS
TX, RX DATA Cycle Time	TCYD	When using on-chip DPLL	250	2000	nS
RXD Setup Timing	TRX	When using on-chip DPLL			nS
$\overline{TXC}$ Active Low	TTTL	When using on-chip DPLL			nS
$\overline{TXC}$ Active High	TTTH	When using on-chip DPLL			nS
TXD Change Delay from $\overline{TXC}\downarrow$	TDTX1	When using on-chip DPLL		50	nS
TXD Change Delay from $\overline{TXC}\uparrow$	TDTX2	When using on-chip DPLL			nS

* 3 DPLLed clock cycle time should be from 250 ns to 2000 ns.

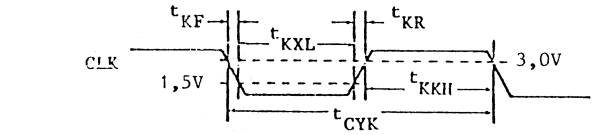
This is a target spec. and can be changed during development.

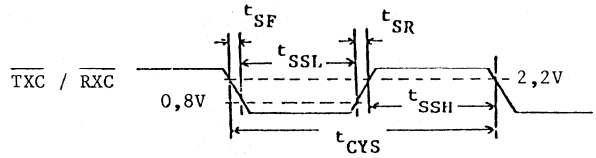
AC Timing Test Points

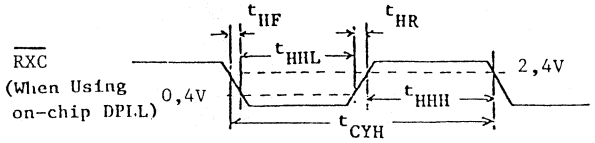


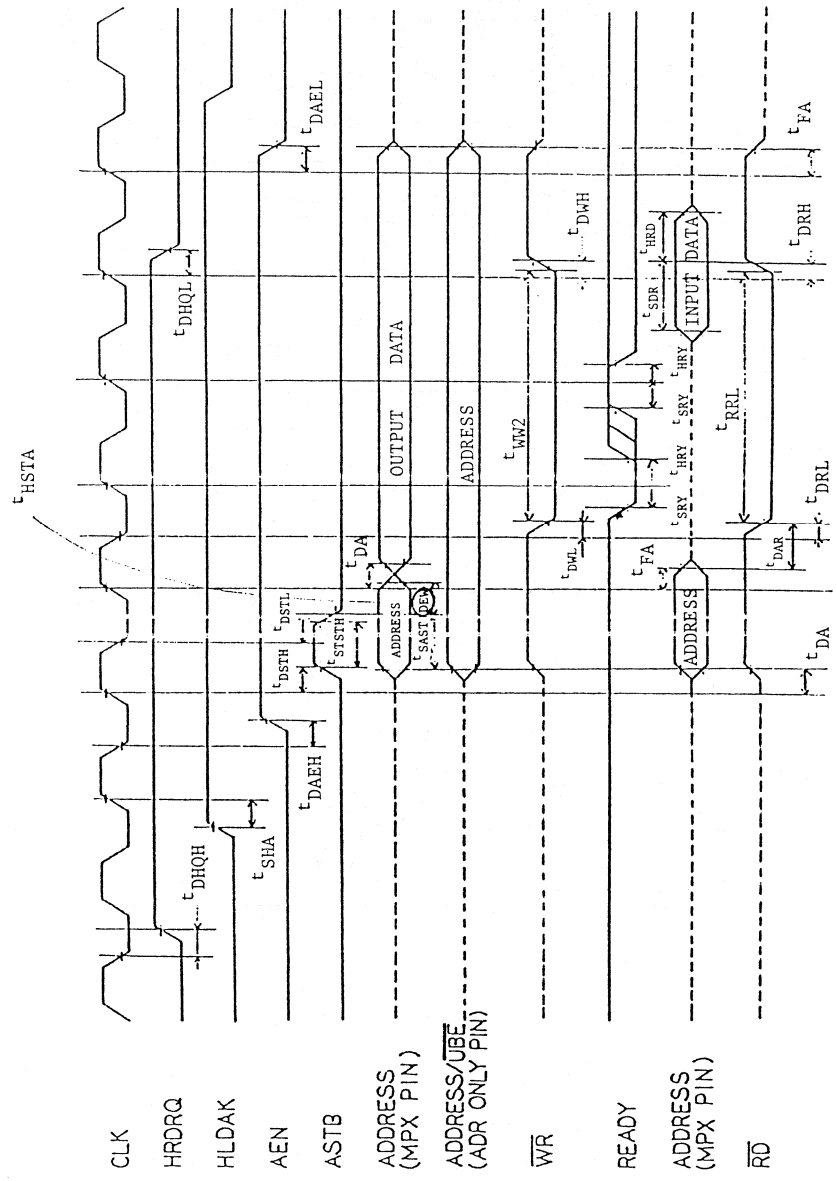
Timing Waveform

CLK Waveform



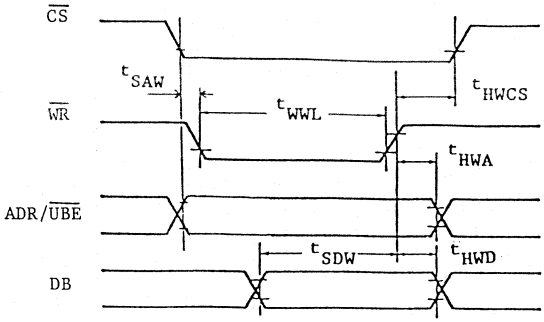


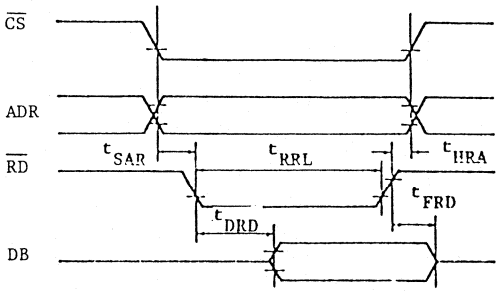


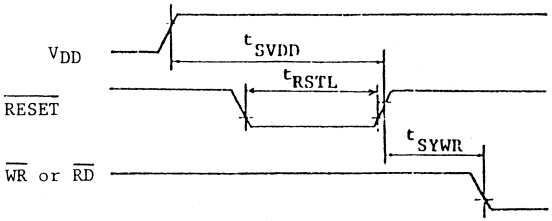


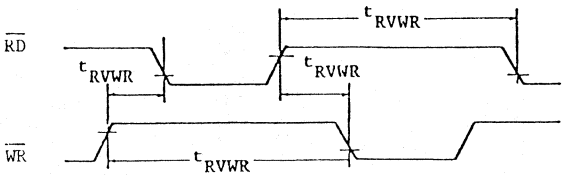
BUS-MASTER MODE

BUS SLAVE MODE (1)

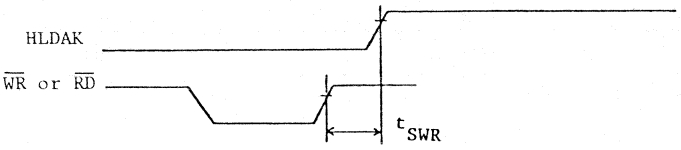


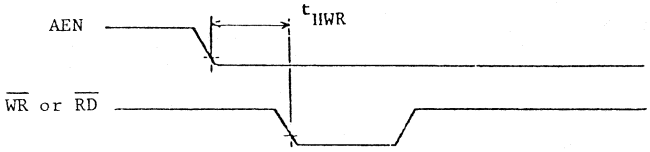


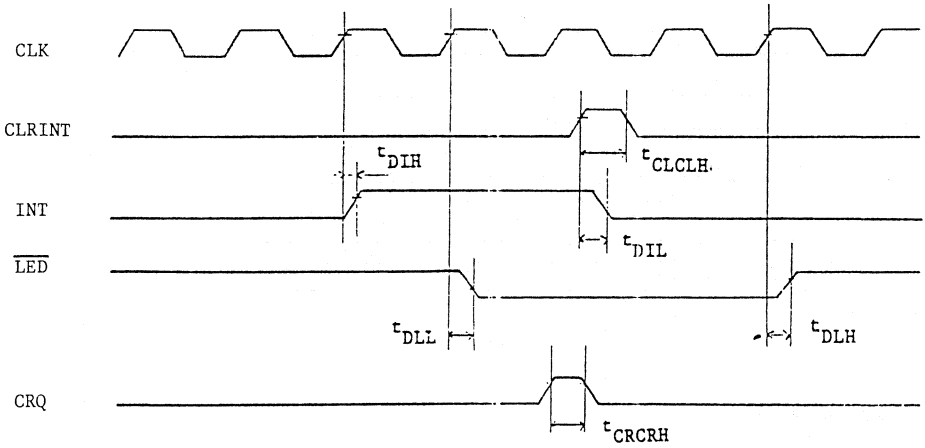


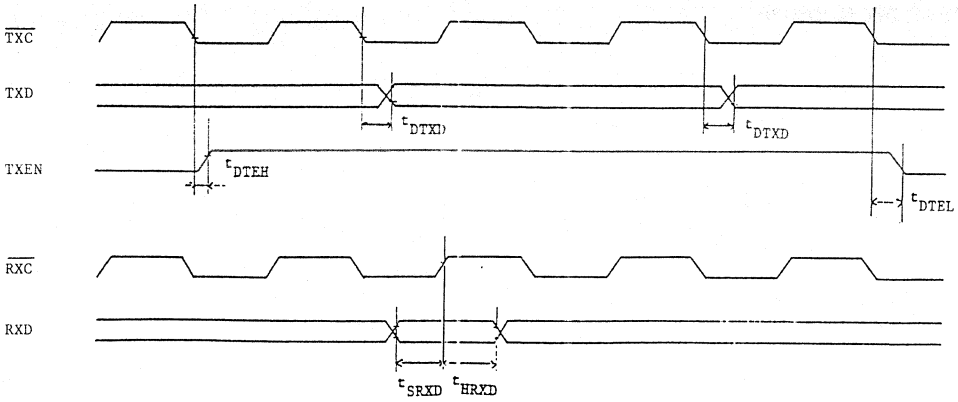


BUS SLAVE MODE (2)

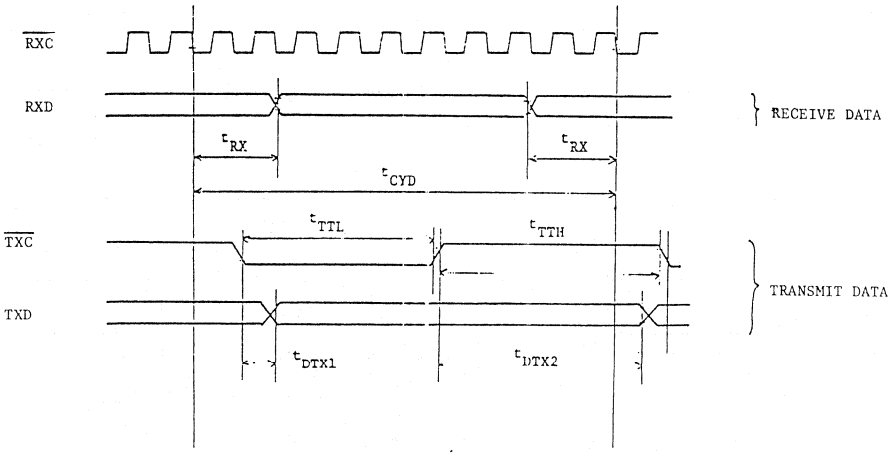








When not using on-chip DPLL



When using on-chip DPLL

Description

The μPD7210 is an intelligent, general purpose interface bus (GPIB) controller designed to meet all of the functional requirements for talker, listener, and controller (TLC) as specified by IEEE Standard 488-1978. Connected between a processor bus and the GPIB, the controller provides high-level management of the GPIB to unburden the processor and to simplify both hardware and software design. The μPD7210 is fully compatible with most processor architectures and requires only the addition of bus driver/receiver components to implement any type of GPIB.

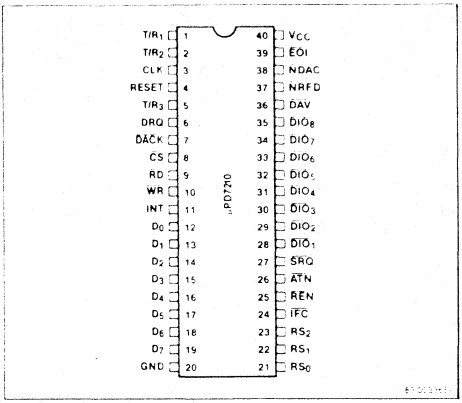
Features

- All-functional interface capability meeting IEEE Standard 488-1978
  - —SH1 (source handshake)
  - —AH1 (acceptor handshake)
  - —L3 or LE3 (listener or extended listener)
  - —T5 or TE5 (talker or extended talker)
  - —SR1 (service request)
  - —RL1 (remote local)
  - —PP1 or PP2 (parallel poll, remote or local configuration)
  - —DC1 (device clear)
  - —DT1 (device trigger)
  - —C1-C5 (controller, all functions)
- Programmable data transfer rate
- 16 MPU accessible registers: 8 read and 8 write
- 2 address registers
  - —Detection of MTA, MLA, MSA (my talk/my listen/my secondary addresses)
  - —2 device addresses
- EOS message automatic detection
- Command (IEEE Standard 488-1978) automatic processing and undefined command read capability
- DMA capability
- Programmable bus transceiver I/O specification (works with T.I./Motorola/Intel)
- 1-MHz to 8-MHz clock range
- TTL-compatible
- NMOS
- +5 V single power supply
- 8080/85/86-compatible

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD7210C	40-pin plastic DIP	8 MHz

Pin Configuration



Pin Identification

No.	Symbol	Function
1, 2, 5	T/R_1-T/R_3	Transmit/receive control outputs
3	CLK	Clock input
4	RESET	Reset input
6	DRQ	DMA request output
7	$\overline{DACK}$	DMA acknowledge input
8	$\overline{CS}$	Chip select input
9	$\overline{RD}$	Read input
10	$\overline{WR}$	Write input
11	INT	Interrupt request output
12-19	D_0-D_7	Bidirectional data bus
20	GND	Ground
21-23	RS_0-RS_2	Register select input
24	$\overline{IFC}$	Interface clear I/O
25	$\overline{REN}$	Remote enable I/O
26	$\overline{ATN}$	Attention control line I/O
27	$\overline{SRQ}$	Service request I/O
28-35	$\overline{DIO_1}$-$\overline{DIO_8}$	8-bit bidirectional data bus
36	$\overline{DAV}$	Data valid I/O
37	$\overline{NRFD}$	Ready for data I/O
38	$\overline{NDAC}$	Data accepted I/O
39	$\overline{EOI}$	End or identify I/O
40	V_{CC}	+5 V power supply

Pin Functions

T/R_1-T/R_3 [Transmit/Receive Control]

This is the input/output control signal for the GPIB transceivers. The values of TRM1 and TRM0 of the address mode register determine the functions of T/R_2 and T/R_3.

CLK [Clock]

This 1-MHz to 8-MHz reference clock generates the state change prohibit times T_1, T_6, T_7, and T_9 specified in IEEE Standard 488-1978.

RESET

When high, the RESET signal places the μPD7210 in an idle state.

DRQ [DMA Request]

DRQ becomes low on input of the DMA acknowledge signal $\overline{DACK}$.

$\overline{DACK}$ [DMA Acknowledge]

This signal connects the computer system data bus to the data register of the μPD7210.

$\overline{CS}$ [Chip Select]

The chip select input enables access to the register selected by the read or write operation (RS_0-RS_2).

$\overline{RD}$ [Read]

The read input places the contents of the read register specified by RS_0-RS_2 on the computer bus (D_0-D_7).

$\overline{WR}$ [Write]

This input writes data on D_0-D_7 into the write register specified by RS_0-RS_2.

INT, $\overline{INT}$ [Interrupt Request]

This output is active high/low. It becomes active due to any one of 13 internal interrupt factors (unmasked). Its active state is software configurable, and it is active high on chip reset.

D_0-D_7 [Data Bus]

The 8-bit bidirectional data bus interfaces to the computer system.

GND [Ground]

This is the ground.

RS_0-RS_2 [Register Select]

These lines select one of eight read (write) registers during a read (write) operation.

$\overline{IFC}$ [Interface Clear]

This bidirectional control line is used for clearing the interface functions.

$\overline{REN}$ [Remote Enable]

This bidirectional control line is used to select remote or local control of the devices.

$\overline{ATN}$ [Attention]

This bidirectional control line indicates whether data on the $\overline{DIO}$ lines is an interface message or a device-dependent message.

$\overline{SRQ}$ [Service Request]

This bidirectional control line is used to request service from the controller.

$\overline{DIO_1}$-$\overline{DIO_8}$ [Data Input/Output]

This 8-bit bidirectional bus transfers messages on the GPIB.

$\overline{DAV}$ [Data Valid]

This handshake line indicates that data on the $\overline{DIO}$ line is valid.

$\overline{NRFD}$ [Ready for Data]

This handshake line indicates that the device is ready for data.

$\overline{NDAC}$ [Data Accepted]

This handshake line indicates the completion of message reception.

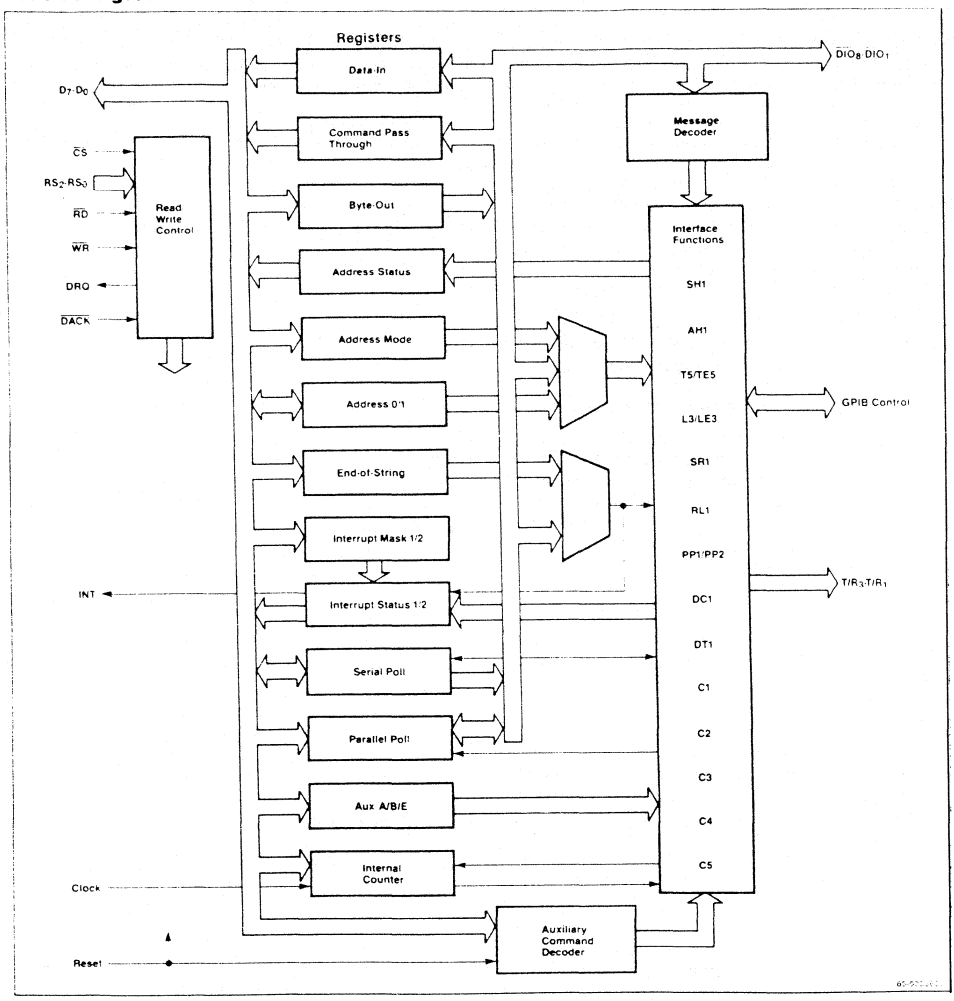
$\overline{EOI}$ [End or Identify]

This control line is used to indicate the end of a multiple byte transfer sequence or to execute parallel polling in conjunction with $\overline{ATN}$.

V_{CC} [Power Supply]

+5 V power supply.

Block Diagram



History

The IEEE Standard 488 describes a "Standard Digital Interface for Programmable Instrumentation" which, since its introduction in 1975, has become the most popular means of interconnecting instruments and controllers in laboratory, automatic test, and even industrial applications. Refined over several years, the 488-1978 Standard, also known as the General Purpose Interface Bus (GPIB), is a highly sophisticated standard providing a high degree of flexibility to meet virtually all instrumentation requirements. The μPD7210 implements all of the functions that are required to interface to the GPIB. While it is beyond the scope of this document to provide a complete explanation of the IEEE 488 Standard, a basic description follows:

The GPIB interconnects up to 15 devices over a common set of data control lines. Three types of devices are defined by the standard: talker, listener, and controller, although some devices may combine functions such as talker/listener or talker/controller.

Data on the GPIB is transferred in a bit-parallel, byte-serial fashion over eight data I/O lines ($\overline{DIO}_1$-$\overline{DIO}_8$). A three-wire handshake is used to ensure synchronization of transmission and reception. In order to permit more than one device to receive data at the same time, these control lines are "open collector" so that the slowest device controls the data rate. A number of other control lines perform a variety of functions such as device addressing, interrupt generation, and so forth.

The μPD7210 implements all functional aspects of talker, listener, and controller functions as defined by the 488-1978 Standard on a single chip.

General

The μPD7210 is an intelligent controller designed to provide high-level protocol management of the GPIB, freeing the host processor for other tasks. Control of the μPD7210 is accomplished via 16 internal registers. Data may be transferred either under program control or via DMA using the μPD7210's DMA control facilities to further reduce processor overhead. The processor interface of the μPD7210 is general in nature and may be readily interfaced to most processor lines.

In addition to providing all control and data lines necessary for a complete GPIB implementation, the μPD7210 also provides a unique set of bus transceiver controls permitting a variety of transceiver configurations for maximum flexibility.

Internal Registers

The μPD7210 has eight read registers (0R-7R) and eight write registers (0W-7W). The register number is selected via the RS_2, RS_1, and RS_0 lines; read or write is selected via WR, RD, and CS.

Register Addressing

Register		Addressing RS_2	RS_1	RS_0	WR	RD	CS
Data-In	0R	0	0	0	1	0	0
Interrupt Status 1	1R	0	0	1	1	0	0
Interrupt Status 2	2R	0	1	0	1	0	0
Serial Poll Status	3R	0	1	1	1	0	0
Address Status	4R	1	0	0	1	0	0
Command Pass Through	5R	1	0	1	1	0	0
Address 0	6R	1	1	0	1	0	0
Address 1	7R	1	1	1	1	0	0
Byte Out	0W	0	0	0	0	1	0
Interrupt Mask 1	1W	0	0	1	0	1	0
Interrupt Mask 2	2W	0	1	0	0	1	0
Serial Poll Mode	3W	0	1	1	0	1	0
Address Mode	4W	1	0	0	0	1	0
Auxiliary Mode	5W	1	0	1	0	1	0
Address 0/1	6W	1	1	0	0	1	0
End of String	7W	1	1	1	0	1	0

Data Registers

Data-In (0R)

DI_7	DI_6	DI_5	DI_4	DI_3	DI_2	DI_1	DI_0

Byte-Out (0W)

BO_7	BO_6	BO_5	BO_4	BO_3	BO_2	BO_1	BO_0

The data registers are used for data and command transfers between the GPIB and the microcomputer system. The Data-In register holds data sent from the GPIB to the computer; the Byte-Out register holds information written into it for transfer to the GPIB.

Interrupt Registers

Interrupt Status 1 (1R)

CPT	APT	DET	END	DEC	ERR	DO	DI

Interrupt Status 2 (2R)

INT	SRQI	LOK	REM	CO	LOKC	REMC	ADSC

Interrupt Mask 1 (1W)

CPT	APT	DET	END	DEC	ERR	DO	DI

Interrupt Mask 2 (2W)

0	SRQI	DMAO	DMAI	CO	LOKC	REMC	ADSC

The interrupt registers are composed of interrupt status bits, interrupt mask bits, and some other non-interrupt related bits.

There are 13 factors that can generate an interrupt from the μPD7210, each with its own status bit and mask bit.

The interrupt status bits are always set to 1 if the interrupt condition is met. The interrupt mask bits decide whether or not the INT bit and the interrupt pin will be active for that condition.

Interrupt Status Bits

INT	OR of all unmasked interrupt status bits
CPT	Command pass through
APT	Address pass through
DET	Device trigger
END	End (END or EOS message received)
DEC	Device clear
ERR	Error
DO	Data out
DI	Data in
SRQI	Service request input
LOKC	Lockout change
REMC	Remote change
ADSC	Address status change
CO	Command output

Noninterrupt Related Bits

LOK	Lockout
REM	Remote/local
DMAO	Enable/disable DMA out
DMAI	Enable/disable DMA in

Serial Poll Registers

Serial Poll Status (3R)

S_8	PEND	S_6	S_5	S_4	S_3	S_2	S_1

Serial Poll Mode (3W)

S_8	rsv	S_6	S_5	S_4	S_3	S_2	S_1

The serial poll mode register holds the STB (status byte: S_8, S_6-S_1) sent over the GPIB and the local message rsv (request service). The serial poll mode register may be read through the serial poll status register. The PEND is set by rsv = 1 and cleared by NPRS · $\overline{\text{rsv}}$ = 1 (NPRS means negative poll response state).

Address Mode/Address Status Registers

Address Status (4R)

CIC	$\overline{\text{ATN}}$	SPMS	LPAS	TPAS	LA	TA	MJMN

Address Mode (4W)

t_{on}	l_{on}	TRM1	TRM0	0	0	AMD1	AMD0

The address mode register selects the address mode of the device and also sets the mode for the transceiver control lines, $T/\overline{R}_3$ and $T/\overline{R}_2$.

The functions of $T/\overline{R}_2$ (pin 2) and $T/\overline{R}_3$ (pin 5) are determined by the TRM1, TRM0 values of the address mode register.

Function of $T/\overline{R}_2$ and $T/\overline{R}_3$

$T/\overline{R}_2$	$T/\overline{R}_3$	TRM1	TRM0
EOIOE	TRIG	0	0
CIC	TRIG	0	1
CIC	EOIOE	1	0
CIC	PE	1	1

EOIOE = TACS + SPAS + CIC · $\overline{\text{CSBS}}$
This denotes the input/output of the $\overline{\text{EOI}}$ terminal.
When 1: output
When 0: input

CIC = $\overline{\text{CIDS}}$ + $\overline{\text{CADS}}$
This denotes whether or not the controller interface function is active.
When 1: $\overline{\text{ATN}}$ = output, $\overline{\text{SRQ}}$ = input
When 0: $\overline{\text{ATN}}$ = input, $\overline{\text{SRQ}}$ = output

PE = CIC + $\overline{\text{PPAS}}$
This indicates the type of bus driver connected to the $\overline{\text{DIO}}_8$ to $\overline{\text{DIO}}_1$ and $\overline{\text{DAV}}$ lines.
When 1: three-state
When 0: open-collector

TRIG: When DTAS state is initiated or when a trigger auxiliary command is issued, a high pulse is generated.

Upon reset, TRM0 and TRM1 become 0 (TRM0 = TRM1 = 0) and a local message port is provided so that $T/\overline{R}_2$ and $T/\overline{R}_3$ both become low.

Address Modes

t_{on}	l_{on}	ADM1	ADM0	Address Mode	Contents of Address 0 Register	Contents of Address 1 Register
1	0	0	0	Talk only mode	Address identification not necessary (No controller on the GPIB)	
0	1	0	0	Listen only mode	Not used	
0	0	0	1	Address mode 1 (Note 1)	Major talk address or major listen address	Minor talk address or minor listen address
0	0	1	0	Address mode 2 (Note 2)	Primary address (talk or listen)	Secondary address (talk or listen)
0	0	1	1	Address mode 3 (Note 3)	Primary address (major talk or major listen)	Primary address (minor talk or minor listen)

Note:

(1) Either MTA or MLA reception is indicated by coincidence of either address with the received address, interface function T or L.

(2) Address register 0 = primary; address register 1 = secondary; interface function TE or LE.

(3) CPU must read secondary address via Command Pass Through register interface function (TE or LE).

(4) Combinations other than those indicated are prohibited.

Address Status Bits

$\overline{ATN}$	Data transfer cycle (device in CSBS)
LPAS	Listener primary addressed state
TPAS	Talker primary addressed state
CIC	Controller active
LA	Listener addressed
TA	Talker addressed
MJMN	Sets minor T/L address, reset = major T/L address
SPMS	Serial poll mode state

Address Registers

Address 0 (6R)

X	DT0	DL0	AD5-0	AD4-0	AD3-0	AD2-0	AD1-0

Address 1 (7R)

EOI	DT1	DL1	AD5-1	AD4-1	AD3-1	AD2-1	AD1-1

Address 0/1 (6W)

ARS	DT	DL	AD_5	AD_4	AD_3	AD_2	AD_1

The μPD7210 is able to detect automatically two types of addresses that are held in address registers 0 and 1. The addressing modes are outlined below.

Address settings are made by writing into the address 0/1 register. The function of each bit is described below.

Address 0/1 Register Bit Selections

ARS	Selects either address register 0 or 1
DT	Permits or prohibits address to be detected as Talk
DL	Permits or prohibits address to be detected as Listen
AD_5-AD_1	Device address value
EOI	Holds the value of EOI line when data is received

Command Pass Through Register [5R]

CPT_7	CPT_6	CPT_5	CPT_4	CPT_3	CPT_2	CPT_1	CPT_0

The CPT register is used such that the CPU may read the DIO lines in the cases of undefined command, secondary address, or parallel poll response.

End-of-String Register [7W]

EC_7	EC_6	EC_5	EC_4	EC_3	EC_2	EC_1	EC_0

This register holds either a 7- or 8-bit EOS message byte used in the GPIB system to detect the end of a data block. Auxiliary register A controls the specific use of this register.

Auxiliary Mode Register [5W]

CNT_2	CNT_1	CNT_0	COM_4	COM_3	COM_2	COM_1	COM_0

This is a multipurpose register. A write to this register generates one of the following operations according to the values of the CNT bits.

Auxiliary Mode Operations

CNT 2	CNT 1	CNT 0	COM 4	COM 3	COM 2	COM 1	COM 0	Operation
0	0	0	C_4	C_3	C_2	C_1	C_0	Issues an auxiliary command specified by C_4 to C_0
0	0	1	0	F_3	F_2	F_1	F_0	The reference clock frequency is specified and T_1, T_6, T_7, and T_9 are determined as a result
0	1	1	U	S	P_3	P_2	P_1	Makes a write operation to the parallel poll register
1	0	0	A_4	A_3	A_2	A_1	A_0	Makes a write operation to the auxiliary A register
1	0	1	B_4	B_3	B_2	B_1	B_0	Makes a write operation to the auxiliary B register
1	1	0	0	0	0	E_1	E_0	Makes a write operation to the auxiliary E register

Commands and Other Registers

Auxiliary Commands

0	0	0	C_4	C_3	C_2	C_1	C_0

Auxiliary Command Descriptions

Command C_4	C_3	C_2	C_1	C_0	Auxiliary Command	Description
0	0	0	0	0	iepon	Immediate execute pon: generate local pon message
0	0	0	1	0	crst	Chip reset (same as external reset)
0	0	0	1	1	rrfd	Release RFD
0	0	1	0	0	trig	Trigger
0	0	1	0	1	rtl	Return to local message generation
0	0	1	1	0	seoi	Send EOI message
0	0	1	1	1	nvid	Nonvalid (OSA reception); release DAC holdoff
0	1	1	1	1	vid	Valid (MSA Reception, CPT, DEC, DET); release DAC holdoff
0	X	0	0	1	sppf	Set/reset parallel poll flag
1	0	0	0	0	gts	Go to standby
1	0	0	0	1	tca	Take control asynchronously

Auxiliary Command Descriptions (cont)

Command C_4	C_3	C_2	C_1	C_0	Auxiliary Command	Description
1	0	0	1	0	tcs	Take control synchronously
1	1	0	1	0	tcse	Take control synchronously on end
1	0	0	1	1	ltn	Listen
1	1	0	1	1	ltnc	Listen with continuous mode
1	1	1	0	0	lun	Local unlisten
1	1	1	0	1	epp	Execute parallel poll
1	X	1	1	0	sifc	Set/reset IFC
1	X	1	1	1	sren	Set/reset REN
1	0	1	0	0	dsc	Disable system control

Internal Counter

0	0	1	0	F_3	F_2	F_1	F_0

The internal counter generates the state change prohibit times (T_1, T_6, T_7, T_9) specified in IEEE Standard 488-1978 with reference to the clock frequency.

Auxiliary A Register

1	0	0	A_4	A_3	A_2	A_1	A_0

Of the five bits that may be specified as part of the access word, two bits control the GPIB data receiving modes of the μPD7210 and three bits control how the end-of-string (EOS) message is used.

Data Receiving Modes

A_1	A_0	Data Receiving Mode
0	0	Normal handshake mode
0	1	RFD holdoff on all data modes
1	0	RFD holdoff on end mode
1	1	Continuous mode

EOS Message

Bit Name			Function
A_2	0	Prohibit	Permits (prohibits) the setting of the END bit by reception of the EOS message
	1	Permit	
A_3	0	Prohibit	Permits (prohibits) automatic transmission of END message simultaneously with the transmission of EOS message TACS
	1	Permit	
A_4	0	7-bit EOS	Makes the 8 bits (7 bits) of the EOS register the valid EOS message
	1	8-bit EOS	

Auxiliary B Register

1	0	1	B_4	B_3	B_2	B_1	B_0

The auxiliary B register is much like the A register in that it controls the special operating features of the device.

Special Features

Bit Name			Function
B_0	1	Permit	Permits (prohibits) the detection of an undefined command. In other words, it permits (prohibits) the setting of the CPT bit on receipt of an undefined command.
	0	Prohibit	
B_1	1	Permit	Permits (prohibits) the transmission of the END message when in serial poll active state (SPAS).
	0	Prohibit	
B_2	1	T_1 (high-speed)	T_1 (high speed) as T_1 in source handshake function after transmission of second byte following data transmission.
	0	T_1 (low-speed)	Sets T_1 (low speed) as T_1 in all cases.
B_3	1	$\overline{INT}$	Specifies the active level of the $\overline{INT}$ pin.
	0	$\overline{INT}$	
B_4	1	ist = SRQS	SRQS indicates the value of the ist level local message (the value of the parallel poll flag is ignored). SRQS = 1 . . . ist = 1 SRQS = 0 . . . ist = 0
	0	ist = Parallel Poll Flag	The value of the parallel poll flag is taken as the ist local message.

Auxiliary E Register

1	1	0	0	0	0	E_1	E_0

This register controls the Data Acceptance modes of the μPD7210.

Data Acceptance Modes

Bit Name			Function
E_0	1	Enable	DAC holdoff by initialization of DCAS
	0	Disable	
E_1	1	Enable	DAC holdoff by initialization of DTAS
	0	Disable	

Parallel Poll Register

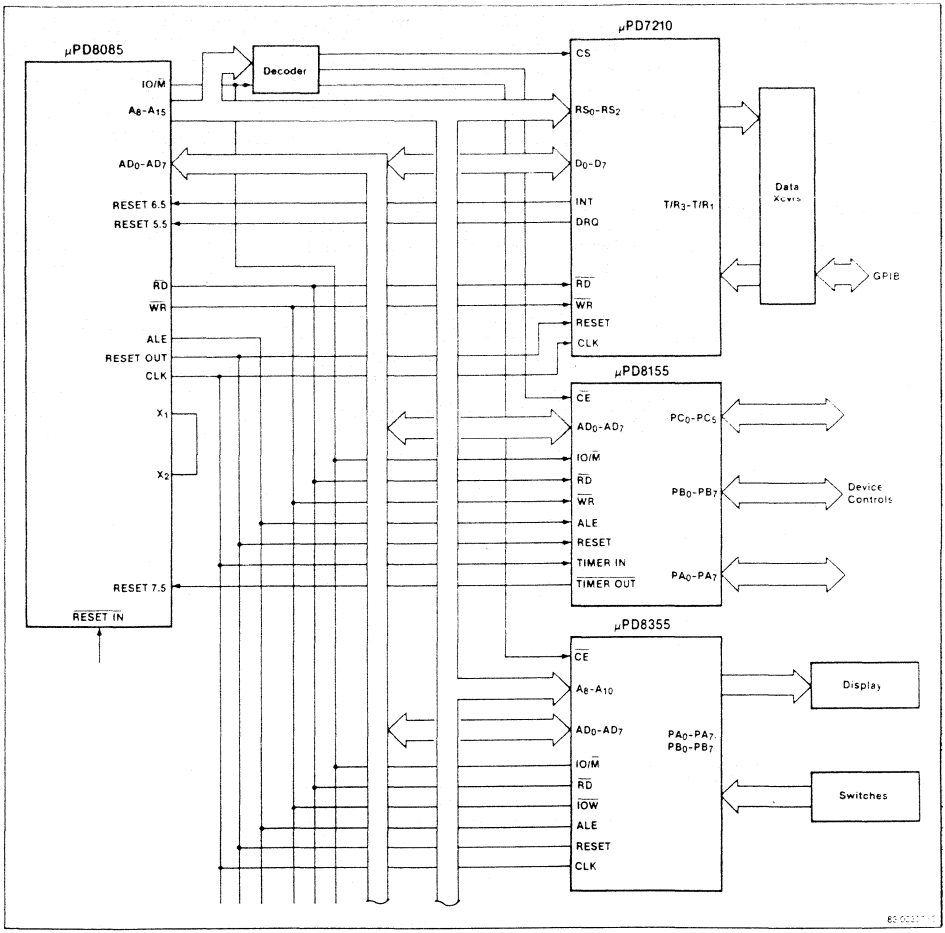
0	1	1	U	S	P_3	P_2	P_1

The parallel poll register defines the parallel poll response of the μPD7210.

Parallel Poll Response

Bit Name		Function
U	1	No response to parallel poll
	0	Response to parallel poll
S	1	In phase
	0	Reverse phase
P_3-P_1	000-111	Status bit output line DIO_1 to DIO_8

Minimum 8085 System with μPD7210



ABSOLUTE MAXIMUM RATINGS

T_a = 25°C

PARAMETER	SYMBOL	TEST CONDITIONS	RATINGS	UNITS
Supply Voltage	V_{CC}		−0.5 ∼ +7.0	V
Input Voltage	V_I		−0.5 ∼ +7.0	V
Output Voltage	V_O		−0.5 ∼ +7.0	V
Operating Temperature	T_{opt}		0 ∼ +70	°C
Strage Temperature	T_{stg}		−65 ∼ + 125	°C

DC CHARACTERISTICS

T_a = 0 ∼ +70°C, V_{CC} = 5V ± 10%

PARAMETER	SYMBOL	TEST CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
Input Low Voltage	V_{IL}		−0.5		+0.8	V
Input High Voltage	V_{IH}		+2.0		V_{CC} +0.5	V
Low Level Output Voltage	V_{OL}	I_{OL} = 2mA (4mA : T/R1 Pin)			+0.45	V
High Level Output Voltage	V_{OH1}	I_{OH} = −400uA, Except INT	+2.4			V
	V_{OH2}	I_{OH} = −400uA, INT Pin	+2.4			V
		I_{OH} = −50uA, INT Pin	+3.5			V
Input Leakage Current	I_{IL}	I_{IN} = 0V ∼ V_{CC}	−10		+10	uA
Output Leakage Current	I_{OL}	I_{OUT} = 0.45V ∼ V_{CC}	−10		+10	uA
Supply Current	I_{CC}				+180	mA

CAPACITANCE

T_a = 25°C, V_{CC} = GND = 0V

PARAMETER	SYMBOL	TEST CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
Input Capacitance	C_{IN}	f = 1 MHz All Pins Except Pin Under Test Tied to AC Ground			10	pF
Output Capacitance	C_{OUT}				15	pF
I/O Capacitance	$C_{I/O}$				20	pF

AC CHARACTERISTICS

T_a = 0 ∼ +70°C, V_{CC} = 5V ± 10%

PARAMETER	SYMBOL	TEST CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
Address Setup to $\overline{RD}$	t_{AR}	$RS_{2\text{-}0}$	85			ns
		$\overline{CS}$	0			
Address Hold from $\overline{RD}$	t_{RA}		0			ns
$\overline{RD}$ Pulse Width	t_{RR}		170			ns
Data Delay from Address	t_{AD}				250	ns
Data Delay from $\overline{RD}$ ↓	t_{RD}				150	ns
Output Float Delay from $\overline{RD}$ ↑	t_{DF}		0		80	ns
$\overline{RD}$ Recovery Time	t_{RV}		250			ns

Address Setup to $\overline{WR}$	t_{AW}		0			ns
Address Hold from $\overline{WR}$	t_{WA}		0			ns
$\overline{WR}$ Pulse Width	t_{WW}		170			ns
Data Setup to $\overline{WR}$	t_{DW}		150			ns
Data Hold from $\overline{WR}$	t_{WD}		0			ns
$\overline{WR}$ Recovery Time	t_{RV}		250			ns

DMAREQ ↓ Delay from $\overline{DMAACK}$	t_{AKRQ}				130	ns
Data Delay from $\overline{DMAACK}$	t_{AKD}				200	ns

AC CHARACTERISTICS

T_a = 0 ~ +70°C, V_{CC} 5V ± 10%

PARAMETER	SYMBOL	TEST CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
$\overline{EOI}$ ↓ → $\overline{DIO}$	t_{EOD1}	PPSS → PPAS, ATN = True			250	ns
$\overline{EOI}$ ↓ → T/$\overline{R1}$ ↑	t_{EOT11}	PPSS → PPAS, ATN = True			155	ns
$\overline{EOI}$ ↑ → T/$\overline{R1}$ ↓	t_{EOT12}	PPAS → PPSS, ATN = False			200	ns
$\overline{ATN}$ ↓ → $\overline{NDAC}$ ↓	t_{ATND}	AIDS → ANRS, LIDS			155	ns
$\overline{ATN}$ ↓ → T/$\overline{R1}$ ↓	t_{ATT1}	TACS + SPAS → TADS, CIDS			155	ns
$\overline{ATN}$ ↓ → T/$\overline{R2}$ ↓	t_{ATT2}	TACS + SPAS → TADS, CIDS			200	ns
$\overline{DAV}$ ↓ → DMAREQ ↑	t_{DVRQ}	ACRS → ACDS, LACS			600	ns
$\overline{DAV}$ ↓ → $\overline{NRFD}$ ↓	t_{DVNR1}	ACRS → ACDS			350	ns
$\overline{DAV}$ ↓ → $\overline{NDAC}$ ↑	t_{DVND1}	ACRS → ACDS → AWNS			650	ns
$\overline{DAV}$ ↑ → $\overline{NDAC}$ ↓	t_{DVND2}	AWNS → ANRS			350	ns
$\overline{DAV}$ ↑ → $\overline{NRFD}$ ↑	t_{DVNR2}	AWNS → ANRS → ACRS			350	ns
$\overline{RD}$ ↓ → $\overline{NRFD}$ ↑	t_{RNR}	ANRS → ACRS LACS, DI reg. selected			500	ns
$\overline{NDAC}$ ↑ → DMAREQ ↑	t_{NDRQ}	STRS → SWNS → SGNS, TACS			400	ns
$\overline{NDAC}$ ↑ → $\overline{DAV}$ ↑	t_{NDDV}	STRS → SWNS → SGNS			350	ns
$\overline{WR}$ ↑ → $\overline{DIO}$	t_{WDI}	SGNS → SDYS, BO reg. selected			250	ns
$\overline{NRFD}$ ↑ → $\overline{DAV}$ ↓	t_{NRDV}	SDYS → STRS, T_1 = True			350	ns
$\overline{WR}$ ↑ → $\overline{DAV}$ ↓	t_{WDV}	SGNS → SDYS → STRS BO reg. selected, RFD = True $N_F = f_c$ = 8 MHz, T_1 (High Speed)			830 +t_{SYNC}	ns
TRIG Pulse Width	t_{TRIG}		50			ns

EXTENDED TEMPERATURE RANGE

T_a = 25°C

ABSOLUTE MAXIMUM RATINGS

PARAMETER	SYMBOL	TEST CONDITIONS	RATINGS	UNITS
Supply Voltage	V_{CC}		−0.5 ~ +7.0	V
Input Voltage	V_I		−0.5 ~ +7.0	V
Output Voltage	V_O		−0.5 ~ +7.0	V
Operating Temperature	T_{opt}		−40 − +85	°C
Strage Temperature	T_{stg}		−65 ~ +125	°C

DC CHARACTERISTICS

T_a=−40°C...+85°C, V_{CC}=+5V±10%

PARAMETER	SYMBOL	TEST CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
Input Low Voltage	V_{IL}		−0.5		+0.6	V
Input High Voltage	V_{IH}		+2.2		V_{CC} +0.5	V
Low Level Output Voltage	V_{OL}	I_{OL} = 2mA (4mA : T/$\overline{R1}$ Pin)			+0.45	V
High Level Output Voltage	V_{OH1}	I_{OH} = −400uA, Except INT	+2.3			V
	V_{OH2}	I_{OH} = −400uA, INT Pin	+2.3			V
		I_{OH} = −50uA	+3.4			V
Input Leakage Current	I_{IL}	I_{IN} = 0V ~ V_{CC}	−10		+10	uA
Output Leakage Current	I_{OL}	I_{OUT} = 0.45V ~ V_{CC}	−10		+10	uA
Supply Current	I_{CC}				+220	mA

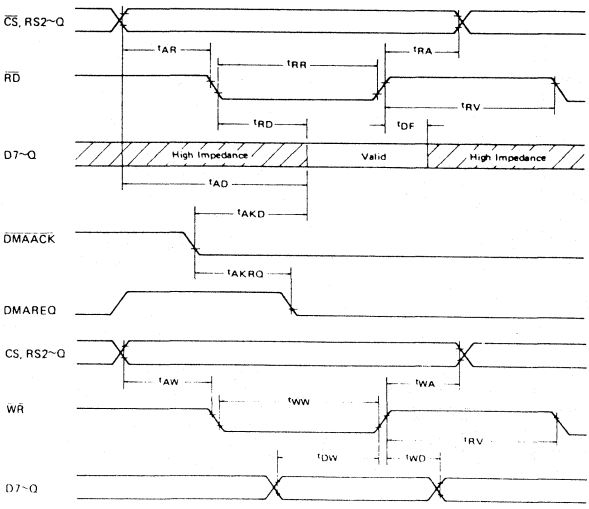
CAPACITANCE

T_a = 25°C, V_{CC} = GND = 0V

PARAMETER	SYMBOL	TEST CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
Input Capacitance	C_{IN}	f = 1 MHz All Pins Except Pin Under Test Tied to AC Ground			10	pF
Output Capacitance	C_{OUT}				15	pF
I/O Capacitance	$C_{I/O}$				20	pF

T_a=−40°C−+85°C, V_{CC}=+5V±10 %

PARAMETER	SYMBOL	TEST CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
Address Setup to $\overline{RD}$	t_{AR}	$RS_{2\sim0}$	85			ns
		$\overline{CS}$	+20			
Address Hold from $\overline{RD}$	t_{RA}		0			ns
$\overline{RD}$ Pulse Width	t_{RR}		170			ns
Data Delay from Address	t_{AD}				275	ns
Data Delay from $\overline{RD}$ ↓	t_{RD}				150	ns
Output Float Delay from $\overline{RD}$ ↑	t_{DF}		0		80	ns
$\overline{RD}$ Recovery Time	t_{RV}		250			ns
DMAREQ ↓ Delay from $\overline{DMAACK}$	t_{AKRQ}				160	ns
Data Delay from $\overline{DMAACK}$	t_{AKD}				240	ns
Address Setup to $\overline{WR}$	t_{AW}		0			ns
Address Hold from $\overline{WR}$	t_{WA}		+20			ns
$\overline{WR}$ Pulse Width	t_{WW}		170			ns
Data Setup to $\overline{WR}$	t_{DW}		150			ns
Data Hold from $\overline{WR}$	t_{WD}		+20			ns
$\overline{WR}$ Recovery Time	t_{RV}		250			ns
$\overline{EOI}$ ↓ → $\overline{DIO}$	t_{EOD1}	PPSS → PPAS, ATN = True			300	ns
$\overline{EOI}$ ↓ → T/R1 ↑	t_{EOT11}	PPSS → PPAS, ATN = True			202	ns
$\overline{EOI}$ ↑ → T/R1 ↓	t_{EOT12}	PPAS → PPSS, ATN = False			260	ns
$\overline{ATN}$ ↓ → $\overline{NDAC}$ ↓	t_{ATND}	AIDS → ANRS, LIDS			202	ns
$\overline{ATN}$ ↓ → T/R1 ↓	t_{ATT1}	TACS + SPAS → TADS, CIDS			202	ns
$\overline{ATN}$ ↓ → T/R2 ↓	t_{ATT2}	TACS + SPAS → TADS, CIDS			260	ns
$\overline{DAV}$ ↓ → DMAREQ ↑	t_{DVRQ}	ACRS → ACDS, LACS			720	ns
$\overline{DAV}$ ↓ → $\overline{NRFD}$ ↓	t_{DVNR1}	ACRS → ACDS			420	ns
$\overline{DAV}$ ↓ → $\overline{NDAC}$ ↑	t_{DVND1}	ACRS → ACDS → AWNS			780	ns
$\overline{DAV}$ ↑ → $\overline{NDAC}$ ↓	t_{DVND2}	AWNS → ANRS			420	ns
$\overline{DAV}$ ↑ → $\overline{NRFD}$ ↑	t_{DVNR2}	AWNS → ANRS → ACRS			420	ns
$\overline{RD}$ ↓ → $\overline{NRFD}$ ↑	t_{RNR}	ANRS → ACRS LACS, DI reg. selected			600	ns
$\overline{NDAC}$ ↑ → DMAREQ ↑	t_{NDRQ}	STRS → SWNS → SGNS, TACS			480	ns
$\overline{NDAC}$ ↑ → $\overline{DAV}$ ↑	t_{NDDV}	STRS → SWNS → SGNS			420	ns
$\overline{WR}$ ↑ → $\overline{DIO}$	t_{WDI}	SGNS → SDYS, BO reg. selected			300	ns
$\overline{NRFD}$ ↑ → $\overline{DAV}$ ↓	t_{NRDV}	SDYS → STRS, T_1 = True			420	ns
$\overline{WR}$ ↑ → $\overline{DAV}$ ↓	t_{WDV}	SGNS → SDYS → STRS BO reg. selected, RFD = True N_F = f_C = 8 MHz, T_1 (High Speed)			860 +t_{SYNC}	ns
TRIG Pulse Width	t_{TRIG}		45			ns



Description

The μPD7220A high-performance graphics display controller (GDC) is an intelligent microprocessor peripheral designed to be the heart of a high-performance raster scan computer graphics and character display system. Positioned between the video display memory and the microprocessor bus, the GDC performs the tasks needed to generate the raster display and manage the display memory. Processor software overhead is minimized by the GDC's sophisticated instruction set, graphics figure drawing, and DMA transfer capabilities. The display memory supported by the GDC can be configured in any number of formats and sizes up to 256K 16-bit words. The display can be zoomed and panned, while partitioned screen areas can be independently scrolled. With its light pen input and multiple controller capability, the GDC is ideal for advanced computer graphics applications.

For a more detailed description of the GDC's operation, please refer to the 7220/7220A product description and users manual.

System Considerations

The GDC is designed to work with a general purpose microprocessor to implement a high-performance computer graphics system. Through the division of labor estabilished by the GDC's design, each of the system components is used to the maximum extent through a six-level hierarchy of simultaneous tasks. At the lowest level, the GDC generates the basic video raster timing, including sync and blanking signals. Partitioning areas on the screen and zooming are also accomplished at this level. At the next level, video display memory is modified during the figure drawing operations and data moves. Third, display memory addresses are calculated pixel by pixel as drawing progresses. Outside the GDC at the next level, preliminary calculations are done to prepare drawing parameters. At the fifth level, the picture must be represented as a list of graphics figures drawable by the GDC. Finally, this representation must be manipulated, stored, and communicated. By handling the first three levels, the GDC takes care of the high-speed and repetitive tasks required to implement a graphics system.

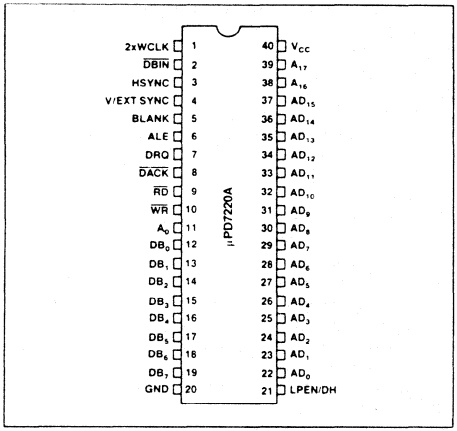
Features

- ☐ Microprocessor interface
  - — DMA transfers with 8257- or 8237-type controllers
  - — FIFO command buffering
- ☐ Display memory interface
  - — Up to 256K words of 16-bits
  - — Read-modify-write (RMW) display memory cycles as fast as 500 ns
  - — Dynamic RAM refresh cycles for nonaccessed memory
- ☐ Light pen input
- ☐ Drawing hold input
- ☐ External video synchronization mode
- ☐ Graphic mode
  - — Four megabit, bit-mapped display memory
- ☐ Character mode
  - — 8K character code and attributes display memory
- ☐ Mixed graphics and character mode
  - — 64K if all characters
  - — 1 megapixel if all graphics
- ☐ Graphics capabilities
  - — Figure drawing of lines, arc/circles, rectangles, and graphics characters in 500 ns per pixel
  - — Display 1024-by-1024 pixels with 4 planes of color or grayscale
  - — Two independently scrollable areas
- ☐ Character capabilities
  - — Auto cursor advanced
  - — Four independently scrollable areas
  - — Programmable cursor height
  - — Characters per row: up to 256
  - — Character rows per screen: up to 100
- ☐ Video display format
  - — Zoom magnification factors of 1 to 16
  - — Panning
  - — Command-settable video raster parameters
- ☐ NMOS technology
- ☐ Single +5 V power supply
- ☐ DMA capability
  - — Bytes or word transfers
  - — 4 clock periods per byte transferred
- ☐ On-chip pull-up resistor for VSYNC/EXT, HSYNC and $\overline{\text{DACK}}$, and a pull-down resistor for LPEN/DH

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD7220AD	40-pin ceramic DIP	6 MHz
μPD7220AD-1	40-pin ceramic DIP	7 MHz
μPD7220AD-2	40-pin ceramic DIP	8 MHz

Pin Configuration



Character Mode Pin Utilization

Pin No.	Symbol	Function
35-37	AD_{13}-AD_{15}	Line counter bits 0 to 2 outputs
38	AD_{16}	Line counter bit 3 output
39	AD_{17}	Cursor output and line counter bit 4

Mixed Mode Pin Utilization

Pin No.	Symbol	Function
35-37	AD_{13}-AD_{15}	Address and data bits 13 to 15
38	A_{16}	Attribute blink and clear line counter output
39	A_{17}	Cursor and bit-map area flag output

Pin Identification

Pin No.	Symbol	Function
1	2xWCLK	Clock input
2	$\overline{DBIN}$	Display memory read input flag
3	HSYNC	Horizontal video sync output
4	V/EXT SYNC	Vertical video sync output or external VSYNC input
5	BLANK	CRT blanking output
6	ALE	Address latch enable output
7	DRQ	DMA request output
8	$\overline{DACK}$	DMA acknowledge input
9	$\overline{RD}$	Read strobe input for microprocessor interface
10	$\overline{WR}$	Write stobe input for microprocessor interface
11	A_0	Address select input for microprocessor interface
12-19	DB_0-DB_7	Bidirectional data bus to host microprocessor
20	GND	Ground
21	LPEN/DH	Light pen detect input drawing hold input
22-34	AD_0-AD_{12}	Address data lines to display memory
35-37	AD_{13}-AD_{15}	Utilization varies with mode of operation
38	A_{16}	Utilization varies with mode of operation
39	A_{17}	Utilization varies with mode of operation
40	V_{CC}	+5 V ±10% power supply

Graphics Mode Pin Utilization

Pin No.	Symbol	Function
35-37	AD_{13}-AD_{15}	Address and data bits 13 to 15
38	A_{16}	Address bit 16 output
39	A_{17}	Address bit 17 output

Pin Functions

2xWCLK [Clock Input]

2xWCLK is the clock input.

$\overline{DBIN}$ [Data Bus Input Enable]

The DBIN output indicates the time the GDC will accept data read from display RAM during read-modify-write (RMW) cycles.

HSYNC [Horizontal Sync]

The HSYNC output indicates the time the CRT's beam is to start its retrace back to the left side of the screen.

V/EXT SYNC [Vertical SYNC Output/External Sync Input]

The GDC can be programmed to output a vertical sync signal at the start of the return of the CRT's beam from the lower right of the screen to the upper left during vertical retrace. The GDC may also be programmed to accept an external sync input when used in slave mode.

BLANK [Blank]

BLANK is output during inactive display times (horizontal and vertical retrace) of the CRT and during a read-modify-write memory cycle when in flash mode.

ALE [Address Latch Enable]

The falling edge of ALE indicates the first clock cycle of a display memory cycle and the availability of the memory address on pins AD_0-AD_{17}. ALE and external logic can generate display memory control signals.

A_0 [Address Bit 0]

A_0 is the address select input for the microprocessor interface.

A_1 [Address Bit 1]

The A_1 input selects registers when reading or writing to the GDC.

$\overline{DACK}$ [DMA Acknowledge]

$\overline{DACK}$ is the DMA acknowledge input handshake line that directly interfaces to the μPD8257 or μPD8237 DMA controller.

DRQ [DMA Request]

DRQ is the DMA request output handshake line that directly interfaces to the μPD8257 or μPD8237 DMA controller.

$\overline{RD}$ [Read Strobe]

The host CPU clears the $\overline{RD}$ input to 0 when reading the internal status and FIFO registers.

$\overline{WR}$ [Write Strobe]

The host CPU clears $\overline{WR}$ to 0 when writing to the internal command and parameter registers.

DB_0-DB_7 [Data Bus]

DB_0-DB_7, the 8-bit, three-state bidirectional data bus transfers data to and from the host CPU via the system bus.

LPEN/DH [Light Pen/Drawing Hold]

The LPEN/DH input can be programmed as either a light pen input or drawing hold input. The drawing hold input halts all read-modify-write operations.

AD_0-AD_{17} [Address and Data Lines]

AD_0-AD_{17} are address and data lines to display memory. AD_{13}-AD_{17} functions vary with the mode of operation of the GDC. The μPD7220/7220A Graphics Display Controller User's Manual describes these functions and modes of operation.

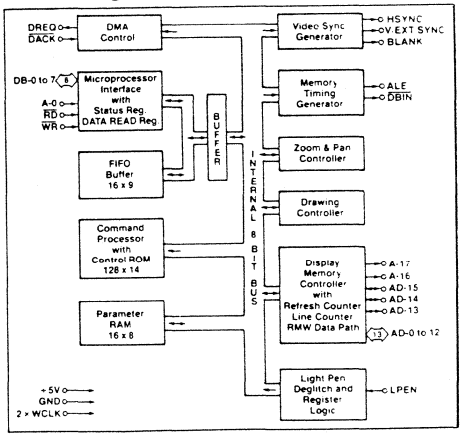
V_{CC} [Power Supply]

V_{CC} is the +5 V power supply input.

GND [Ground]

GND is ground potential.

Block Diagram



HGDC Components

Microprocessor Bus Interface

Control of the GDC by the system microprocessor is achieved through an 8-bit bidirectional interface. The status register is readable at any time. Access to the FIFO buffer is coordinated through flags in the status register and operates independently of the various internal GDC operations, due to the separate data bus connecting the interface and the FIFO buffer.

Command Processor

The contents of the FIFO are interpreted by the command processor. The command bytes are decoded, and the succeeding parameters are distributed to their properdestinations within the GDC. The command processor yields to the bus interface when both access the FIFO simultaneously.

DMA Control

The DMA control circuitry in the GDC coordinates transfers over the microprocessor interface when using an external DMA controller. The DMA Request and Acknowledge handshake lines directly interface with a μPD8257 or μPD8237 DMA controller, so that display data can be moved between the microprocessor memory and the display memory.

Parameter RAM

The 16-byte RAM stores parameters that are used repetitively during the display and drawing processes. In character mode, this RAM holds four sets of partitioned display area parameters; in graphics mode, the drawing pattern and graphics character take the place of two of the sets of parameters.

Video Sync Generator

Based on the clock input, the sync logic generates the raster timing signals for almost interlaced, non-interlaced, or "repeat field" interlaced video format. The generator is programmed during the idle period following a reset. In video sync slave mode, it coordinates timing between multiple GDC's.

Memory Timing Generator

The memory timing circuitry provides two memory cycle types: a two-clock period refresh cycle and the read-modify-write (RMW) cycle, which takes four clock periods. The memory control signals needed to drive the display memory devices are easily generated from the GDC's ALE and $\overline{\text{DBIN}}$ outputs.

Zoom & Pan Controller

Based on the programmable zoom display factor and the display area entries in the parameter RAM, the zoom and pan controller determines when to advance to the next memory address for display refresh and when to go on to the next display area. A horizontal zoom is produced by slowing down the display refresh rate while maintaining the video sync rates. Vertical zoom is accomplished by repeatedly accessing each line a number of times equal to the horizontal repeat. Once the line count for a display area is exhausted, the controller accesses the starting address and line count of the next display area from the parameter RAM. The system microprocessor, by modifying a display area starting address, can pan in any direction, independently of the other display areas.

Drawing Controller

The drawing processor contains the logic necessary to calculate the addresses and positions of the pixels of the various graphics figures. Given a starting point and the appropriate drawing parameters, the drawing controller needs no further assistance to complete the figure drawing.

Display Memory Controller

The display memory contoller's tasks are numerous. Its primary purpose is to multiplex the address and data information in and out of the display memory. It also contains the 16-bit logic unit used to modify the display memory contents during RMW cycles, the character mode line counter, and the refresh counter for dynamic RAMs. The memory controller apportions the video field time between the various types of cycles.

Light Pen Deglitcher/Drawing Hold

Only if two rising edges on the light pen input occur at the same point during successive video fields are the pulses accepted as a valid light pen detection. A status bit indicates to the system microprocessor that the light pen register contains a valid address. If this input is held high for a period greater than four 2xWCLK cycles, drawing execution is halted when bit 7 of P5 of the SYNC command is set.

Programmer's View of GDC

The GDC occupies two addresses on the system microprocessor bus through which the GDC's status register and FIFO are accessed. Commands and parameters are written into the GDC's FIFO and are differentiaated based on address bit A_0. The status address line.

Commands to the GDC take the form of a command byte followed by a series of parameter bytes as needed for specifying the details of the command. The command processor decodes the commands, unpacks the parameters, loads them into the appropriate registers within the GDC, and initiates the required operations.

The commands available the GDC can be organized into five categories as described in the following section.

GDC Microprocessor Bus Interface Registers

A0	READ	WRITE
0	Status Register	Parameter Into FIFO
1	FIFO Read	Command Into FIFO

GDC Commands Summary

Video Control Commands

1. RESET1 — Resets the GDC to its idle state Resychronizes video timing. Blanks the display.
2. RESET2 — Resets the HGDC to its idle state Does not resynchronize video timing. Blanks the display.
3. RESET3 — Resets the HGDC to its idle state Does not resynchronize video timing. Does not blank the display.
4. SYNC — Specifies the video display format.
5. VSYNC — Selects master or slave video synchronization mode.
6. CCHAR — Specifies the cursor and character row heights.

Display Control Commands

1. START — Ends idle mode and unblanks the display.
2. BLANK1 — Controls the blanking and unblanking of the display, along with video resynchronization.
3. BLANK2 — Controls the blanking and unblanking of the display. Does not blank the display.
4. ZOOM — Specifies zoom factors for the display and graphics characters writing.
5. CURS — Sets the position of the cursor in display memory.
6. PRAM — Defines starting addresses and lengths of the display areas and specifies the eight bytes for the graphics character.
7. PITCH — Specifies the width of the X dimension of display memory.

Drawing Control Commands

1. WDAT — Writes data words or bytes into display memory.
2. MASK — Sets the mask register contents
3. FIGS — Specifies the parameters for the drawing controller.
4. FIGD — Draws the figure as specified above.
5. GCHRD — Draws the graphics character into display memory.

Data Read Commands

1. RDAT Reads data words or bytes from display memory.
2. CURD Reads the cursor position.
3. LPRD Reads the light pen address.

DMA Control Commands

1. DMAR Requests a DMA read transfer.
2. DMAW Requests a DMA write transfer.

Status Register Flags

SR-7: Light Pen Detect

When this bit is set to 1, the light pen address (LAD) register contains a deglitched value that the system microprocessor may read. This flag is reset after the 3-byte LAD is moved into the FIFO in response to the light pen read command.

SR-6: Horizontal Blank Active/Vertical Blank Active

A 1 value for this flag signifies that horizontal retrace blanking or vertical retrace blanking is currently underway dependent on the status of the VH bit in SYNC or the RESETx parameter 6.

SR-5: Vertical Sync

Vertical retrace sync occurs while this flag is a 1. The vertical sync flag coordinates display format modifying commands to the blanked interval surrounding vertical sync. This eliminates display disturbances.

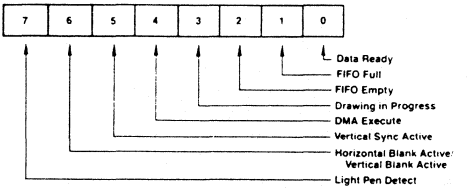
SR-4: DMA Execute

This bit is a 1 during DMA data tranfers.

SR-3: Drawing in Progress

While the GDC is drawing a graphics figure, this status bit is a 1.

Status Register (SR)



SR-2: FIFO Empty

This bit and the FIFO-full flag coordinate system microprocessor accesses with the GDC FIFO. When it is 1, the Empty flag ensures that all the commands and parameters previously sent to the GDC have been interpreted.

SR-1: FIFO Full

A 1 at this flag indicates a full FIFO in the GDC. A 0 ensures that there is room for at least one byte. This flag needs to be checked before each write into the HGDC.

SR-0: Data Ready

When this flag is a 1, it indicates that a byte is available to be read by the system microprocessor. This bit must be tested before each read operation. It drops to a 0 while the data is transferred from the FIFO into the microprocessor interface data register.

FIFO Operation & Command Protocol

The first-in, first-out buffer (FIFO) in the GDC handles the command dialogue with the system microprocessor. This flow of information uses a half-duplex technique, in which the single 16-location FIFO is used for both directions of data movement, one direction at a time. The FIFO's direction is controlled by the system microprocessor through the GDC's command set. The host microprocessor coordinates these transfers by checking the appropriate status register bits.

The command protocol used by the GDC requires differentiation of the first byte of a command sequence from the succeeding bytes. The first byte contains the operation code and the remaining bytes carry parameters. Writing into the GDC causes the FIFO to store a flag value alongside the data byte to signify whether the byte was written into the command or the parameter address. The command processor in the GDC tests this bit as it interprets the entries in the FIFO.

The receipt of a command byte by the command processor marks the end of any previous operation. The number of parameter bytes supplied with a command is cut short by the receipt of the next command byte. A read operation from the GDC to the microprocessor can be terminated at any time by the next command.

The FIFO changes direction under the control of the system microprocessor. Commands written into the GDC always put the FIFO into write mode if it was not in it already. If it was in read mode, any read data in the FIFO at the time of the turnaround is lost. Commands which require an GDC response, such as RDAT, CURD and LPRD, put the FIFO into read mode after the command is interpreted by the GDC's command processor. Any commands and parameters behind the read-evoking command are discarded when the FIFO direction is reversed.

Read-Modify-Write Cycle

Data transfers between the GDC and the display memory are accomplished using a read-modify-write (RMW) memory cycle. The four-clock period timing of the RMW cycle is used to 1. output the address, 2. read data rom the memory, 3. modify the data, and 4. write the modified data back into the initially selected memory address. This type of memory cycle is used for all interactions with display memory including DMA transfers, except for the two-clock period display and RAM refresh cycles.

The operations performed during the modify portion of the RMW cycle merit additional explanation. The circuitrdy in the GDC uses three main elements: the Pattern register, the Mask register, and the 16-bit Logic unit. The Pattern register holds the data pattern to be moved into memory. It is loaded by the WDAT parameters or, during drawing, from the parameter RAM. The Mask register contents determine which bits of the read data will be modified. Based on the contents of these registers, the Logic unit performs the selected operations of REPLACE, COMPLEMENT, SET, or CLEAR on the data read from display memory.

The Pattern register contents are ANDed with the Mask register contents to enable the actual modification of the memory read data, on a bit-by-bit basis. For graphics drawing, one bit at a time from the Pattern register is combined with the Mask. When ANDed with the bit set to a 1 in the Mask register, the proper single pixel is modified by the Logic unit. For the next pixel in the figure, the next bit in the Pattern register is selected and the Mask register bit is moved to identify the pixel's location within the word. The Execution word address pointer register, EAD, is also adjusted as required to address the word containing the next pixel.

In character mode, all of the bits in the Pattern register are used in parallel to form the respective bits of the modify data word. Since the bits of the character code word are used in parallel, unlike the one-bit-at-a-time graphics drawing process, this facility allows any or all of the bits in a memory word to be modified in one RMW memory cycle. The Mask register must be loaded with ones in the positions where modification is to be permitted.

The Mask register can be loaded in either of two ways. In graphics mode, the CURS command contains a 4-bit dAD field to specify the dot address. The command processor converts this parameter into the 1-of-16 format used in the Mask register for figure drawing. A full 16-bits can be loaded into the Mask register using the MASK command. In addition to the character mode use mentioned above, the 16-bit MASK load is convenient in graphics mode when all of the pixels of a word are to be set to the same value.

The Logic unit combines the data read from display memory, the Pattern register, and the Mask register to generate the data to be written back into display memory. Any one of four operations can be selected: REPLACE, COMPLEMENT, CLEAR or SET. In each case, if the respective Mask bit is 0, that particular bit of the read data is returned to memory unmodified. If the Mask bit is 1, the modification is enabled. With the REPLACE operation, the Pattern register data simply takes the place of the read data for modification enabled bits. For the other three operations, a 0 in the modify data allows the read data bit to be returned to memory. A 1 value causes the specified operation to be performed in the bit positions with set Mask bits.

Figure Drawing

The GDC draws graphics figures at the rate of one pixel per read-modify-write (RMW) display memory cycle. These cycles take four clock periods to complete. At a clock frequency of 8 MHz, this is equal to 500 ns. During the RMW cycle the GDC simultaneously calculates the address and position of the next pixel to be drawn.

The graphics figure drawing process depends on the display memory addressing structure. Groups of 16 horizontally adjacent pixels form the 16-bit words which are handled by the GDC. Display memory is organized as a linearly addressed space of these words. Addressing of individual pixels is handled by the GDC's internal RMW logic.

During the drawing process,, the GDC finds the next pixel ofthe figure which is one of the eight nrarest neighbors of the last pixel drawn. The GDC assigns each of these eight directions a number from 0 to 7, starting with straight down and proceeding counter-clockwise.

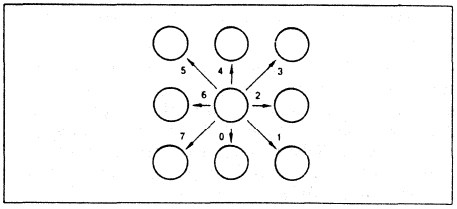
Figure drawing requires the proper manipulation of the address and the pixel bit position according to the drawing direction to determine the next pixel of the figure. To move to the word above or below the current one, it is necessary to subtract or add the number of words per line in display memory. This parameter is called the pitch. To move to the word to either side, the Execute word address cursor, EAD, must be incremented or decremented as the dot address pointer bit reaches the LSB or the MSB of the Mask register. To move to a pixel within the same word, it is necessary to rotate the dot address pointer to the right or left. The table below summarizes these operations for each direction.

Dir	Operations to Address the Next Pixel
000	EAD – P → EAD
001	EAD – P → EAD dAD (MSB) = 1:EAD – 1 → EAD dAD → LR
010	dAD (MSB) = 1:EAD – 1 → EAD dAD → LR
011	EAD – P → EAD dAD (MSB) = 1:EAD – 1 → EAD dAD → LR
100	EAD – P → EAD
101	EAD – P → EAD dAD (LSB) = 1:EAD – 1 → EAD dAD → RR
110	dAD (LSB) = 1:EAD – 1 → EAD dAD → RR
111	EAD – P → EAD dAD (LSB) = 1:EAD – 1 → EAD dAD → RR

Note:

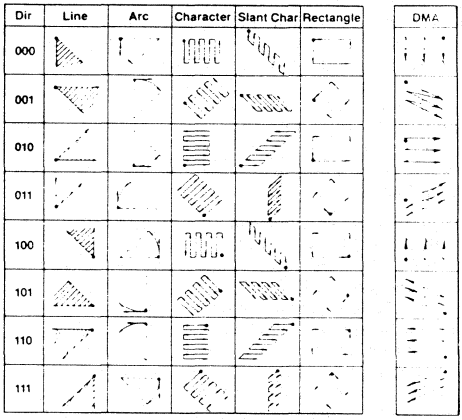
P = Pitch, LR = Left Rotate, RR = Right Rotate, EAD = Execute Word Address, and dAD = Dot Address stored in the Mask register.

Drawing Directions



Whole word drawing is useful for filling areas in memory with a single value. By setting the Mask register to all 1s with the MASK command, both the LSB and MSB of the dAD will always be 1, so that the EAD value will be incremented or decremented for each cycle regardless of direction. One RMW cycle will be able to affect all 16 bits of the word for any drawing type. One bit in the Pattern register is used per RMW cycle to write all the bits of the word to the same value The next Pattern bit is used for the word, etc.

For the various figures, the effect of the initial direction upon the resulting drawing is shown below:



Note that during line drawing, the angle of the line may be anywhere within the shaded octant defined by the DIR value. Arc drawing starts in the direction initially specified by the DIR value and veers into an arc as drawing proceeds. An arc may be up to 45° in length DMA transfers are done on word boundaries only, and follow the arrows indicated in the table to find successive word addresses. The slanted paths for DMA transfers indicate the GDC changing both the X and Y components of the word address when moving to the next word. It does not follow a 45° diagonal path by pixels.

Drawing Parameters

In preparation for graphics figure drawing, the GDC's Drawing processor needs the figure type, direction and drawing parameters, the starting pixel address, and the pattern from the microprocessor. Once these are in place within the GDC, the Figure Draw command, FIGD, initiates the drawing operation. From that point on, the system microprocessor is not involved in the drawing process. The GDC Drawing controller coordinates the RMW circuitry and address registers to draw the specified figure pixel by pixel.

The algorithms used by the processor for figure drawing are designed to optimize its drawing speed. To this end, the specific details about the figure to be drawn are reduced by the microprocessor to form conducive to high-speed address calculations within the GDC. In this way the repetitive, pixel-by-pixel calculations can be done quickly, thereby minimizing the overall figure drawing time. The table below summarizes the parameters.

Drawing Type	DC	D	D2	D1	DM
Initial Value (1)	0	δ	δ	−1	−1
Line	↓Δl	2ΔD − ↓Δl↓	2(↓ΔD − ↑Δl↑)	2↓ΔD	−
Arc (2)	r sin φ	r−1	2(r−1)	−1	r sin θ
Rectangle	3	A−1	B−1	−1	A−1
Area fill	B−1	A	A	−	−
Graphic character (3)	B−1	A	A	−	−
Read & write data	W−1	−	−	−	−
DMAW	D−1	C−1	−	−	−
DMAR	D−1	C−1	(C−1)/2/†	−	−

Note:

All numbers are shown in base 10 for convenience. The HGDC accepts base 2 numbers (2's complement notation) where appropriate.

(1) Initial values for the various parameters remain as each drawing process ends.

(2) Circles are drawn with 8 arcs, each of which span 45°, so that sin $\phi = 1/\sqrt{2}$ and sin $\theta = 0$.

(3) Graphic characters are a special case of bit-map area filling in which B and A ≤ 8. If A = 8 there is no need to load D and D2.

Symbol Definitions

−1 = All ONES value.
− = No parameter bytes sent to GDC for this parameter.
Δl = The larger at Δx or Δy.
ΔD = The smaller at Δx or Δy.
r = Radius of curvature, in pixels.
ϕ = Angle from major axis to end of the arc. $\phi \leq 45°$.
θ = Angle from major axis to start of the arc. $\theta \leq 45°$.
↑ = Round up to the next higher integer.
↓ = Round down to the next lower integer.
A = Number of pixels in the initially specified direction.
B = Number of pixels in the direction at right angles to the initially specified direction.
W = Number of words to be accessed.
C = Number of bytes to be transferred in the initially specified direction. (Two bytes per word if word transfer mode is selected.)
D = Number of words to be accessed in the direction at right angles to the initially specified direction.
DC = Drawing count parameter which is one less than the number of RMW cycles to be executed.
DM = Dots masked from drawing during arc drawing.
† = Needed only for word reads.

Graphics Character Drawing

Graphics characters can be drawn into display memory pixel by pixel. The up to 8-by-8 character display is loaded into the GDC's parameter RAM by the system microprocessor. Consequently, there are no limitations on the character set used. By varying the drawing parameters and drawing direction, numerous drawing options are available. In area fill applications, a character can be written into display memory as many times as desired without reloading the parameter RAM.

Once the parameter RAM has been loaded with up to eight graphics character bytes by the appropriate PRAM command, the GCHRD command can be used to draw the bytes into display memory starting at the cursor. The zoom magnification factor for writing, set by the ZOOM command, controls the size of the character written into the display memory in integer multiples of 1 through 16. The bit values in the PRAM are repeated horizontally and vertically the number of times specified by the zoom factor.

The movement of these PRAM bytes to the display memory is controlled by the parameters of the FIGS command.

Based on the specified height and width of the area to be drawn, the parameter RAM is scanned to fill the required area.

For an 8-by-8 graphics character, the first pixel drawn uses the LSB of RA-15, the second pixel uses bit 1 of RA-15, and so on, until the MSB of RA-15 is reached.

The GDC jumps to the corresponding bit in RA-14 to continue the drawing. The progression then advances toward the LSB of RA-14. This snaking sequence is continued for the other 6 PRAM bytes. This progression matches the sequence of display memory addresses calculated by the drawing processor as shown above. If the area is narrower than 8 pixels wide, the snaking will advance to the next PRAM byte before the MSB is reached. If the area is less than 8 lines high, fewer bytes in the parameter RAM will be scanned. If the area is larger than 8 by 8, the GDC will repeat the contents of the parameter RAM in two dimensions, as required to fill the area with the 8-by-8 mosaic. (Fractions of the 8-by-8 pattern will be used to fill areas which are not multiples of 8 by 8.)

Parameter RAM Contents: RAM Address RA-0 to RA-15

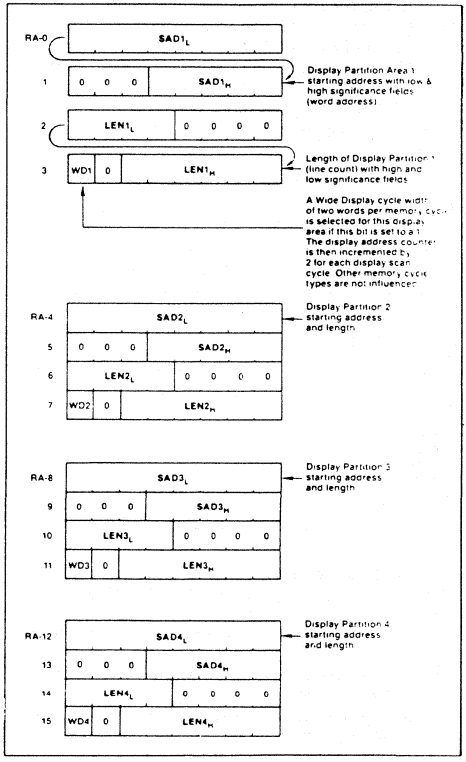
The parameters stored in the parameter RAM, PRAM, are available for the GDC to refer to repeatedly during figure drawing and raster-scanning. In each mode of operation the values in the PRAM are interpreted by the GDC in a predetermined fashion. The host microprocessor must load the appropriate parameters into the proper PRAM locations. PRAM loading command allows the host to write into any location of the PRAM and transfer as many bytes as desired. In this way any stored parameter byte or bytes may be changed without influencing the other bytes.

The PRAM stores two types of information. For specifying the details of the display area partitions, blocks of four bytes are used. The four parameters stored in each block include the starting address in display memory of each display area, and its length. In addition, there are two mode bits for each area which specify whether the area is a bit-mapped graphics area or a coded-character area, and whether a 16-bit or a 32-bit wide display cycle is to be used for that area.

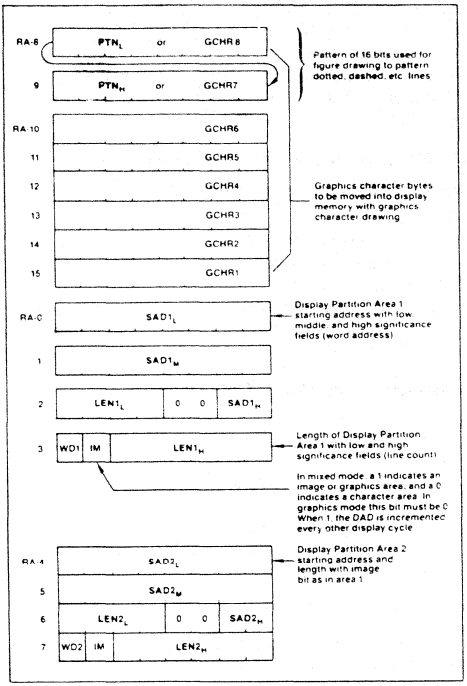
The other use for the PRAM contents is to supply the pattern for figure drawing when in a bit-mapped graphics area or mode. In these situations, PRAM bytes 8 through 16 are reserved for this patterning information. For line, arc, and rectangle drawing (linear figures) locations 8 and 9 are loaded into the Pattern register to allow the GDC to draw dotted, dashed, etc. lines. For area filling and graphics bit-mapped character drawing, locations 8 through 15 are referenced for the pattern or character to be drawn.

Details of the bit assignments are shown for the various modes of operation.

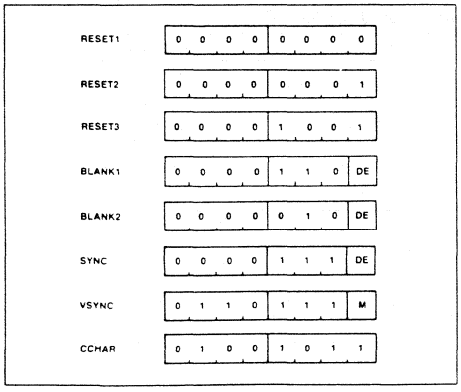
Character Mode



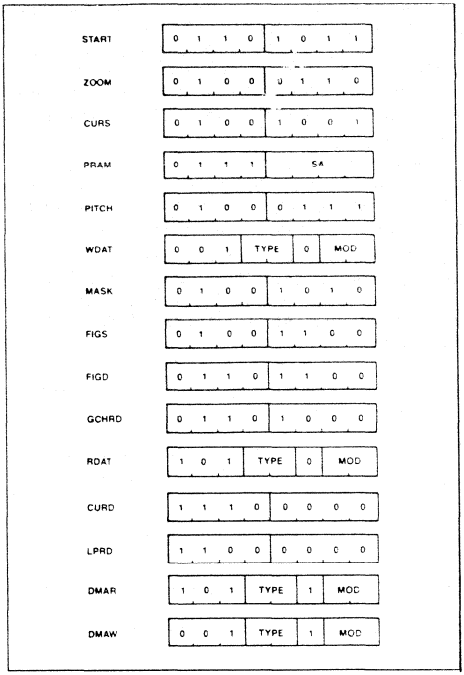
Graphics and Mixed Graphics and Character Modes



Command Bytes Summary

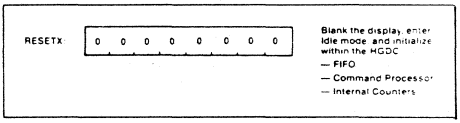


Command Bytes Summary



Video Control Commands

Reset



This command can be executed at any time and does not modify any of the parameters already loaded into the GDC.

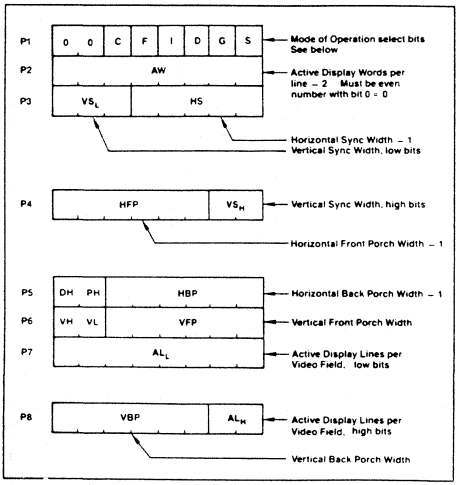
If followed by the parameter bytes, this command also sets the sync generator parameters as described below. Idle mode is exited with the START command.

RESET1: Resync video timing in slave mode.
RESET2: Blank the display and so not resync.
RESET3: Unblank the display and do not resync.

In graphics mode, a word is a group of 16 pixels. In character mode, a word is one character code and its attributes, if any. The number of active words per line must be an even number from 2 to 256. An all-zero parameter value selects a count equal to 2^n where n = number of bits in the parameter field for vertical parameters. All horizontal widths are counted in display words. All vertical invervals are counted in lines.

If the Drawing Hold (DH) is set to one, pin 21 (LPEN/DH) is used as the drawing hold control pin. When the input to LPEN/DH is held high for over four 2 x WCLK clocks, the drawing address output is temporarily held and the display address is output.

The GDC allows an even or odd number of lines per frame. Selection is via the VL flag, the seventh bit of the sixth parameter byte following a RESET or SYNC command. When VL is 0, an odd number of display lines is generated.



VL	Number of lines in interlaced mode
0	Odd, as in 7220
1	Even

When VH = 0, status operation is as in μPD7220.

VH	Blank Status Bit Definition
0	Status register bit 6 indicates horizontal blank
1	Status register bit 6 indicates vertical blank

PH is the most significant bit (9) of the display pitch parameter. Use the PITCH command to set the lower eight bits.

SYNC Generator Period Constraints

Horizontal Back Porch Constraints

1. In general:
   HBP ≧ 3 Display Word Cycles (6 clock cycles).
2. If the Image bit or WD mode changes within one video field:
   HBP ≧ 5 Display Word Cycles (10 clock cycles).
3. If interlaced, mixed mode, or split screen is used:
   HBP ≧ 5 Display Word Cycles (10 clock cycles).

Horizontal Front Porch Constraints

1. In general:
   HFP ≧ 2 Display Word Cycles (4 clock cycles).
2. If the GDC is used in video sync Slave mode.
   HFP ≧ 4 Display Word Cycles (8 clock cycles).
3. If the Light Pen is used:
   HFP ≧ 6 Display Word Cycles (12 clock cycles).
4. If interlaced mode, DMA, or ZOOM is used.
   HFP ≧ 3 Display Word Cycles (6 clock cycles).

Horizontal Sync Constraints

1. If interlaced display mode is used:
   HS ≧ 5 Display Word Cycles (6 clock cycles).
2. If DRAM Refresh is enabled:
   HS ≧ 2 Display Word Cycles (4 clock cycles).

Modes of Operation Bits

C	G	Display Mode
0	0	Mixed graphics and character
0	1	Graphics mode
1	0	Character mode
1	1	Invalid

I	S	Video Framing
0	0	Non-interlaced
0	1	Invalid
1	0	Interlaced repeat field for character displays
1	1	Interlaced

Repeat Field Framing: 2 field sequence with 1/2 line offset between otherwise identical fields.
Interlaced Framing: 2 field sequence with 1/2 line offset. Each field displays alternate lines.
Non-Interlaced Framing: 1 field brings all the information to the screen.

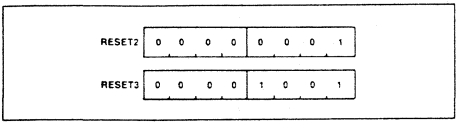
D	Dynamic RAM Refresh Cycles Enable
0	No refresh—static RAM
1	Refresh—dynamic RAM

Dynamic RAM refresh is important when high display zoom factors or DMA are used in such a way that not all of the rows in the RAMs are regularly accessed during display raster generation and for otherwise inactive display memory.

F	Drawing Time Window
0	Drawing during active display time and retrace blanking
1	Drawing only during retrace blanking

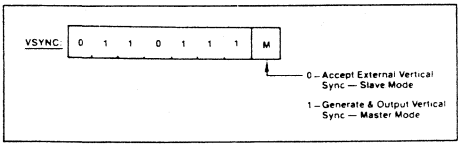
Access to display memory can be limited to retrace blanking intervals only, so that no disruptions of the image are seen on the screen.

Both commands allow a reset while preventing re-initialization of the internal sync generator by an external sync source (slave mode).



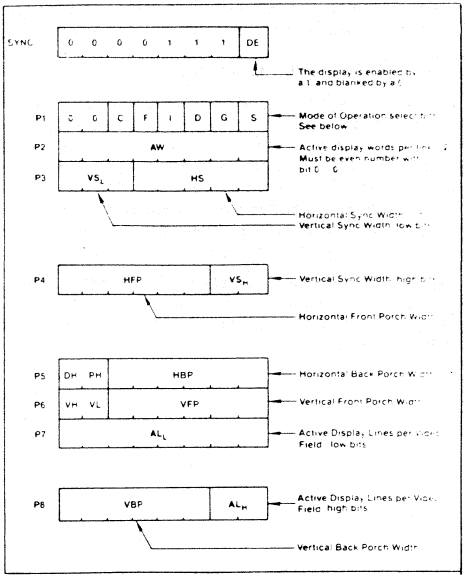
Vertical Sync Mode

When using two or more GDCs to contribute to one image, one GDC is defined as the master sync generator, and the others operate as its slaves. The VSYNC pins of all GDCs are connected together.



SYNC Format Specify

This command also loads parameters into the sync generator. The various parameter fields and bits are identical to those at the RESET command. The GDC is not reset nor does it enter idle mode.



Slave Mode Operation

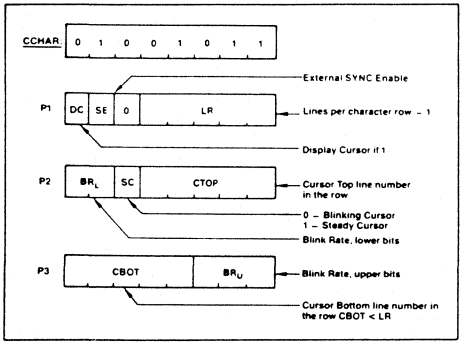
A few considerations should be observed when synchronizing two or more GDC's to generate overlayed video via the V/EXT SYNC pin. As mentioned above, the Horizontal Front Porch (HFP) must be four or more display cycles wide. This is equivalent to eight or more clock cycles. This gives the slave GDC's time to initialize their internal video sync generators to the proper point in the video field to match the incoming vertical sync pulse (VSYNC). This resetting of the generator occurs just after the end of the incoming VSYNC pulse, during the HFP interval. Enough time during HFP is required to allow the slave GDC to complete the operation before the start of the HSYNC interval.

Once the GDC's are initialized and set up as master and slaves, they must be given time to synchronize. It is a good idea to watch the VSYNC status bit of the master GDC and wait until after one or more VSYNC pulses have been generated before the display progess is started. The START command will begin the active display of data and will end the video synchronization process, so be sure there has been at least one VSYNC pulse generated to which the slaves can synchronize.

Cursor and Character Characteristics

In graphics mode, LR should be set to 0. The blink rate parameter controls both the cursor and attribute blink rates. The cursor blink-on time = blink-off time = 2 x BR (video frames). The attribute blink rate is always one-half the cursor rate but with a 3/4-on-1/4-off duty cycle. **All three parameter bytes must be output for interlaced displays, regardless of mode.** For interlaced displays in graphics mode, the parameter $BR_L = 3$.

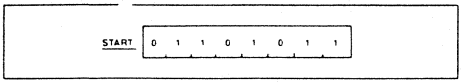
When SE = 0, the GDC, in slave mode, detects the falling edge of EX. SYNC on the first frame. When SE = 1, the GDC, in slave mode, detects the falling edge of EX. SYNC on every frame.



Display Control Commands

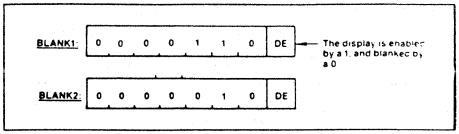
Start Display and End Idle Mode

The START command generates the video signals as specified by the RESETX or SYNC command.



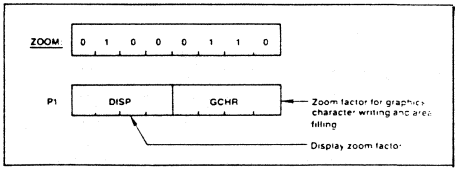
Display Blanking Control

BLANK2 does not cause the resyncing of an HGDC in slave mode. BLANK1 does cause the resyncing of an GDC in slave mode.



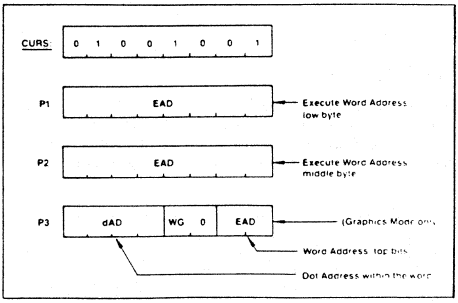
Zoom Factors Specify

Zoom magnification factors of 1 through 16 are available using codes 0 through 15, respectively.



Cursor Position Specify

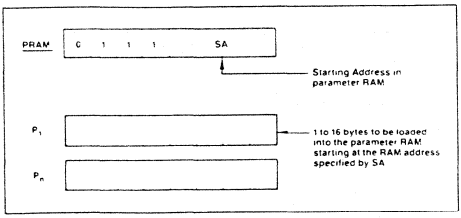
In character mode, the third parameter byte is not needed. The cursor is displayed for the word time in which the display scan address (DAD) equals the cursor address. In graphics mode, the cursor word address specifies the word containing the starting pixel of the drawing; the dot address value specifies the pixel within that word.



When the WG bit is set to one, any data following the WDAT command is written as is. When the WG bit is set to zero, the 7220A performs as the 7220 does: The pattern written is determined by the least significant bit of each parameter byte following the WDAT command. This bit is expanded into 16 identical bits which form the pattern.

Parameter RAM Load

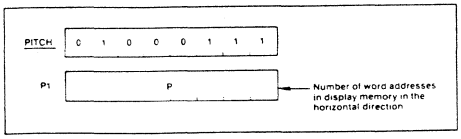
From the starting address, SA, any number of bytes may be loaded into the parameter RAM at incrementing addresses, up to location 15. The sequence of parameter bytes is determined by the next command byte entered into the FIFO. The parameter RAM stores 16 bytes of information in predefined locations which differ for graphics and character modes. See the parameter RAM discussion for bit assignments.



Pitch Specification

This value is used during drawing by the drawing processor to find the word directly above or below the current word, and during display to find the start of the next line.

The Pitch parameter (width of display memory) is set by two different commands. In addition to the PITCH command, the RESET (or SYNC) command also sets the pitch value. The "active-words-per-line" parameter, which specifies the width of the raster-scan display, also sets the pitch of the display memory. Note that the AW value is two less than the display window width. The PITCH command must be used to set the proper memory width larger than the window width.



Drawing Control Commands

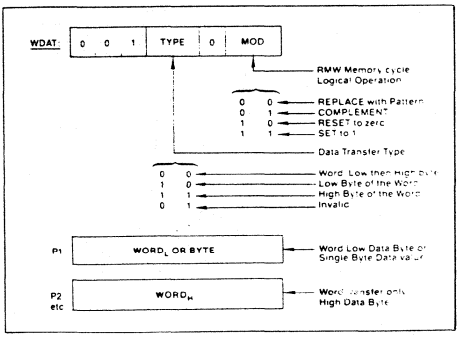
Write Data into Display Memory

Upon receiving a set of parameters (two bytes for a word transfer, one for a byte transfer), one RMW cycle into video memory is done at the address pointed to by the cursor EAD. The EAD pointer is advanced to the next word, according to the previously specified direction. More parameters can then be accepted.

For byte writes, the unspecified byte is treated as all zeros during the RMW memory cycle.

In graphics bit-map situations, only the LSB of the WDAT parameter bytes is used as the pattern in the RMW operations. Therefore it is possible to have only an all ones or all zeros pattern. If the WG bit of the third parameter of the CURS command is set to one, any byte following the WDAT command is written as is. In coded character applications all the bits of the WDAT parameters are used to establish the drawing pattern.

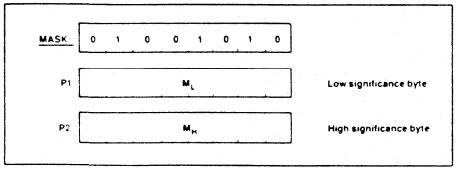
The WDAT command operates differently from the other commands which initiate RMW cycle activity. It requires parameters to set up the Pattern register while the other commands use the stored values in the parameter RAM. Like all of these commands, the WDAT command must be preceded by a FIGS command and its parameters. Only the first three parameters need be given following the FIGS opcode to set up the type of drawing, the DIR direction, and DC value. The DC parameter +1 will be the number of RMW cycles done by the GDC with the first set of WDAT parameters. Additional sets of WDAT parameters will see a DC value of 0 which will cause only one RMW cycle to be executed per set of parameters.



Mask Register Load

This command sets the value of the 16-bit Mask register of the figure drawing processor. The Mask register controls which bits can be modified in the display memory during a read-modify-write cycle.

The Mask register is loaded both by the MASK command and the third parameter byte of the CURS command. The MASK command accepts two parameter bytes to load a 16-bit value into the Mask register. All 16-bits can be individually one or zero, under program control. The CURS command, on the other hand, puts a 1-of-16 pattern into the Mask register based on the value of the Dot Address value, dAD. If normal single-pixel-at-a-time graphics figure drawing is desired, there is no need to do a MASK command at all since the CURS command will set up the proper pattern to address the proper pixels as drawing progresses. For coded character DMA, and screen setting and clearing operations using the WDAT command, the MASK command should be used after the CURS command if its third parameter byte has been output. The Mask register should be set to all ones for any "word-at-a-time" operation.



Valid Figure Type Select Combinations

SL	R	A	GC	L	Operation
0	0	0	0	0	Character display mode drawing, individual dot drawing, DMA, WDAT, and RDAT
0	0	0	0	1	Straight line drawing
0	0	0	1	0	Graphics character drawing and area filling with graphics character pattern
0	0	1	0	0	Arc and circle drawing
0	1	0	0	0	Rectangle drawing
1	0	0	1	0	Slanted graphics character drawing and slanted area filling

Only these bit combinations assure correct drawing operation.

Figure Drawing Parameters Specify

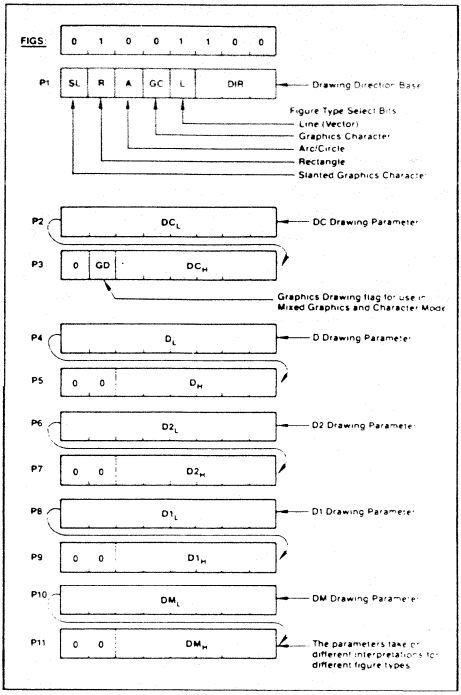
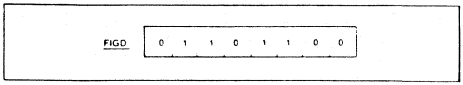


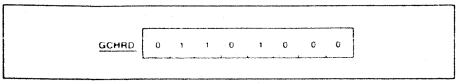
Figure Draw Start

On execution of this instruction, the GDC loads the parameters from the parameter RAM into the drawing processor and starts the drawing process at the pixel pointed to by the cursor, EAD, and the dot address dAD.



Graphics Character Draw and Area Filling Start

Based on parameters loaded with the FIGS command, this command initiates the drawing of the graphics character or area filling pattern stored in parameter RAM. Drawing begins at the address in display memory pointed to by the EAD and dAD values.

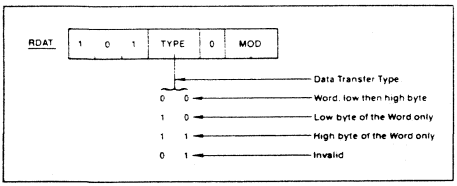


Data Read Commands

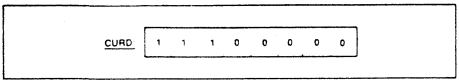
Read Data from Display Memory

Using the DIR and DC parameters of the FIGS command to establish direction and transfer count, multiple RMW cycles can be executed without specification of the cursor address after the initial load (DC = number of words or bytes).

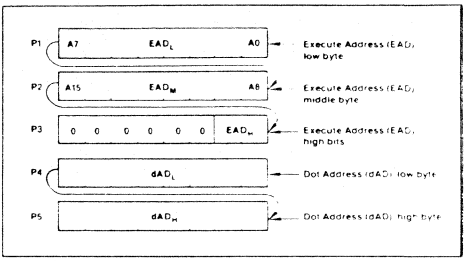
As this instruction begins to execute, the FIFO buffer direction is reversed so that the data read from display memory can pass to the microprocessor. Any commands or parameters in the FIFO at this time will be lost. A command byte sent to the GDC will immediately reverse the buffer direction back to write mode, and all RDAT information not yet read from the FIFO will be lost. MOD should be set to 00 if no modification to video buffer is desired.



Cursor Address Read



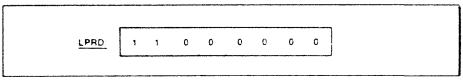
The following bytes are returned by the GDC through the FIFO:



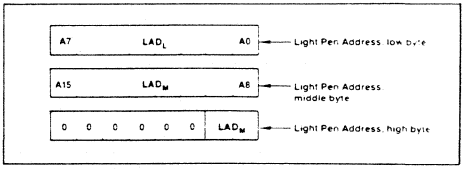
The execute address, EAD, points to the display memory word containing the pixel to be addressed.

The dot address, dAD, within the word is represented as a 1-of-16 code for graphics drawing operations.

Light Pen Address Read



The following bytes are returned by the GDC through the FIFO:

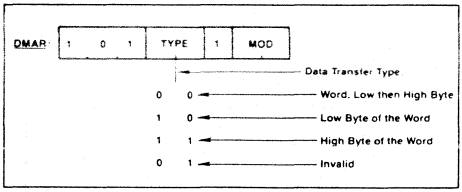


The light pen address, LAD, corresponds to the display word address, DAD, at which the light pen input signal is detected and deglitched.

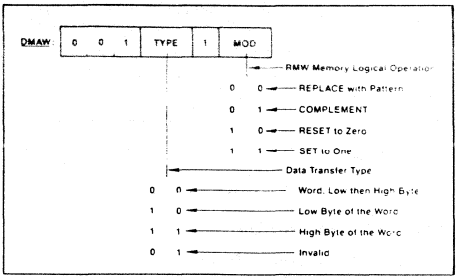
The light pen may be used in graphics, character, or mixed modes but only indicates the word address of light pen position.

DMA Control Commands

DMA Read Request



DMA Write Request



AC Characteristics

T_A = 0 to −70°C; V_{CC} = 5.0 V ±10%; GND = 0 V

Parameter	Symbol	7220AD Limits Min	7220AD Limits Max	7220AD-1 Limits Min	7220AD-1 Limits Max	7220AD-2 Limits Min	7220AD-2 Limits Max	Unit	Test Conditions
Read Cycle (GDC ⟵ CPU)									
Address setup to $\overline{RD}\downarrow$	t_{AR}	0		0		0		ns	
Address hold from $\overline{RD}\uparrow$	t_{RA}	0		0		0		ns	
$\overline{RD}$ pulse width	t_{RR}	$t_{RD1} - 20$	$t_{RCY} - 1/2\ t_{CLK}$	$t_{RD1} - 20$	$t_{RCY} - 1/2\ t_{CLK}$	$t_{RD1} - 20$	$t_{RCY} - 1/2\ t_{CLK}$	ns	
Data delay from $\overline{RD}\downarrow$	t_{RD1}		75		65		55	ns	C_L = 50 pF
Data floating from $\overline{RD}\uparrow$	t_{DF}	0	75	0	65	0	55	ns	
$\overline{RD}$ pulse cycle	t_{RCY}	$4\ t_{CLK}$		$4\ t_{CLK}$		$4\ t_{CLK}$		ns	
Write Cycle (GDC ⟵ CPU)									
Address setup to $\overline{WR}\downarrow$	t_{AW}	0		0		0		ns	
Address hold from $\overline{WR}\uparrow$	t_{WA}	10		10		10		ns	
$\overline{WR}$ pulse width	t_{WW}	80	$t_{WCY} - t_{CLK}$	70	$t_{WCY} - t_{CLK}$	60	$t_{WCY} - t_{CLK}$	ns	
Data setup to $\overline{WR}\uparrow$	t_{DW}	65		55		45		ns	
Data hold from $\overline{WR}\uparrow$	t_{WD}	0		10		10		ns	
$\overline{WR}$ pulse cycle	t_{WCY}	$4\ t_{CLK}$		$4\ t_{CLK}$		$4\ t_{CLK}$		ns	

AC Characteristics (cont)

T_A = 0 to +70°C, V_{CC} = 5.0 V ± 10%, GND = 0 V

Parameter	Symbol	7220AD Limits Min	7220AD Limits Max	7220AD-1 Limits Min	7220AD-1 Limits Max	7220AD-2 Limits Min	7220AD-2 Limits Max	Unit	Test Conditions
DMA Read Cycle (GDC ⟶ CPU)									
$\overline{DACK}$ setup to $\overline{RD}\downarrow$	t_{KR}	0		0		0		ns	
$\overline{DACK}$ hold from $\overline{RD}\uparrow$	t_{RK}	0		0		0		ns	
$\overline{RD}$ pulse width	t_{RR2}	t_{RD2} − 20		t_{RD2} − 20		t_{RD2} − 20		ns	
Data delay from $\overline{RD}\downarrow$	t_{RD2}		1.5 t_{CLK} − 80		1.5 t_{CLK} − 70		1.5 t_{CLK} − 60	ns	C_L = 50 pF
DREQ delay from 2xWCLK↑	t_{REQ}		100		85		75	ns	C_L = 50 pF
DREQ setup to $\overline{DACK}\downarrow$	t_{QK}	0		0		0		ns	
$\overline{DACK}$ high-level width	t_{DK}	t_{CLK}		t_{CLK}		t_{CLK}		ns	
$\overline{DACK}$ pulse cycle	t_E	4 t_{CLK} (1)		4 t_{CLK} (1)		4 t_{CLK} (1)		ns	
DREQ↓ delay from $\overline{DACK}\downarrow$	$t_{KQ(R)}$		t_{CLK} − 100		t_{CLK} − 90		t_{CLK} − 80	ns	C_L = 50 pF
$\overline{DACK}$ low-level width	t_{LK}	2 t_{CLK}		2 t_{CLK}		2 t_{CLK}			
DMA Write Cycle (GDC ⟶ CPU)									
$\overline{DACK}$ setup to $\overline{WR}\downarrow$	t_{KW}	0		0		0		ns	
$\overline{DACK}$ hold from $\overline{WR}\uparrow$	t_{WK}	0		0		0		ns	
RMW Cycle (GDC ⟶ Display Memory)									
Address/data display from 2xWCLK↑	t_{AD}	20	105	20	90	15	80	ns	C_L = 50 pF
Address/data floating from 2xWCLK↑	t_{DFF}	20	105	20	90	15	80	ns	C_L = 50 pF
Input data setup to 2xWCLK↓	t_{DIS}	0		0		0		ns	
Input data hold from 2xWCLK↓	t_{DIH}	t_{DE}		t_{DE}		t_{DE}		ns	
$\overline{DBIN}$ delay from 2xWCLK↓	t_{DE}	20	80	20	70	15	60	ns	C_L = 50 pF
ALE↑ delay from 2xWCLK↑	t_{RR}	20	80	20	70	15	60	ns	C_L = 50 pF
ALE↓ delay from 2xWCLK↓	t_{RF}	20	65	20	55	15	50	ns	C_L = 50 pF
ALE high width	t_{RW}	1/3 t_{CLK}		1/3 t_{CLK}		1/3 t_{CLK}		ns	C_L = 50 pF
ALE low width	t_{RL}	1.5 t_{CLK} − 30		1.5 t_{CLK} − 30		1.5 t_{CLK} − 30		ns	
Address setup to ALE↓	t_{AA}	30		30		30			

Note:

(1) For high-byte and low-byte transfers: t_E = 5 t_{CLK}.

AC Characteristics (cont)

T_A = 0 to +70°C; V_{CC} = 5.0 V ±10%; GND = 0 V

Parameter	Symbol	7220AD Limits Min	7220AD Limits Max	7220AD-1 Limits Min	7220AD-1 Limits Max	7220AD-2 Limits Min	7220AD-2 Limits Max	Unit	Test Conditions
Display Cycle (GDC ⟵ Display Memory)									
Video signal display from 2xWCLK↑	t_{VD}		90		80		70	ns	C_L = 50 pF
Input Cycle (GDC ⟵ Display Memory)									
Input signal setup to 2xWCLK↑	t_{PS}	10		10		10		ns	
Input signal width	t_{PW}	t_{CLK}		t_{CLK}		t_{CLK}		ns	
Clock (2xWCLK)									
Clock rise time	t_{CR}		15		15		15	ns	
Clock fall time	t_{CF}		15		15		15	ns	
Clock high pulse width	t_{CH}	70		61		52		ns	
Clock low pulse width	t_{CL}	70		61		52		ns	
Clock cycle	t_{CLK}	165	10000	145	10000	125	10000	ns	

Capacitance

T_A = 25°C; V_{CC} = GND = 0 V

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input capacitance	C_{IN}			10	pF	f_C = 1 MHz
IO capacitance	C_{IO}			20	pF	V_I (unmeasured) = 0 V
Output capacitance	C_{OUT}			20	pF	
Clock input capacitance	$C\phi$			20	pF	

Absolute Maximum Ratings (Tentative)

Ambient temperature under bias	0 to +70°C
Storage temperature	−65 to +150°C
Voltage on any pin with respect to ground	−0.5 to +7 V
Power dissipation	1.5 W

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

T_A = 0 to +70°C; V_{CC} = 5 V ±10%; GND = 0 V

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input low voltage	V_{IL}	−0.5		0.8	V	(Note 1)
Input high voltage	V_{IH}	2.2		V_{CC} + 0.5	V	(Notes 2, 3)
Output low voltage	V_{OL}			0.45	V	I_{OL} = 2.2 mA
Output high voltage	V_{OH}	2.4			V	I_{OH} = −400 μA

DC Characteristics (cont)

T_A = 0 to +70°C; V_{CC} = 5 V ±10%, GND = 0 V

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input low leak current (except VSYNC, $\overline{DACK}$)	I_{IL}			−10	μA	V_I = 0 V
Input low leak current (VSYNC, $\overline{DACK}$)	I_{IL}			−500	μA	V_I = 0 V
Input high leak current (except LPEN/DH)	I_{IH}			+10	μA	V_I = V_{CC}
Input high leak current (LPEN/DH)	I_{IH}			+500	μA	V_I = V_{CC}
Output low leak current	I_{OL}			−10	μA	V_O = 0 V
Output high leak current	I_{OH}			+10	μA	V_O = V_{CC}
Clock input low voltage	V_{CL}	−0.5		0.6	V	
Clock input high voltage	V_{CH}	3.5		V_{CC} + 1.0	V	
V_{CC} supply current	I_{CC}			270	mA	

Note:

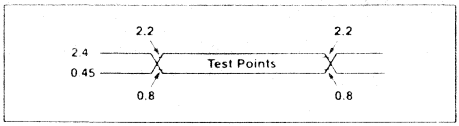
(1) For 2xWCLK, V_{IL} = −0.5 to +0.6 V

(2) For 2xWCLK, V_{IH} = +3.9 V to V_{CC} +1.0 V

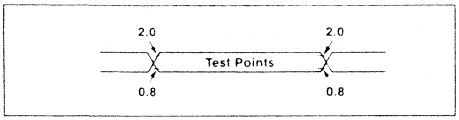
(3) For $\overline{WR}$, V_{IH} = 2.5 V to V_{CC} +0.5 V

AC Testing Conditions

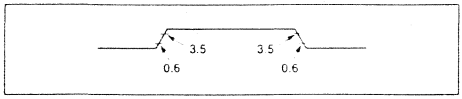
Input Waveform for AC Test (Except 2xCCLK)



Output Waveform for AC Test

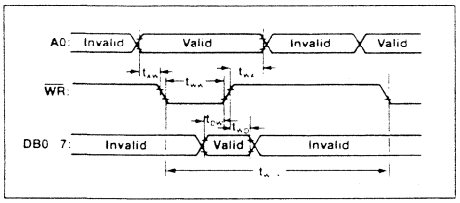


Clock Timing (2xCCLK)

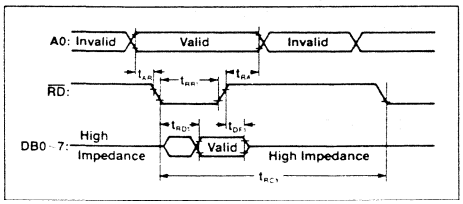


Timing Waveforms

Microprocessor Interface Write Timing

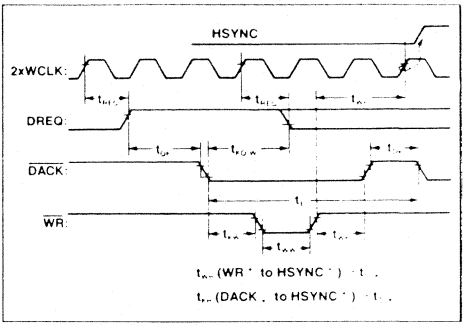


Microprocessor Interface Read Timing

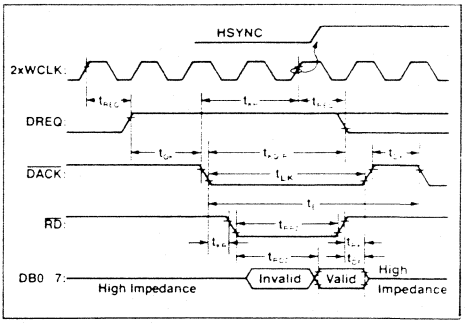


Timing Waveforms (cont)

Microprocessor Interface DMA Write Timing

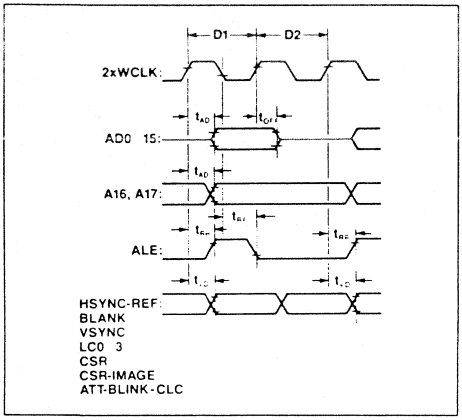


Microprocessor Interface DMA Read Timing

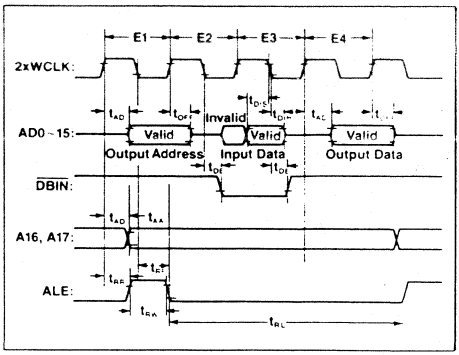


Timing Waveforms (cont)

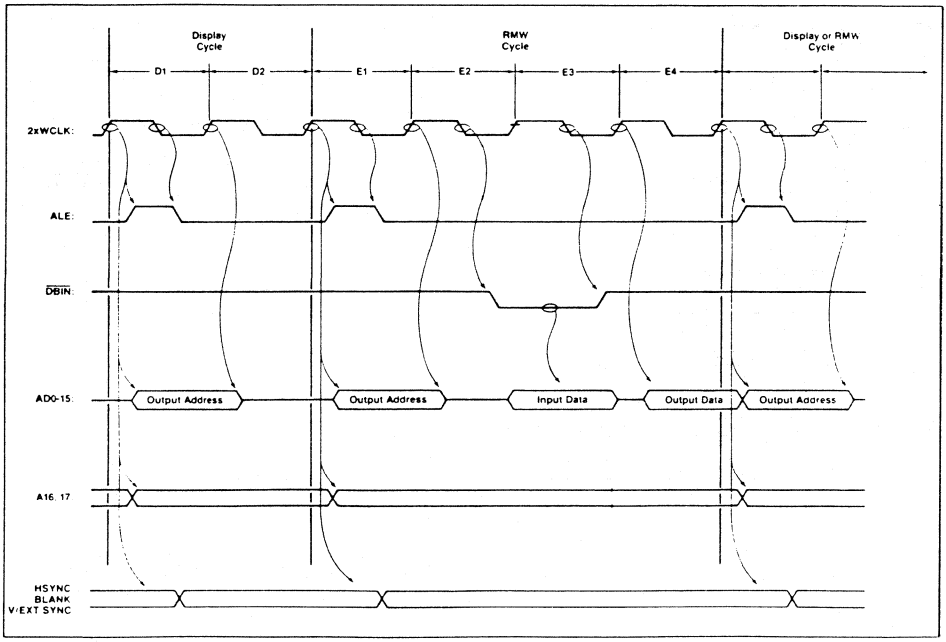
Display Memory Display Cycle Timing



Display Memory RMW Timing

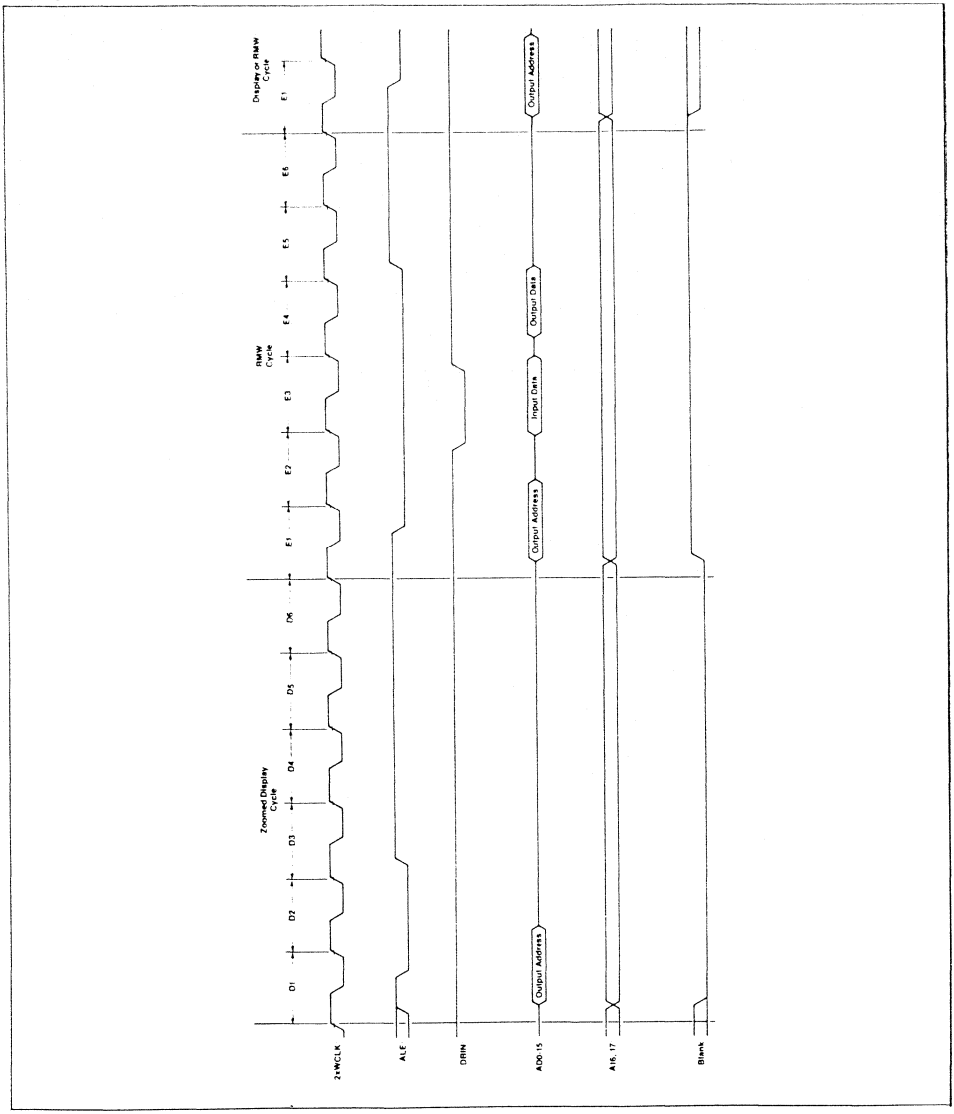


Display and RMW Cycles (1x Zoom)



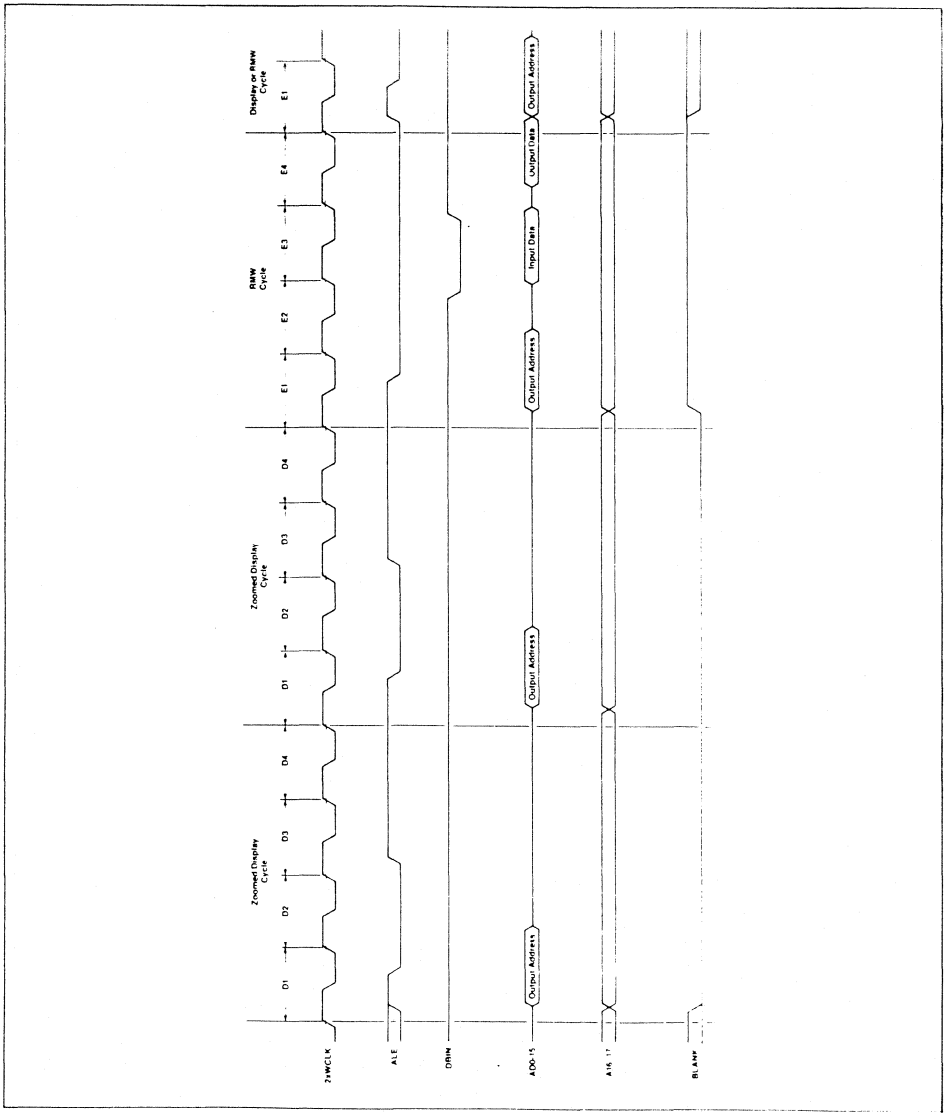
Timing Waveforms (cont)

Display and RMW Cycles (2x Zoom)



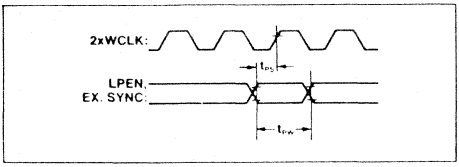
Timing Waveforms (cont)

Display and RMW Cycles (3x Zoom)

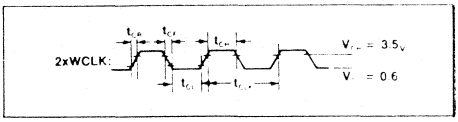


Timing Waveforms (cont)

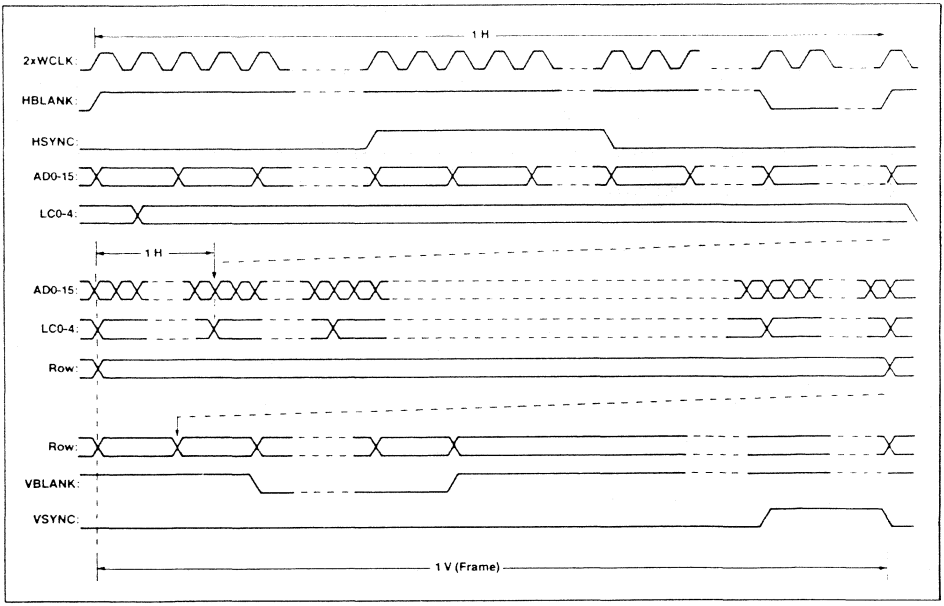
Light Pen and External Sync Input Timing



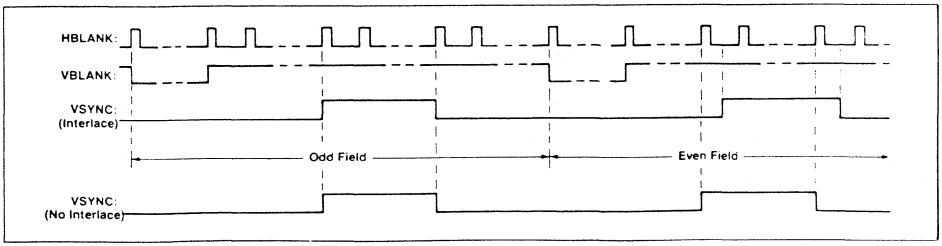
Clock Timing (2xWCLK)



Video Sync Signals Timing

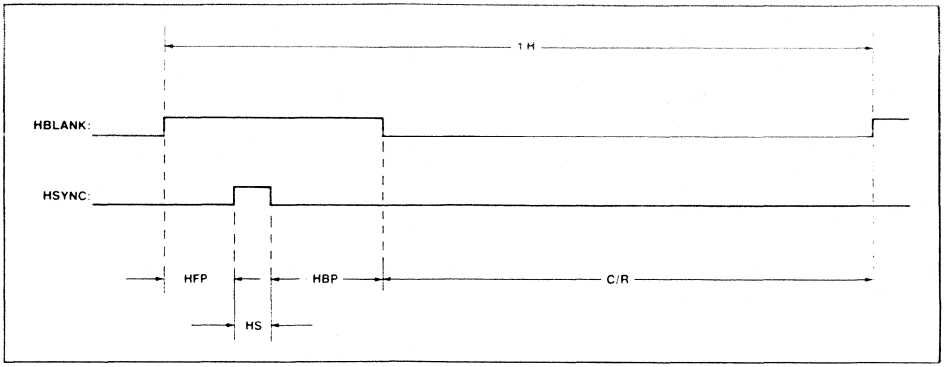


Interlaced Video Timing

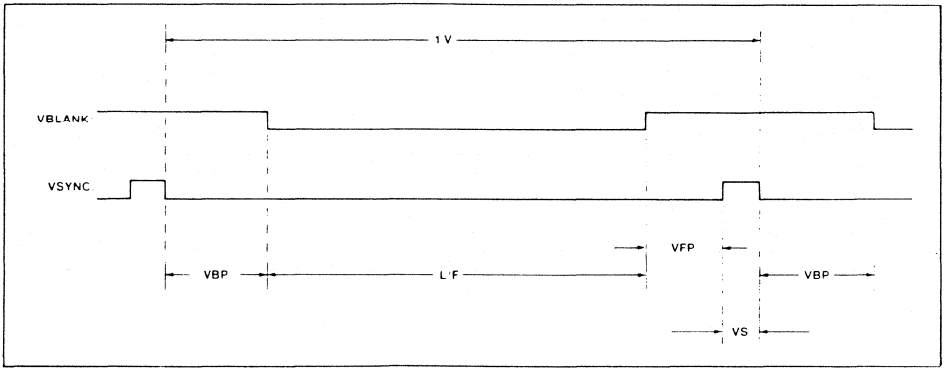


Timing Waveforms (cont)

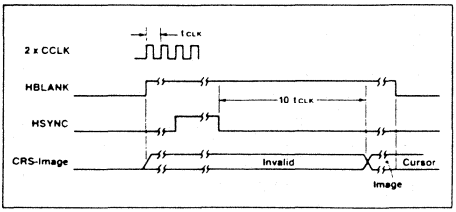
Video Horizontal Sync Generator Parameters



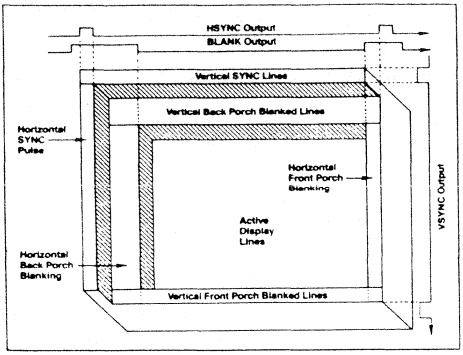
Video Vertical Sync Generator Parameters



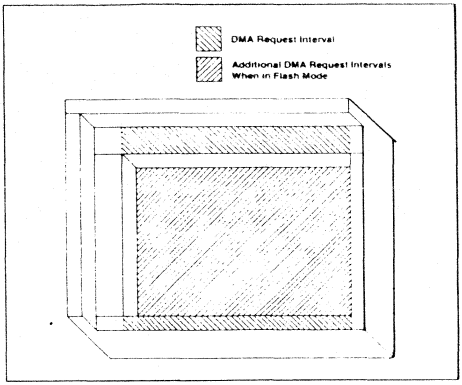
Cursor—Image Bit Flag



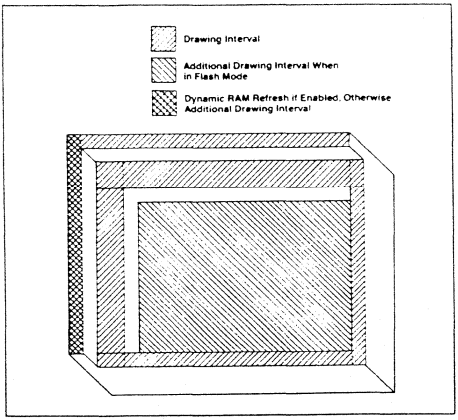
Video Field Timing



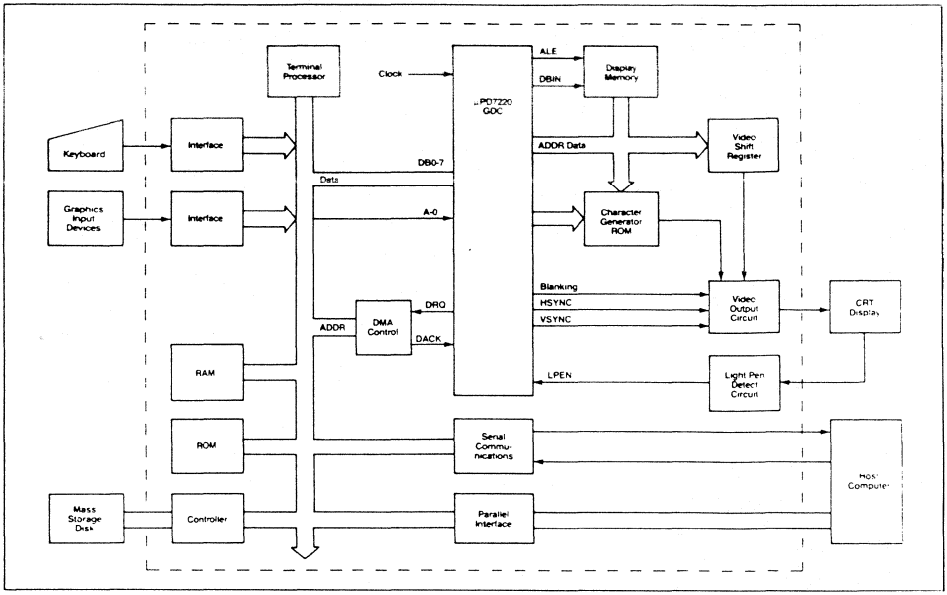
DMA Request Intervals



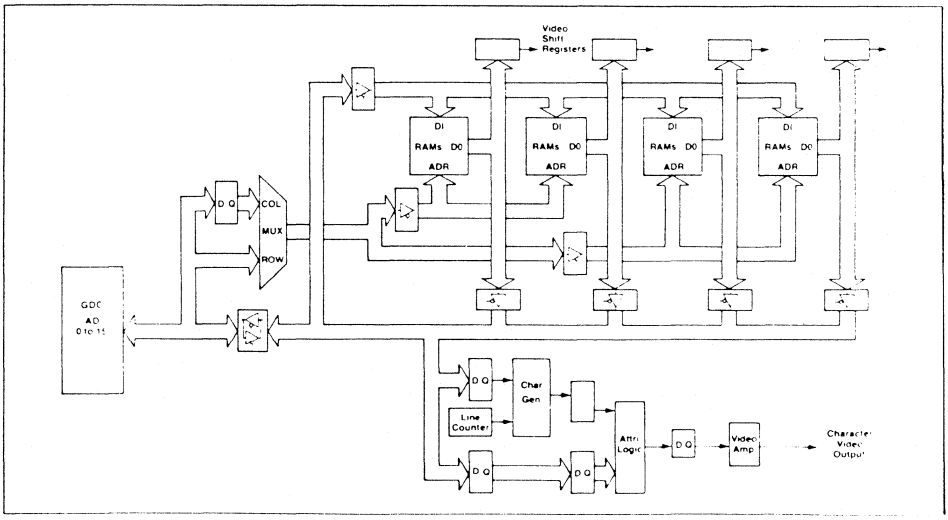
Drawing Intervals



Block Diagram of a Graphics Terminal



Multiplane Display Memory Diagram



The most significant difference between the current μPD7220 graphic display controller and the μPD7220A is the speed increase of the μPD7220A. Currently, the 7220 is available in 4.0-MHz, 5.0-MHz, and 5.5-MHz versions. The 7220A will be available in 6.0-MHz, 7.0-MHz, and 8.0-MHz versions. A number of other differences, in the form of corrections and enhancements, that exist between the parts are described below.

Commands

Two new RESET command variations and one new BLANK command variation have been added to the GDC. All of the new commands allow a reset or display blank to be accomplished while preventing reinitialization of the internal sync generator by an external sync source (slave mode).

	Command	Opcode
RESET1	Same as RESET in 7220	0 0 0 0 0 0 0 0
RESET2	Blank display; no resync	0 0 0 0 0 0 0 1
RESET3	Enable display; no resync	0 0 0 0 1 0 0 1
BLANK1	Same as BLANK in 7220	0 0 0 0 1 1 0 0
BLANK2	Blank display; no resync	0 0 0 0 0 1 0 1

Operation may be characterized as follows:

	Display Blanked	Reset Performed	External Sync (Slave Only)
RESET1	Yes	Yes	Accepted
RESET2	Yes	Yes	Ignored
RESET3	No	Yes	Ignored
BLANK1	Yes	No	Accepted
BLANK2	Yes	No	Ignored

Flag Bits

Six additional operation flag bits have been added. They are located as shown in figure E-1 and their effect on GDC operation follows.

PH Bit. The width of the display pitch register has been increased from 8 to 9 bits. This additional bit (PH) is defined as the seventh bit of the fifth parameter following a SYNC or RESET command. Utilizing this bit, the GDC can handle pitches up to 511 words per line.

DS Bit. A drawing wait function has been added to the GDC. The Light Pen input (LPEN) may be used as a drawing wait control input. If this input is held high for a period greater than four 2xWCLK cycles drawing execution is halted. During the wait cycle, display address (DAD) is output instead of drawing address (EAD). See figure E-2.

Figure E-1. Additional Flag Bits

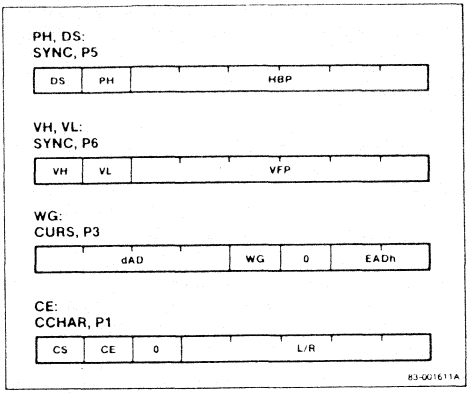
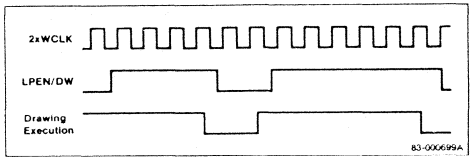


Figure E-2. Draw Wait Timing



VH Bit. A vertical blank status flag is available in the status register to replace the horizontal blank status flag if required.

7220: Outputs a horizontal blank status flag as DB6 in the status register.

7220A: User may select between the standard horizontal blank status flag and the new vertical blank status flag.

Selection is via the new VH flag. This flag is the eighth bit of the sixth parameter following a SYNC or RESET command. When VH is 1, vertical blank status is output. When VH is 0, operation is as in the 7220.

VL Bit. The number of display lines per video frame may be selected as odd or even when in interlaced mode if this bit is set.

7220: Allows only an odd number of lines per video frame.

7220A: Allows an even or odd number of lines per frame. Selection is via the VL flag created in the seventh bit of the sixth parameter byte following a SYNC or RESET command.

WG Bit. When in graphics mode, the state of a newly defined bit in the CURS (cursor position specify) instruction will determine the operation of the WDAT command. This flag bit is known as the WG bit, and is the fourth bit (from LSB) in the third parameter of the CURS command.

7220: In graphics mode, only patterns of 0FFFFH or 0000H may be written with the WDAT command. The pattern written is determined by the least significant bit of each parameter byte following the WDAT command. This bit is expanded into 16 identical bits which form the pattern.

7220A: When the WG bit is set to one, any data following the WDAT command is written as is. If WG is set to zero, the 7220A performs as the 7220 does. The WG bit is not modified by the WDAT or any drawing commands.

CE Bit. Unconditionally reinitializes the internal sync generator when the GDC is programmed for slave mode and the falling edge of an external sync input is detected. When this bit is set, the GDC will resynchronize its vertical sync to the external source during every frame. If the CE bit is set to 0 the GDC ignores any external sync after execution of the start command.

Cursor Position

Cursor postion in character mode is specified by the lower 16 bits of address rather than the lower 13 bits as in the 7220.

Cursor Format

Cursor format restrictions in character mode or character areas in mixed mode have been removed.

Pins A_{16} and A_{17}

A_{16} and A_{17} will now provide static signals.

7220A: A_{16} and A_{17} are invalid during E4 of a read-modify-write cycle. Currently, an external latch is required.

7220: A_{16} and A_{17} will be valid during E4 and any other time. No external latch is required.

Display Word

Display word addresses are incremented during the AW and HPF periods, even during vertical blanking time.

ALE Signal

The ALE signal generated by the 7220A remains as per specifications even while zooming. Corrects problem 3 as described in Product Bulletin #29.

7220: ALE is lengthened by one half 2xWCLK cycle if horizontal blanking begins while in a zoomed display.

7220A: The problem no longer exists.

Resistors

On-chip pull-up/pull-down resistors have been added.

7220: All such resistors are external.

7220A: Added are a pull-up resistor for V/EXT SYNC and $\overline{\text{DACK}}$, and a pull-down resistor for LPEN/DH.

Software

In the area of software, only one modification to existing software is required. Bit 6 of parameter RAM bytes 3 and 7 must be set for the GDC to operate in image mode. These bits are known as the IM or image bits for display partitions one and two. Note that if the above circuitry is installed and these bits are not set, the display will not be correct as every other display word would be skipped.

PROGRAMMABLE LCD CONTROLLER/DRIVER

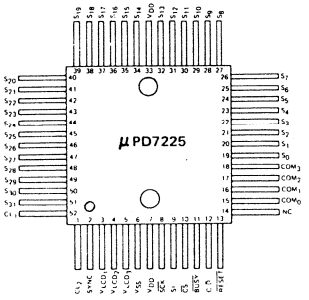
DESCRIPTION

The μPD7225 is a programmable peripheral device containing all the circuitry necessary for interfacing a microprocessor to a wide variety of alpha-numeric Liquid Crystal Displays (LCDs). The display controller hardware automatically synchronizes the drive signals for any static or multiplexed LCD containing up to 4 backplanes, and up to 32 segments . The μPD7225 is fully compatible with most microprocessors, and communicates with them through a 2-line, 8-bit Serial port. It can be easily configured into multiple chip designs for larger LCD applications. In addition, the μPD7225 includes on board 8-segment Numeric and 15-segment Alpha-Numeric decoders, and programmable blinking capabilities. The μPD7225 is manufactured with a low-power single 5V CMOS process, and is available in a 52-pin plastic flat package.

FEATURES

- Single Chip LCD Controller
- Direct LCD Drive
- Selectable Backplace Drive Configuration
  - Static; 2-, 3-, or 4-Backplane Multiplexed
- Programmable Display Configurations
  - 8-Segment Numeric – up to 16 Characters
  - 15-Segment Alpha-Numeric – up to 8 Characters
- 32-Segment Drive Lines
- Selectable Display Bias Configuration
  - Static; 1/2 or 1/3
- Automatic Synchronization of Segment and Backplane Drive Lines
- Dual 32 x 4 Bit RAMs for Display Data Storage
- Programmable Display Data Addressing
  - Individual Segment
  - 16-Character, 8-Segment Numeric Decoder
  - 64-Character, 15-Segment Alpha-Numeric Decoder
- Programmable Blinking Capability
  - Individual Segment, Individual Character, or Entire Display
- 8-Bit Serial Interface
- Compatible with most 4-Bit, 8-Bit, and 16-Bit Microprocessors
- Fully Cascadable for Larger LCD Applications
- Single +5V Power Supply
- CMOS Technology
- 52-Pin Plastic Flat Package

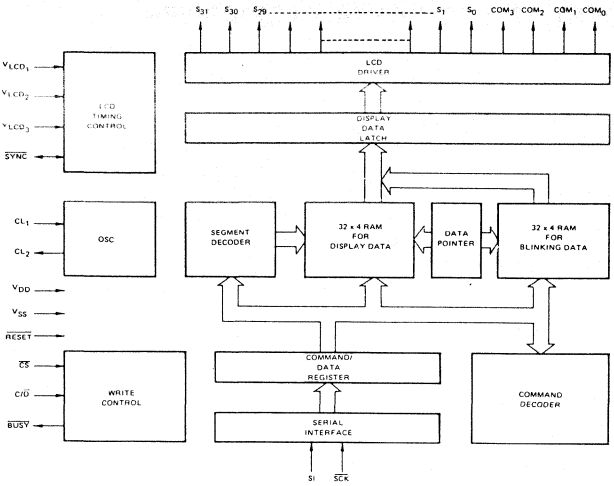
PIN CONFIGURATION



PIN DESCRIPTION

SYMBOL	DESCRIPTION
S_0-S_{31}	LCD Segment Drive Outputs
COM_0-COM_3	LCD Backplane Drive Outputs
V_{SS}	Ground
V_{DD}	Power Supply Positive
V_{LCD_1}-V_{LCD_3}	LCD Power Supply
$\overline{SCK}$	Serial Clock Input
SI	Serial Input
$\overline{CS}$	Chip Select
C/$\overline{D}$	Command/Data Select
CL_1, CL_2	System Clock Input, Output
$\overline{SYNC}$	Synchronization Signal I/O Port for multiple chip
$\overline{BUSY}$	Busy Output
$\overline{RESET}$	Reset Input
NC	No Connection

BLOCK DIAGRAM



COMMAND DESCRIPTION

1. MODE SET

0	1	0	D_4	D_3	D_2	D_1	D_0	40-5F

The MODE SET command sets up the Backplane Drive Configuration, the Display Bias Voltage Configuration, and the A/C Drive Frequency for the μPD7225.

The Backplane Drive Configuration is defined as follows:

D_3	D_2	Backplane Drive Configuration
0	1	Static (1-Backplane)
1	1	2-Backplane Multiplexed
1	0	3-Backplane Multiplexed
0	0	4-Backplane Multiplexed

The Display Bias Voltage Configuration is defined as follows:

D_4	Display Bias Voltage Configuration
0	1/3 (three voltage)
1	1/2 (two voltage)
X	Static (single voltage; default when D_3D_2 = 00)

The A/C Drive Frequency is defined as follows:

D_1	D_0	A/C Drive Frequency
0	0	$f_c/2^7$ Hz
0	1	$f_c/2^8$ Hz
1	0	$f_c/2^9$ Hz
1	1	$f_c/2^{11}$ Hz

Note: LCD Frame Frequency = $\frac{\text{A/C Drive Frequency}}{\#\text{ of active Backplane Drive lines}}$

2. UNSYNCHRONOUS DATA TRANSFER

0 0 1 1 0 0 0 0	30

The Normal Transfer of data from the Display Data RAM to the segment output latches latches occurs with the rising edge of CS. The UNSYNCHRONOUS DATA TRANSFER command implements this mode of data transfer, and also disables the SYNCHRONOUS DATA TRANSFER operation.

3. SYNCHRONOUS DATA TRANSFER

0 0 1 1 0 0 0 1	31

Data can also be transferred from the Display Data RAM to the segment output latches with the rising edge of f_C. The SYNCHRONOUS DATA TRANSFER command implements this mode of data transfer, and also disables the UNSYNCHRONOUS DATA TRANSFER operation.

4. INTERRUPT DATA TRANSFER

0 0 1 1 1 0 0 0	38

Occasionally, the Host microprocessor system may experience events, such as prioritized Hardware interrupts, that may disrupt communications with the μPD7225. Display Data transfers to the μPD7225 may be interrupted, without disrupting the μPD7225 internal display data protocol, by issuing an INTERRUPT DATA TRANSFER command at the beginning of the interrupt service routine. Display data updating may be resumed in an orderly fashion after the interrupt service routine is completed.

5. CLEAR Display Data

0 0 1 0 0 0 0 0	20

All locations in the Display Data RAM are set to zero by executing the CLEAR DISPLAY DATA command. The Data Pointer is also cleared, and set to its initial location.

6. CLEAR BLINKING DATA

0 0 0 0 0 0 0 0	00

All locations in to Blinking Data RAM are set to zero by executing the CLEAR BLINKING DATA command. The Data Pointer is also cleared, and set to its initial location.

7. LOAD DATA POINTER

0 0 0 D_4 D_3 D_2 D_1 D_0	E0-FF

To access a particular location in either the Display Data RAM, or the BLINKING DATA RAM the Data Pointer must be given the corresponding address of that location. The LOAD DATA POINTER command transfers 5 bits of immediate data to the Data Pointer.

8. WRITE DISPLAY DATA

1 1 0 1 D_3 D_2 D_1 D_0	D0-DF

The WRITE DISPLAY DATA command transfers 4 bits of immediate data to the Display Data RAM location addressed by the Data Pointer. After the transfer is complete, the Data Pointer is automatically incremented.

COMMAND DESCRIPTION (CONT.)

9. WRITE BLINKING DATA

1	1	0	0	D_3	D_2	D_1	D_0	C0-CF

The WRITE BLINKING DATA command transfers 4 bits of immediate data to the Blinking Data RAM location addressed by the Data Pointer. After the transfer is complete, the Data Pointer is automatically incremented.

10. ENABLE DISPLAY

0	0	0	1	0	0	0	1	11

The ENABLE DISPLAY command turns on the LCD, and starts the automatic display controller hardware of the μPD7225.

11. DISABLE DISPLAY

0	0	0	1	0	0	0	0	10

The DISABLE DISPLAY command turns off the LCD, and stops the automatic display controller hardware of the μPD7225.

12. ENABLE BLINKING

0	0	0	1	1	0	1	D_0	1A-1B

If a particular LCD application requires blinking several segments, the appropriate information must have been transferred to the Blinking Data RAM previously. The ENABLE BLINKING command selects the Blinking frequency according to the value of D_0, and turns the Blinking feature on.

D_0	Blinking Frequency
0	$f_c/2^{16}$ Hz
1	$f_c/2^{17}$ Hz

13. DISABLE BLINKING

0	0	0	1	1	0	0	0	18

The DISABLE BLINKING command turns the Blinking feature OFF.

14. ENABLE SEGMENT DECODER

0	0	0	1	0	1	0	1	15

The μPD7225 has an internal 8-segment Numeric data decoder, and an internal 15-segment Alpha-Numeric data decoder. These decoders can be used for automatic display data addressing, by the Host microprocessor to absorb some of the system overhead required to decode display data for the μPD7225.

The ENABLE SEGMENT DECODER command implements this mode of display data addressing. Upon execution, display data received by the μPD7225 is diverted to one of the segment decoders. The segment decoder then writes display data to the Display Data RAM. The distinction between 8-segment decoding and 15-segment decoding is made by the MSB of the display data:

MSB	Decoding Selected
0	8-segment Numeric
1	15-segment Alpha-Numeric

15. DISABLE SEGMENT DECODER

0 0 0 1 0 1 0 0	14

The DISABLE SEGMENT DECODER command stops the segment decode addressing, and enables the transfers of Display Data from the Host microprocessor directly to the Display Data RAM.

16. OR DISPLAY DATA

1 0 1 1 D_3 D_2 D_1 D_0	B0-BF

The OR DISPLAY DATA command performs a LOGICAL OR between the Display Data addressed by the Data Pointer, and 4 bits of immediate data. The result is written to the same Display Data location, and the Data Pointer is automatically incremented.

17. AND DISPLAY DATA

1 0 0 1 D_3 D_2 D_1 D_0	90-9F

The AND DISPLAY DATA command performs a LOGICAL AND between the Display Data addressed by the Data Pointer, and 4 bits of immediate data. The result is written to the same Display Data location, and the Data Pointer is automatically incremented.

18. OR BLINKING DATA

1 0 1 0 D_3 D_2 D_1 D_0	A0-AF

The OR BLINKING DATA command performs a LOGICAL OR between the Blinking Data addressed by the Data Pointer, and 4 bits of immediate data. The result is written to the same Blinking Data location, and the Data Pointer is automatically incremented.

19. AND BLINKING DATA

1 0 0 0 D_3 D_2 D_1 D_0	80-8F

The AND BLINKING DATA command performs a LOGICAL AND between the Blinking Data addressed by the Data Pointer, and 4 bits of immediate data. The result is written to the same Blinking Data location, and the Data Pointer is automatically incremented.

COMMAND SUMMARY

COMMAND	DESCRIPTION	INSTRUCTION CODE BINARY D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	HEX
1. Mode Set	Set up Driving Mode of LCD, including: 1) Backplane drive 2) Display Bias 3) LCD Frame Frequency	0	1	0	D_4	D_3	D_2	D_1	D_0	40-5F
2. Unsychronous Data Transfer	Synchronize writing of display data with CS	0	0	1	1	0	0	0	0	30
3. Synchronous Data Transfer	Synchronize writing of display data with LCD Frame Frequency	0	0	1	1	0	0	0	1	31
4. Interrupt Data Transfer	Interrupt writing of display data	0	0	1	1	1	0	0	0	38
5. Clear Display Data	Clear the Display Data RAM and the Data Pointer	0	0	1	0	0	0	0	0	20
6. Clear Blinking Data	Clear the Blinking Data RAM and the Data Pointer	0	0	0	0	0	0	0	0	00
7. Load Data Pointer	Load Data Pointer with 5 Bits of Immediate Data	1	1	1	D_4	D_3	D_2	D_1	D_0	E0-FF
8. Write Display Data	Write 4 Bits of Immediate Data to the Display Data Location addressed by the Data Pointer; Increment Data Pointer	1	1	0	1	D_3	D_2	D_1	D_0	D0-DF
9. Write Blinking Data	Write 4 Bits of Immediate Data to the Blinking Data Location addressed by the Data Pointer; Increment Data Pointer	1	1	0	0	D_3	D_2	D_1	D_0	C0-CF
10. Enable Display	Start Automatic LCD Controller Hardware	0	0	0	1	0	0	0	1	11
11. Disable Display	Stop Automatic LCD Controller Hardware	0	0	0	1	0	0	0	0	10
12. Enable Blinking	Start the Blinking Operation at the Frequency Specified by 1 Bit of Immediate Data	0	0	0	1	1	0	1	D_0	1A-1B
13. Disable Blinking	Stop Blinking Operation	0	0	0	1	1	0	0	0	18
14. Enable Segment Decoder	Select 8-Segment Numeric or 15-Segment Alphanumeric Decoder Addressing	0	0	0	1	0	1	0	1	15
15. Disable Segment Decoder	Stop Segment Decoder Addressing; Return to individual segment addressing	0	0	0	1	0	1	0	0	14
16. OR Display Data	Perform a Logical OR between the Display Data addressed by the Data Pointer and 4 Bits of Immediate Data; Write Results to same Display Data Location; Increment Data Pointer	1	0	1	1	D_3	D_2	D_1	D_0	B0-BF
17. AND Display Data	Perform a Logical AND between the Display Data addressed by the Data Pointer and 4 Bits of Immediate Data; Write Result to same Display Data Location; Increment Data Pointer	1	0	0	1	D_3	D_2	D_1	D_0	90-9F
18. OR Blinking Data	Perform a Logical OR between Blinking Data addressed by the Data Pointer and 4 Bits of Immediate Data; Write Result to same Blinking Data Location; Increment Data Pointer	1	0	1	0	D_3	D_2	D_1	D_0	A0-AF
19. AND Blinking Data	Perform a Logical AND between Blinking Data addressed by the Data Pointer and 4 Bits of Immediate Data; Write Result to same Location; Increment Data Pointer	1	0	0	0	D_3	D_2	D_1	D_0	80-8F

ABSOLUTE MAXIMUM RATINGS*

Supply Voltage	−0.3~+ 7.0V
Input Voltage	−0.3~V_{DD} + 0.3V
Output Voltage	−0.3~V_{DD} + 0.3V
Operating Temperature	−40~+85°C
Storage Temperature	−40~+ 125 °C

COMMENT: Stress above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

*T_a = 25°C

DC ELECTRICAL CHARACTERISTICS

D. C. Characteristics (T_a = −10~+ 70 °C, V_{DD} = 5V ± 10 %

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input High Voltage	V_{IH}		0.7V_{DD}		V_{DD}	V
Input Low Voltage	V_{IL}		0		0.3V_{DD}	V
Output High Voltage	V_{OH}	$\overline{SYNC}$, $\overline{BUSY}$, I_{OH} = −10μA	V_{DD}−0.5			V
Output Low Voltage	V_{OL1}	$\overline{BUSY}$, I_{OL} = 100μA			0.5	V
	V_{OL2}	$\overline{SYNC}$, I_{OL} = 900μA			1.0	V
Output Short Circuit Current	I_{OS}	$\overline{SYNC}$, V_O = 1V			−300	μA
Input Leakage High	I_{LIH}	V_I = 5.5V			2	μA
Input Leakage Low	I_{LIL}	V_I = 0V			−2	μA
Output Leakage High	I_{LOH}	V_O = V_{DD}			2	μA
Output Leakage Low	I_{LOL}	V_O = 0V			−2	μA
Common Output Impedance	R_{COM}	COM 0~COM 3,(1)$V_{DD} \geqq V_{LCD}$		5	7	KΩ
Segment Output Impedance	R_{SEG}	SO~S31,(1)$V_{DD} \geqq V_{LCD}$		7	14	KΩ
Supply Current	I_{DD}	CL1: External Clock, fc = 200KHz		100	250	μA

AC CHARACTERISTICS

A. C. Characteristics (T_a = −10~+70 °C, V_{DD} = 5V ± 10 %)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Operating Frequency	f_c		50		200	KH_z
Oscillation Frequency	f_{OSC}	R = 180KΩ ± 5 %	85	130	175	KH_z
Clock Pulse Width High	t_{WHC}	CL1, External Clock	2		16	μs
Clock Pulse Width Low	t_{WLC}	CL1, External Clock	2		16	μs
$\overline{SCK}$ Cycle	t_{CYK}		1			μs
$\overline{SCK}$ Pulse Width High	t_{WHK}		400			ns
$\overline{SCK}$ Pulse Width Low	t_{WLK}		400			ns
$\overline{BUSY}$ ↑→ $\overline{SCK}$ ↓ Hold Time	t_{HBK}		0			ns
SI Setup Time to $\overline{SCK}$ ↑	t_{SIK}		250			ns
SI Hold Time after $\overline{SCK}$ ↑	t_{HKI}		200			ns
8th SCK ↑→ $\overline{BUSY}$ ↓ Delay Time	t_{DKB}	C_L = 50pF			3	μs
$\overline{CS}$ ↓→ $\overline{BUSY}$ ↓ Delay Time	t_{DCB}	C_L = 50 pf			1.5	μs
C/$\overline{D}$ Setup Time to 8th $\overline{SCK}$ ↑	t_{SDK}		9			μs
C/$\overline{D}$ Hold Time after 8th $\overline{SCK}$ ↑	t_{HKD}		1			μs
$\overline{CS}$ Hold Time after 8th $\overline{SCK}$ ↑	t_{HKG}		1			μs
$\overline{CS}$ Pulse Width High	t_{WCH}		(2)			μs
$\overline{CS}$ Pulse Width Low	t_{WLC}		(2)			μs
$\overline{SYNC}$ Load Capacitance	C_{LSY}	t_{CYC} = 5μs			50	pF

Notes (1) Applies to static, 1/2 and 1/3 multiplexed drive
(2) $8/f_C$

AC CHARACTERISTICS

A. C. Characteristics (T_a = 0~+70 °C, V_{DD} = 2.7V~5.5V)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Operating Frequency	f_c		50		140	KH_z
Oscillation Frequency	f_{OSC}	R=180KΩ ± 5 %, V_{DD}=3V±10 %	50	40	140	KH_z
Clock Pulse Width High	t_{WHC}	CL1, External Clock	3		16	μs
Clock Pulse Width Low	t_{WLC}	CL1, External Clock	3		16	μs
$\overline{SCK}$ Cycle	t_{CYK}		4			μs
$\overline{SCK}$ Pulse Width High	t_{WHK}		1.8			μs
$\overline{SCK}$ Pulse Width Low	t_{WLK}		1.8			μs
$\overline{BUSY}$ ↑→ $\overline{SCK}$ ↓ Hold Time	t_{HBK}		0			ns
SI Setup Time to $\overline{SCK}$ ↑	t_{SIK}		1			μs
SI Hold Time after $\overline{SCK}$ ↑	t_{HKI}		1			μs
8th SCK ↑→ $\overline{BUSY}$ ↓ Delay Time	t_{DKB}	C_L = 50pF			5	μs
$\overline{CS}$ ↓→ $\overline{BUSY}$ ↓ Delay Time	t_{DCB}	C_L = 50 pf			5	μs
C/$\overline{D}$ Setup Time to 8th $\overline{SCK}$ ↑	t_{SDK}		18			μs
C/$\overline{D}$ Hold Time after 8th $\overline{SCK}$ ↑	t_{HKD}		1			μs
$\overline{CS}$ Hold Time after 8th $\overline{SCK}$ ↑	t_{HKC}		1			μs
$\overline{CS}$ Pulse Width High	t_{WCH}		(2)			μs
$\overline{CS}$ Pulse Width Low	t_{WLC}		(2)			μs
$\overline{SYNC}$ Load Capacitance	C_{LSY}	t_{CYC} = 5μs			50	pF

Notes (1) Applies to static and 1/3-multiplexed drive.
(2) $8/f_C$

DC ELECTRICAL CHARACTERISTICS FOR LCD

2.7 ≤ V_{LCD} ≤ V_{DD}

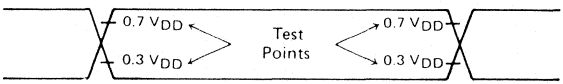
PARAMETER	SYMBOL	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS	CONDITIONS
Backplane Drive Output Impedance	R_{COM}		2		kΩ	COM_0 - COM_3, Display Bias = 1/3 or Static
					kΩ	COM_0 - COM_3 Display Bias = 1/2
Segment Drive Output Impedance	$R_{\overline{SEG}}$		11		kΩ	$\overline{S_0}$ - $\overline{S_{31}}$

CAPACITANCE

Capacitance (T_a = 25 °C, V_{DD} = 0V)

PARAMETER	SYMBOL	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Input Capacitance	C_{IN}		f_C = 1MHz Unmeasured pins returned to 0V			10	pF
Output Capacitance	C_{OUT1}	Except $\overline{BUSY}$				20	pF
Output Capacitance	C_{OUT2}	$\overline{BUSY}$				15	pF
I/O Capacitance	C_{IO}	$\overline{SYNC}$				15	pF
Clock Capacitance	C_c	CL1				30	pF

A. C. Timing Measurement Voltage



EXTENDED TEMPERATURE RANGE (–40 to +85 °C)

DC ELECTRICAL CHARACTERISTICS

D. C. Characteristics (T_a = –40 to +85 °C, V_{DD} = 5V ± 10%

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input High Voltage	V_{IH1}	Excetp $\overline{SCK}$	$0.7V_{DD}$		V_{DD}	V
	V_{IH2}	$\overline{SCK}$	$0.75V_{DD}$		V_{DD}	V
Input Low Voltage	V_{IL1}	Except $\overline{SCK}$	0		$0.3V_{DD}$	V
	V_{IL2}	$\overline{SCK}$	0		$0.25V_{DD}$	V
Output High Voltage	V_{OH}	$\overline{SYNC}$, $\overline{BUSY}$, I_{OH} = –7μA	V_{DD} –0.5			V
Output Low Voltage	V_{OL1}	$\overline{BUSY}$, I_{OL} = 100μA			0.5	V
	V_{OL2}	$\overline{SYNC}$, I_{OL} = 400μA			0.5	V
Output Short Circuit Current	I_{OS}	$\overline{SYNC}$, V_O = 0.5V (1)			–350	μA
Input Leakage High	I_{LIH}	V_I = 5.5V			2	μA
Input Leakage Low	I_{LIL}	V_I = 0V			–2	μA
Output Leakage High	I_{LOH}	V_O = V_{DD}			2	μA
Output Leakage Low	I_{LOL}	V_O = 0V			–2	μA
Common Output	R_{COM}	COM 0-COM 3, $V_{DD} \geq V_{LCD}$		5	8	KΩ
Segment Output Impedance	R_{SEG}	S0-S31, (1) $V_{DD} \geq V_{LCD}$		7	20	KΩ
Supply Current	I_{DD}	CL1, External Clock, V_{DD} = 3V ± 10%, fc = 140KHz		90	250	μA

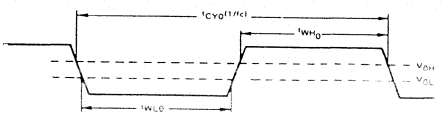
AC CHARACTERISTICS

A. C. Characteristics (T_a = –40 to +85 °C, V_{DD} = 5V ± 10%

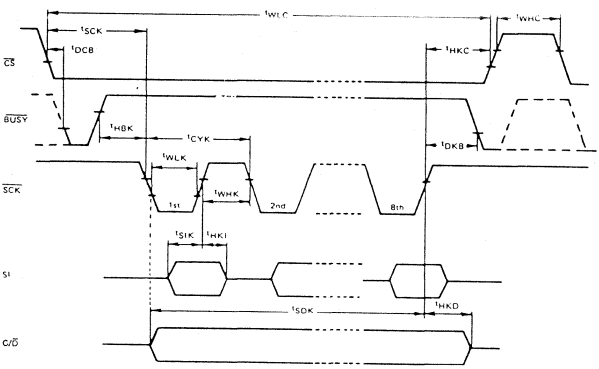
PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Operating Frequency	f_c		75		180	KH_z
Oscillation Frequency	f_{OSC}	R = 180KΩ ± 5%	80	130	180	KH_z
Clock Pulse Width High	t_{WHC}	CL1, External Clock	2		10	μs
Clock Pulse Width Low	t_{WLC}	CL1, External Clock	2		10	μs
$\overline{SCK}$ Cycle	t_{CYK}		1.2			μs
$\overline{SCK}$ Pulse Width High	t_{WHK}		500			ns
$\overline{SCK}$ Pulse Width Low	t_{WLK}		500			ns
$\overline{BUSY}$ ↑→ $\overline{SCK}$ ↓ Hold Time	t_{HBK}		0			ns
SI Setup Time to $\overline{SCK}$ ↑	t_{SIK}		100			ns
SI Hold Time after $\overline{SCK}$ ↑	t_{HKI}		200			ns
8th SCK ↑→ $\overline{BUSY}$ ↓ Delay Time	t_{DKB}	C_L = 50pF			3	μs
$\overline{CS}$ ↓→ $\overline{BUSY}$ ↓ Delay Time	t_{DCB}	C_L = 50 pf			1.5	μs
C/$\overline{D}$ Setup Time to 8th $\overline{SCK}$ ↑	t_{SDK}		9			μs
C/$\overline{D}$ Hold Time after 8th $\overline{SCK}$ ↑	t_{HKD}		1			μs
$\overline{CS}$ Hold Time after 8th $\overline{SCK}$ ↑	t_{HKG}		1			μs
$\overline{CS}$ Pulse Width High	t_{WCH}		(3)			μs
$\overline{CS}$ Pulse Width Low	t_{WLC}		(3)			μs
$\overline{SYNC}$ Load Capacitance	C_{LSY}	t_{CYC} = 5μs			50	pF

Notes (1) Output short circuit caused by conflict among $\overline{SYNC}$ outputs in multi-chip configuration
(2) Applies to static, 1/2-and 1/3-multiplexed drive
(3) 8/fC

CLOCK WAVE FORM

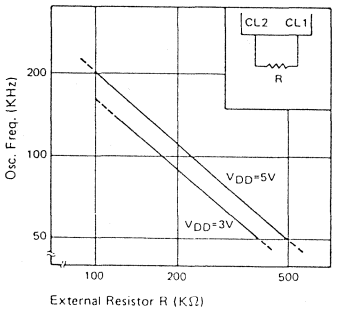


SERIAL INTERFACE TIMING

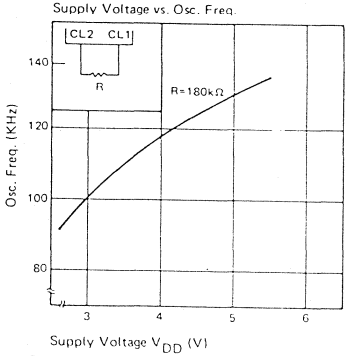


Characteristics Curves (Ta = 25 °C)

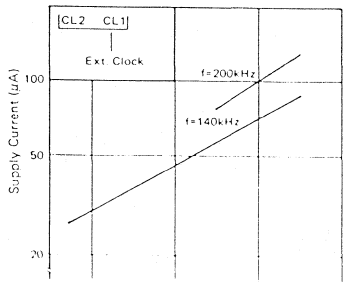
External Resistor vs. Osc. Freq.



Supply Voltage vs. Osc. Freq.



Supply Voltage vs. Supply Current



INTRODUCTION

The μPD7227 Intelligent Dot-matrix LCD Controller/Driver is a pheripheral device designed to interface most microprocessors with a wide variety of dot matrix LCDs. It can directly drive any multiplexed LCD organized as 8 rows by 40 columns, and is easily cascaded up to 16 rows and 320 columns. The μPD7227 is equipped with several hardware logic blocks, such as an 8-bit serial interface, ASCII character generator, 40 x 16 static RAM with full read/write capability, and an LCD timing controller; all of which reduce microprocessor system software requirements. The μPD7227 is manufactured with a single 5V CMOS process, and is available in a space-saving 64-pin flat plastic package.

Features

Single-chip LCD controller with direct LCD drive
Compatible with most microprocessors
Eight row drives
  Designed for dot-matrix LCD configurations up to 320 dots
  Designed for 5 x 7 dot-matrix character LCD configuration; up to 8 characters
  Cascadable to 16 row drives
40 column drives
  Cascadable to 320 column drives
Hardware logic blocks reduce system software requirements
  8-bit serial interface for communication
  ASCII 5 x 7 dot-matrix character generator with 64-character vocabulary
  40 x 16 bit static RAM for data storage, retrieval, and complete back-up memory capability
  Voltage controller generates LCD bias voltages
  Timing controller synchronizes column drives with sequentially-multiplexed row drives
Single +5V power supply
CMOS technology

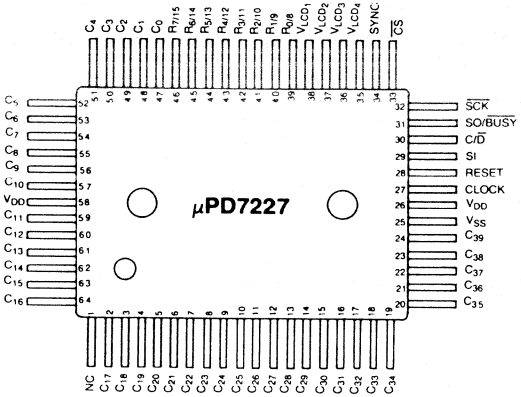


Figure 1.1 Pin Configuration

Pin Description

Symbol	Description
$R_{0/7}$-$R_{8/15}$	LCD Row Drive Outputs
C_0-C_{39}	LCD Column Drive Outputs
$\overline{CS}$	Chip Select Input
C/$\overline{D}$	Command/Data Select Input
SO/$\overline{BUSY}$	Serial Output/Busy Output
$\overline{SCK}$	Serial Clock Input
SI	Serial Input
SYNC	Synchronization Port for Cascaded Applications
CLOCK	System Clock Input
RESET	Reset Input
V_{DD}	Power Supply Positive
V_{LCD_1}-V_{LCD_4}	LCD Power Supply
V_{SS}	Ground
NC	No Connection

Table 1.1 Pin Description

LCD Panel				
Dot Matrix		5 x 7 Dot Matrix Character		
8 Row	16 Row	8 Row	16 Row	μPD7227s Required
640 dots (8 x 80)	1280 dots (16 x 80)	16 characters plus 80 dots	2 rows of 16 characters plus 160 dots	2
960 dots (8 x 120)	1920 dots (16 x 120)	24 characters plus 120 dots	2 rows of 24 characters plus 240 dots	3
1280 dots (8 x 160)	2560 dots (16 x 160)	32 characters plus 160 dots	2 rows of 32 characters plus 320 dots	4
1600 dots (8 x 200)	3200 dots (16 x 200)	40 characters plus 200 dots	2 rows of 40 characters plus 400 dots	5
1920 dots (8 x 240)	3840 dots (16 x 240)	48 characters plus 240 dots	2 rows of 48 characters plus 480 dots	6
2240 dots (8 x 280)	4480 dots (16 x 280)	56 characters plus 280 dots	2 rows of 56 characters plus 560 dots	7
2560 dots (8 x 320)	5120 dots (16 x 320)	64 characters plus 320 dots	2 rows of 64 characters plus 640 dots	8

Cascaded display configuration

One μPD7227 is selected as the master LCD controller, and the remaining μPD7227s become slave column drivers. You should connect the following pins of the master μPD7227 to the corresponding pins of each slave μPD7227.

CLOCK, RESET, V_{DD}, V_{SS}, V_{LCD1}, V_{LCD2}, V_{LCD3}, V_{LCD4}, SYNC,
SO/BUSY C/$\overline{D}$, $\overline{SCK}$, SI

Each of the $\overline{CS}$ inputs is brought out separately to the microprocessor.

Command Summary

Command	Description	Instruction Code Binary D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	HEX
1. MODE SET	Initialize the μPD7227, including selection of 1. LCD Drive Configuration 2. Row Driver Port Function 3. RAM Bank 4. SYNC Port Function	0	0	0	1	1	D_2	D_1	D_0	18-1F
2. FRAME FREQUENCY SET	Set LCD Frame Frequency	0	0	0	1	0	D_2	D_1	D_0	10-17
3. LOAD DATA POINTER	Load Data Pointer with 7 bits of Immediate Data	1	D_6	D_5	D_4	D_3	D_2	D_1	D_0	80-E7
4. WRITE MODE	Write Display Byte in Serial Register to RAM location addressed by Data Pointer; modify Data Pointer	0	1	1	0	0	1	D_1	D_0	64-67
5. READ MODE	Load RAM contents addressed by Data Pointer into Serial Register for output; modify Data Pointer	0	1	1	0	0	0	D_1	D_0	60-63
6. AND MODE	Perform a Logical AND between the display byte in the Serial Register and the RAM contents addressed by Data Pointer; write result to same RAM location; modify Data Pointer	0	1	1	0	1	1	D_1	D_0	6C-6F
7. OR MODE	Perform a Logical OR between the display byte in the Serial Register and the RAM contents addressed by Data Pointer; write Result to same RAM location; modify Data Pointer	0	1	1	0	1	0	D_1	D_0	68-6B
8. CHARACTER MODE	Decode display byte in Serial Register into 5 x 7 character with Character Generator; write character to RAM location addressed by Data Pointer; increment Data Pointer by 5	0	1	1	1	0	0	1	0	72
9. SET BIT	Set single bit of RAM location addressed by Data Pointer; modify Data Pointer	0	1	0	D_4	D_3	D_2	D_1	D_0	40-5F
10. RESET BIT	Reset single bit of RAM location addressed by Data Pointer; modify Data Pointer	0	0	1	D_4	D_3	D_2	D_1	D_0	20-3F
11. ENABLE DISPLAY	Turn on the LCD	0	0	0	0	1	0	0	1	09
12. DISABLE DISPLAY	Turn off the LCD	0	0	0	0	1	0	0	0	08

ELECTRICAL SPECS

Absolute Maximum Ratings*

$T_a = 25°C$

Power supply	−0.3V to + 7.0V
All inputs and outputs with respect to V_{SS}	−0.3V to V_{DD}+0.3
Storage temperature	−65°C to +150°C
Operating temperature	−10°C to +70°C

*Comment: Exposing the device to stresses above those listend in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections this specification. Exposure to absolute maximum rating conditions for extended periods amy affect device reliability.

DC Characteristics

T_a = −10°C to +70°C, V_{DD} = +5.0V ± 10%

Parameter	Symbol	Limits MIN	TYP	MAX	Units	Conditions
Input Voltage High	V_{IH}	0.7 V_{DD}		V_{DD}	V	SI, $\overline{SCK}$, C/$\overline{D}$, $\overline{CS}$, $\overline{SYNC}$, RESET
Input Voltage Low	V_{IL}	0		0.3 V_{DD}	V	SI, $\overline{SCK}$, C/$\overline{D}$, $\overline{CS}$, $\overline{SYNC}$, RESET
Clock Voltage High	$V_{\phi H}$	0.7 V_{DD}		V_{DD}	V	Clock, External Clock
Clock Voltage Low	$V_{\phi L}$	0		0.3 V_{DD}	V	Clock, External Clock
Input Leakage Current High	I_{LIH}			10	μA	SI, $\overline{SCK}$, C/$\overline{D}$, $\overline{CS}$, RESET V_{IH} = V_{DD}
Input Leakage Current Low	I_{LIL}			−10	μA	SI, SCK, C/D, CS, RESET V_{IH} = 0V
Output Current High	I_{OH}		−2.0		mA	SO/$\overline{BUSY}$, SYNC, V_{OH} = V_{DD} − 0.5V
Output Current Low	I_{OL}		+3.5		mA	SO/$\overline{BUSY}$, V_{OL} = 0.5V
LCD Operating Voltage	V_{LCD}	3.0		V_{DD}	V	8-Row Multiplexed LCD Drive Configuration
			V_{DD}			16-Row Multiplexed LCD Drive Configuration
Supply Current	I_{DD}		100	250	μA	No Load

DC Characteristics for LCD

Parameter	Symbol	Limits MIN	TYP	MAX	Units	Conditions
Row Drive Output Impedance	R_{ROW}		4		KΩ	$R_{0/8}$ – $R_{7/15}$ 8-Row Multiplexed LCD Drive Configuration, $3.0 \le V_{LCD} \le V_{DD}$; 16-Row Multiplexed LCD Drive Configuration, $V_{SS} = V_{DD} - V_{LCD}$
Column	R_{COLUMN}		12		KΩ	C_0-C_{39} 8-Row Multiplexed LCD Drive Configuration, $3.0 \le V_{LCD} \le V_{DD}$; 16-Row Multiplexed LCD Drive Configuration $V_{SS} = V_{DD} - V_{LCD}$

AC Characteristics

T_a = −10°C to +70°C, V_{DD} = +5.0V ±10%

Parameter	Symbol	Limits MIN	TYP	MAX	Units	Conditions
Clock Frequency	f_ϕ	100	400	1000	kHz	
Clock Pulse Width High	$t_{\phi W_H}$	400			ns	External Clock
Clock Pulse Width Low	$t_{\phi W_L}$	400			μs	External Clock
$\overline{SCK}$ Cycle	t_{CY_K}	1			μs	
$\overline{SCK}$ Pulse Width High	t_{KW_H}	400			ns	
$\overline{SCK}$ Pulse Width Low	t_{KW_L}	400			ns	
$\overline{SCK}$ Hold Time	t_{KH}	0			ns	After BUSY↑
SI Setup Time	t_{IS}	300			ns	To $\overline{SCK}$↑
SI Hold Time	t_{IH}	250			ns	After $\overline{SCK}$↑
$\overline{BUSY}$ Delay Time	t_{BD_C}			2	μs	After $\overline{CS}$↓
	t_{BD_D}			2	μs	After C/$\overline{D}$↑
	t_{BD_K}			3	μs	After 8th $\overline{SCK}$↑
	t_{OD_D}			2	μs	After C/$\overline{D}$↓
	t_{OD_K}		260		ns	After $\overline{SCK}$↓
C/$\overline{D}$ Setup Time	t_{DS}	2			μs	To 8th $\overline{SCK}$↑
C/$\overline{D}$ Hold Time	t_{DH}	2			μs	After 8th $\overline{SCK}$↑
$\overline{CS}$ Hold Time	t_{CH}	2			μs	After 8th $\overline{SCK}$↑
$\overline{CS}$ Pulse Width High	t_{CW_H}	1			μs	
$\overline{CS}$ Pulse Width Low	t_{CW_L}	1			μs	

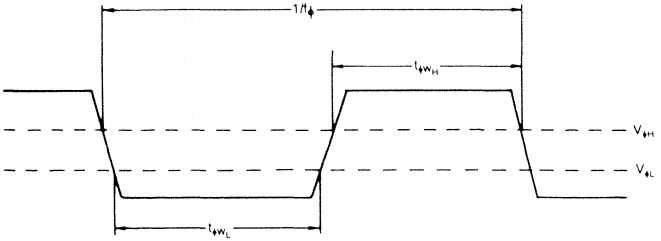
C_{LOAD} = 50 pF

Capacitance

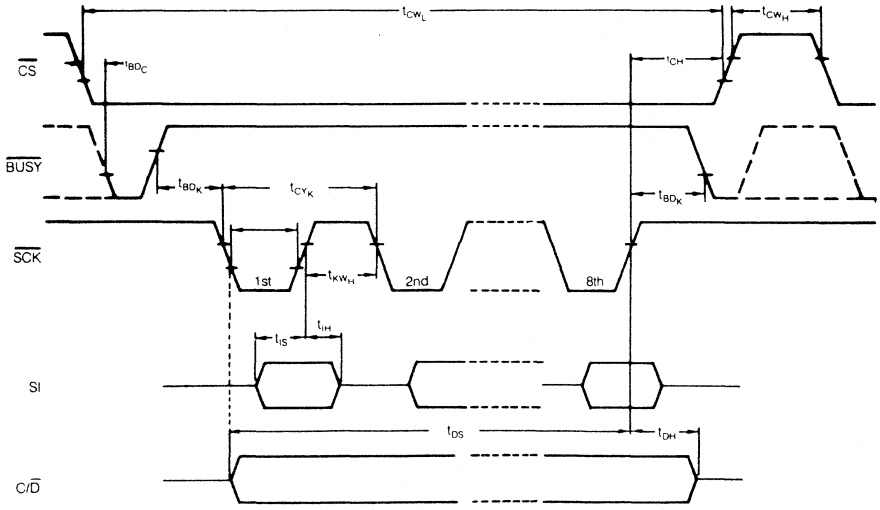
T_a = 25°C

Parameter	Symbol	Limits MIN	TYP	MAX	Units	Conditions
Input Capacitance	C_I			10	pF	SI, $\overline{SCK}$, C/$\overline{D}$, $\overline{CS}$, $\overline{RESET}$
Output Capacitance	C_O			25	pF	SO/$\overline{BUSY}$, $R_{0/8}$-$R_{7/15}$, C_0-C_{39}
Input/Output Capacitance	C_{IO}			20	pF	SYNC
Load Capacitance	C_{LOAD}			100	pF	SYNC
Clock Capacitance	C_{CLOCK}			10	pF	Clock Input

Clock Waveform



Serial Interface Timing Waveforms



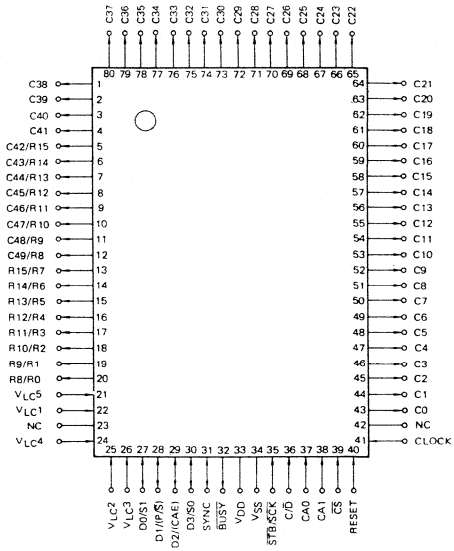
MOS DIGITAL INTEGRATED CIRCUIT
μPD7228G

The μPD7228 is a programmable LCD controller/driver containing all the circuitry necessary for interfacing a microprocessor to LCD of 8-line multiplexing or 16-line multiplexing dot matrix configuration. The μPD7228 is able to drive the dot matrix LCD of up to 50 columns by 8-line multiplexing and up to 42 columns by 16-line multiplexing in the single chip configuration. When more than two chips are used in combination, large pattern LCD drive can easily be made. The μPD7228 contains a 5 x 7 dot matrix character generator conforming to ASCII/JIS so that alphanumerics and "kana" can easily be displayed. As an interface with the microprocessor, serial or 4 bit parallel interface can be selected and used.

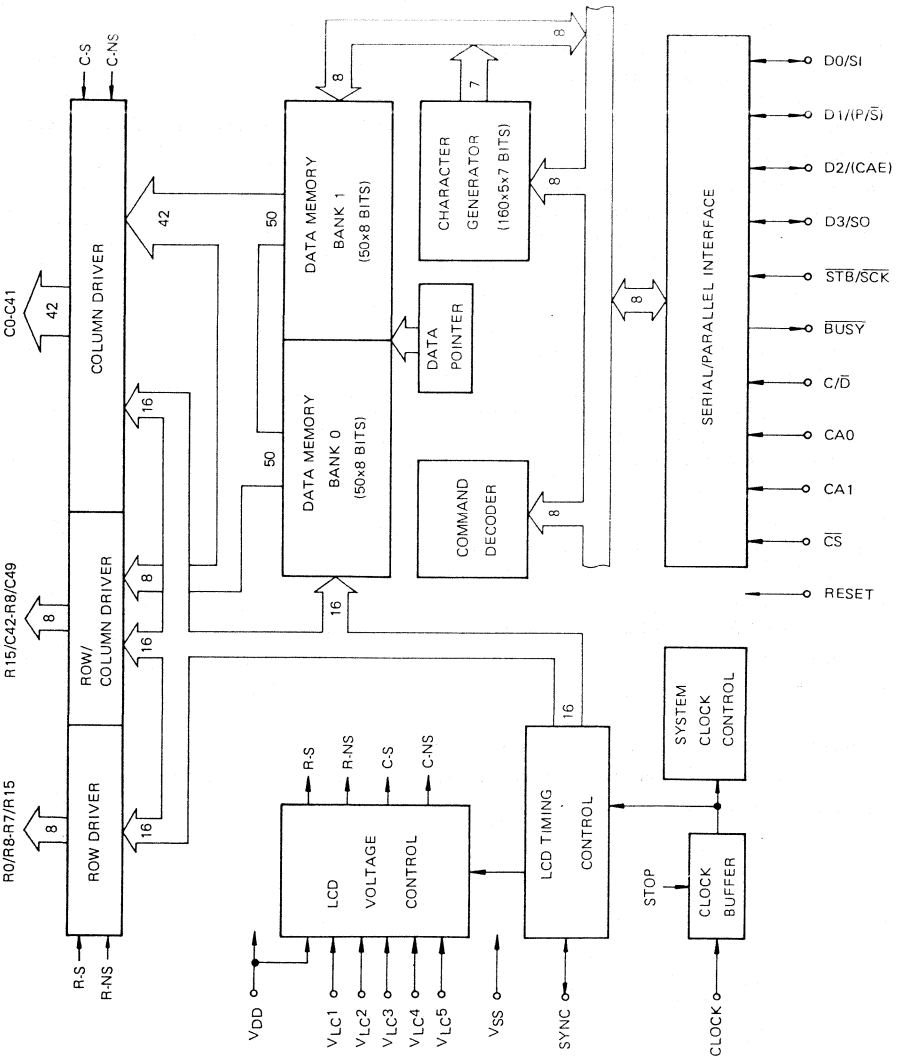
FEATURES

- LCD direct drive.
- 8-line or 16-line multiplexing drive possible with single chip.
  - 8-line multiplexing — 400 (50 x 8) dots
  - 16-line multiplexing — 672 (42 x 16) dots
- 8-line or 16-line multiplexing drive with n chip configuration
  - 8-line multiplexing — n x 400 (n x 50 x 8) dots
  - 16-line multiplexing — n x 800 (n x 50 x 16) dots
- RAM — 2 x 50 x 8 bits for display data storage
- Programmable dot (graphics) display
- 5 x 7 dot matrix display by on-chip character generator
  - ASCII characters (alphanumerics, others) — 64 characters
  - JIS characters (kana and others) — 96 characters
- Cursor operating command
- 8-bit serial interface
  - Compatible with μPD7500, μCOM-43N, μCOM-87/87LC Series
- 4-bit parallel interface
  - Compatible with μPD7500, μCOM-84/84C Series
- Standby function
- CMOS Technology
- Single power supply
- μPD7228A for LCD voltage up to 12.5V for enhanced contrast
- μPD7229 is available for a customized character set eg to get the European non ASCII characters.
- 80 pin plastic flat package

PIN CONNECTION (Top View)



μPD7228 BLOCK DIAGRAM



1. PIN FUNCTIONS

1.1 D0-D3 (DATA BUS) . . . 3 STATE INPUT AND OUTPUT

The data bus serves as an input/output pin for 4 bit parallel data in the parallel interface mode.

Data on D0-D3 lines is read at the rising edge of the $\overline{STB}$ signal, and the 4 bit data read in the 1st $\overline{STB}$ is loaded in the high-order 4 bits of the serial/parallel register, and the 2nd data is loaded in the low-order 4 bits.

The contents of serial/parallel register are output to D0-D3 pins synchronizing with the falling edge of the $\overline{STB}$ signal. Just as in the case of read operation, the high-order 4 bits correspond to the 1st $\overline{STB}$, and the low-order 4 bits to the 2nd $\overline{STB}$.

In the serial interface mode, D0 serves as a serial data input pin (SI), and D3 as a serial data output pin (SO).

Also, D1 operates as a parallel/serial interface mode selection pin (P/$\overline{S}$), and D2 as a chip address enable pin (CAE).

1.2 SI (SERIAL DATA IN) . . . INPUT COMMON TO D0

In the serial interface mode, SI operates as an input pin of serial data. Data on SI line is loaded in the serial/parallel register at the rising edge of $\overline{SCK}$.

The first data becomes MSB. To preclude the possibility of error operations due to noise, the Schmitt trigger input having hysteresis is employed.

1.3 SO (SERIAL DATA OUT) . . . OUTPUT COMMON TO D3

In the serial interface mode, SO operates as an output pin of serial data. The contents of serial/parallel register are output to SO pin sequentially as from MSB in synchronization with the falling edge of $\overline{SCK}$.

1.4 P/$\overline{S}$ (PARALLEL/SERIAL SELECT) . . . INPUT COMMON TO D1

If this input is high at the falling edge of the RESET signal (at the time of reset release), the parallel interface mode is set, and if it is low at the falling edge of the reset signal, the serial interface mode is set. The Schmitt trigger input design having hysteresis is employed to prevent error operations from being made due to noise.

1.5 CAE (CHIP ADDRESS ENABLE) . . . INPUT COMMON TO D2

CAE input is valid when P/$\overline{S}$ input is low (serial interface mode) at the falling edge of the RESET signal, and if CAE input is high at the falling edge of RESET signal, the serial interface mode with the chip address function is set. Also, it is without the chip address function when CAE input is low. The Schmitt trigger input design with hysteresis is employed to prevent error operations from being caused by noise.

1.6 CA0, 1 (CHIP ADDRESS) . . . INPUT

These are input pins for addressing for selection of each individual μPD7228 in multi-chip configuration. CA0, 1 inputs are not related to CAE input in the parallel interface mode, and these inputs are compared with chip address data sent from the CPU.

In the serial interface mode, however, these are compared with the chip address data when the chip address selection function is enabled by CAE input.

Table 1-1 Specification of CA1 and CA0

MODE	SPECIFICATION
With Chip Address Function	
* In Parallel	CA1, CA0 = 00, 01, 10, or 11
* In Serial, CAE = 1	(In Single-chip Configuration, CA1, CA0 = 00 only)
Without Chip Address Function	
* In Serial, CAE = 0	CA1, CA0 = 00 (always)

Note 1 : In the case of multi-chip configuration in the seiral interface mode, if a proper decoded $\overline{CS}$ signal is supplied to each chip, the chip address information is not needed.
In this case, CAE of every chip should be set to 0, and every CA1, 0 should be set to 00.

The CA0 and CA1 are composed of Schmitt trigger inputs to prevent error operations by noise.

1.7 $\overline{CS}$ (CHIP SELECT) . . . INPUT

This is a low-active chip select input pin.

When the chip address selection function is not in use, $\overline{STB}/\overline{SCK}$ input and C/$\overline{D}$ input are enabled if a low level is input into $\overline{CS}$ input, thereby making the input of command and input/output of data possible.

When using the chip address select function, if $\overline{CS}$ is brought low and that chip address data matches CA0, 1 inputs, then $\overline{STB}/\overline{SCK}$ and C/$\overline{D}$ input are to be enabled.

When $\overline{CS}$ input is made high, D3—D0 and $\overline{BUSY}$ pins are unconditionally placed into a high impedance state. The Schmitt trigger input design having hysteresis is employed to prevent error operations from being caused by noise.

1.8 $\overline{STB}/\overline{SCK}$ (STROBE/SERIAL CLOCK) . . . INPUT

In the parallel interface mode, this is the strobe signal input pin ($\overline{STB}$) for 4 bit parallel data inptu and output. In the serial interface mode, this is the serial clock input pin ($\overline{SCK}$) for serial data input and output.

1.9 C/$\overline{D}$ (COMMAND/DATA) . . . INPUT

This is a pin to specify whether parallel or serial input is a command or data. When a command is to be input, C/$\overline{D}$ input has to be brought high, but when data is to be input, C/$\overline{D}$ has to be made low.

In the case of command or data input, the contents of C/$\overline{D}$ input are latched at the rising edge of the 2nd $\overline{STB}$ in the parallel interface mode, but these are latched at the rising edge of the 8th $\overline{SCK}$ in the serial interface mode.

In the parallel input, however, change of C/$\overline{D}$ input should be performed prior to the falling edge of 1st $\overline{STB}$.

In addition, in the data output, C/$\overline{D}$ input should be held low, whichever it is serial or parallel.

The Schmitt trigger input design with hysteresis is employed to prevent error operations from being operated by noise.

1.10 $\overline{BUSY}$ (BUSY) . . . 3-STATE OUTPUT

This is a pin for outputting the $\overline{BUSY}$ signal warning the CPU a busy state during internal process of the μPD7228.

When this signal is low, the CPU can not make read/write operation to the μPD7228 because this chip is in a busy state.

In the parallel interface mode, the $\overline{BUSY}$ signal is forced low at the rising edge of the 2nd $\overline{STB}$.

In the serial interface mode, it is forced low at the rising edge of the 8th $\overline{SCK}$.

In case of deselected chip ($\overline{CS}$ = high or chip address mismatch), the $\overline{BUSY}$ output is placed in a high impedance state.

1.11 SYNC (SYNCHRONOUS) . . . 3-STATE INPUT/OUTPUT

This is an input/output pin for synchronous signal to match the phase of LCD-drive AC signal (Row/Column signal) of all μPD7228 with the frame period in case of multi-chip configuration using a Row drive signal as a common signal.

With oen of chips as a master, the SYNC pin of the master chip is placed in the output mode, and the remaining chips are all made slave chips. In this case, the SYNC pins of these chips are placed in the input mode.

Designation of either input or output is made by the SMM command.

The master chip designated for the output mode outputs a SYNC pulse in the last cycle of each frame. The slave chip reads the SYNC pulse from the SYNC input for synchronization with the master chip.

The output timing for the SYNC pulse in case of the 8-multiplexing or 16-multiplexing is shown in Fig. 1-1 and Fig. 1-2.

In case of single chip configuration, the SYNC pin may be set in either the input mode or output mode. However, if the input mode is set, the SYNC pin must be connected to V_{SS}. On the other hand, if the output mode is set, the SYNC pin must be open.

Fig. 1-1 SYNC SIGNAL BASED ON 8-LINE MULTIPLEXING

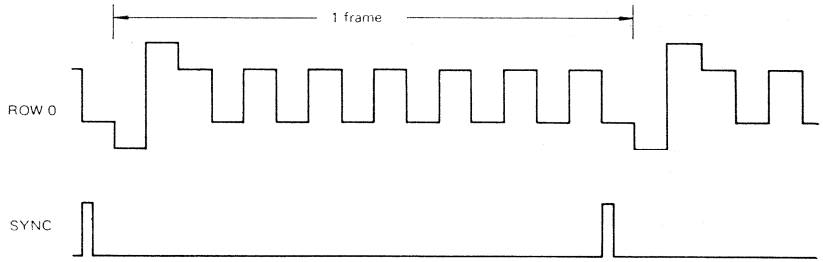
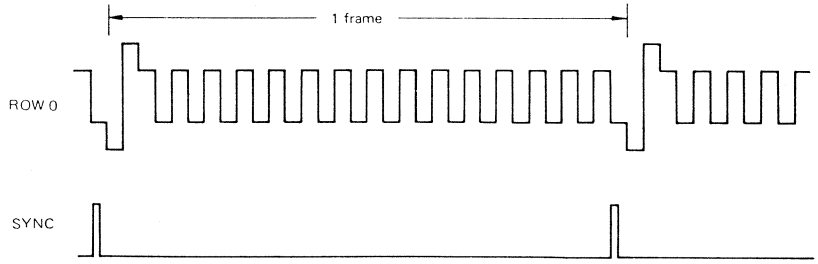


Fig. 1-2 SYNC SIGNAL BASED ON 16-LINE MULTIPLEXING



1.12 C0–C41 (COLUMN) . . . OUTPUT

These are output pins for the column drive signal of the LCD.

1.13 R8/C49 – R15/C42 (ROW/COLUMN) . . . OUTPUT

These are output pins for Row drive signals R8–R15 of the LCD or for column drive signals C49–C42. The output pins operate as Row drive signals or column drive signals depending upon the SMM command.

1.14 R0/R8 – R7/R15 (ROW) . . . OUTPUT

These are output pins for Row drive signals R0–R7 or R8–R15 of the LCD. The output pins operate as an either drive signal, depending upon the SMM command.

1.15 V_{LC1} – V_{LC5} (LCD DRIVE VOLTAGE SUPPLY) . . . INPUT

This is a reference voltage input pin for determining the voltage level of the Row/column drive signal of the LCD.

1.16 CLOCK (CLOCK) . . . INPUT

This is an external clock input pin.

1.17 RESET (RESET) . . . INPUT

This is a high-active reset signal input pin. It has priority over all the operations. It can also be used for release of the stand-by mode and for the low power data retention.

1.18 V_{DD}

This is a positive power supply pin to V_{SS} for circuits.

1.19 V_{SS}

This is a GND potential for circuits.

2. FUNCTIONAL DESCRIPTION

2.1 SERIAL/PARALLEL INTERFACE

This circuit is provided with the functions of serial and parallel interfaces. It operates as an either function depending upon whether P/S input is high (parallel interface) or low (serial interface) at the falling edge of the RESET signal.

The write operation of command/data from the CPU, and the output of data to the CPU, are all done via this interface.

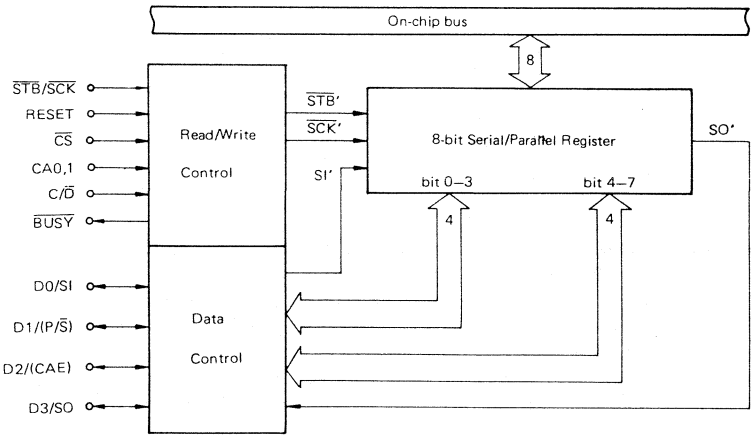
The operation of serial/parallel interface depends on a data processing mode. The data processing mode is initialized to the write mode by RESET input, to make command input possible. Thereafter, it is set to the data processing mode for the write group (Write, AND, OR, Character mode) or that for the read mode by the command setting a data processing mode.

When the write group is set as the data processing mode, the serial/parallel interface becomes the data input mode and takes data from the SI pin (serial data) or the D3—D0 pins (4-bit parallel data) in synchronization with the rising edge of $\overline{SCK}$ or $\overline{STB}$.

Also, when the read mode is set, it becomes the data output mode and then outputs data from either the SO pin (serial data) or the D3—D0 pins (parallel data) in synchronization with the falling edge of $\overline{SCK}$ or $\overline{STB}$.

The serial/parallel register operates as a buffer either between the 8-bit parallel data of data memory and the 8-bit serial data to be transferred via a serial input/output line (SI, SO) or between the 8-bit parallel data of data memory and 2x4-bit parallel data to be transferred via parallel input/output lines (D3—D0).

Fig. 2-1 SERIAL/PARALLEL INTERFACE



The data input into the serial/parallel register via the serial/parallel interface is sent to the command decoder if the designation by C/$\overline{D}$ is a command, and is decoded. But if it is a data designation, the data loaded in the serial/parallel register is stored in the data memory in the write mode, or the data and the contents of the data memory addressed by the data pointer are ANDed or ORed in the AND or OR mode, and the result is stored in the data memory.

In the character mode, if the designation by C/$\overline{D}$ is a data, the data loaded in the serial/parallel register is regarded as either ASCII or JIS code, and is sent to the character generator for decoding into the character display pattern of 5x7 bit configuration, after that it is stored in 5 consecutive addresses of the data memory.

Only when the μPD7228 is set in the read mode, it performs data output operation. But if it is set in read mode, the μPD7228 always reads 8-bit data from the data memory in preparation for the next read cycle and keeps data in the serial/parallel register.

In the serial interface mode, the serial/parallel register data is output from SO pin sequentially as from MSB at the falling edge of $\overline{SCK}$.

In the parallel interface mode, high-order 4 bits fo the serial/parallel register are output at the falling edge of the 1st $\overline{STB}$, and the lower-order 4 bits of the serial/parallel register at the falling edge of the 2nd $\overline{STB}$. These data are output from D3–D0 pins.

In both serial and parallel interface mode, after 8-bit data is output, next 8-bit data is automatically read out from the data memory and is set in the serial/parallel register.

2.2 COMMAND DECODER

If the 8-bit data input via serial/parallel interface is the command designation (C/$\overline{D}$=1), the data is taken in as a command and decoded to generate an internal control signal.

2.3 CHARACTER GENERATOR

The character generator is enabled when the mode setting commands (SCML, SCMR) are executed to interpret 8-bit data to be written via serial/parallel interface as ASCII code (alphanumerics and symbols) or JIS code (kana and symbols), and generate the corresponding 5x7 dot matrix pattern for transfer to five continuous addresses (7 bits x 5 times) of data memory.

The character generator contains 160 types of pattern data indicated below.

ASCII		JIS	
Capital letters	26	Kana	55
Small letters	26	Symbols	9
Numerics	10		
Symbols	34		

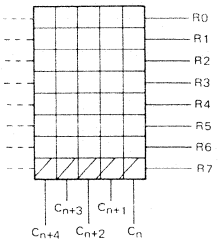
Character (ASCII/JIS) codes and the corresponding 5x7 dot display patterns are shown in Fig. 2-3. 96 codes of 20H–7FH correspond to ASCII, and 64 codes of A0H–DFH correspond to JIS.

The LCD configuration using a character generator is shown in Fig. 2-2. The character is 5x7 dot type, and the most significant bit (bit 7) of data memory is not used by the character generator. So, the dot of LCD corresponding to the most significant bit (R7 in case of 8-line multiplexing, or R7 and R15 in case of 16-line multiplexing) can be used as a display pattern of the cursor or indicator independently of character generator.

Operation of the most significant bit is done by the cursor operating command (WRCURS and CLCURS) and so on.

Fig. 2-2 LCD STRUCTURE IN CASE OF CHARACTER GENERATOR USE

(a) 8-Line Multiplexing



(b) 16-Line Multiplexing

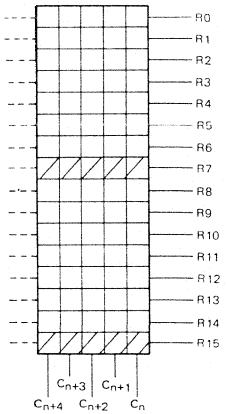
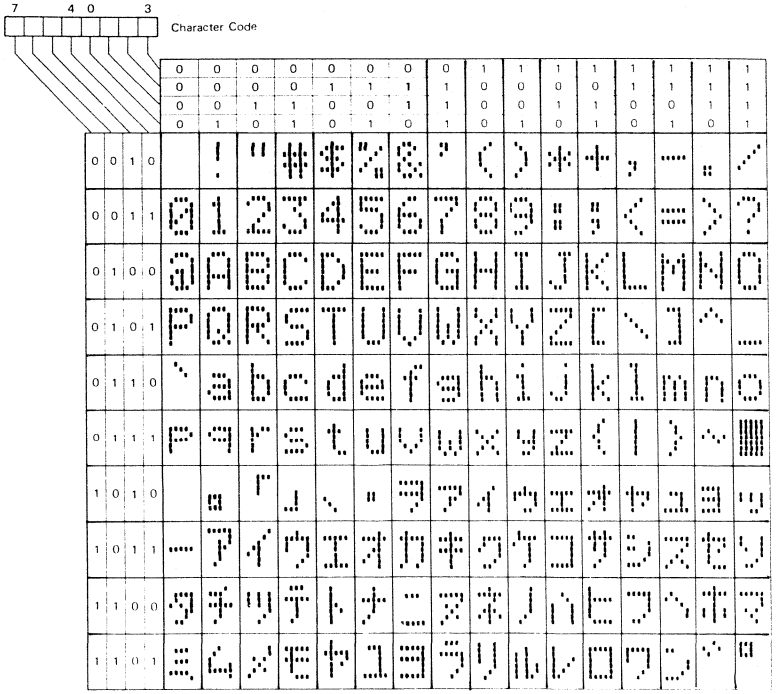


Fig. 2-3 CHARACTER CODES AND DISPLAY PATTERNS



3. DATA INPUT AND OUTPUT OPERATIONS

In the μPD7228, command/data consists of one byte (8 bits) length, and the process is made at the end of data transfer of one byte data in both serial and parallel interface modes.

The byte counter (octal/binary counter) checks an end of byte-data transfer by counting 8 $\overline{SCK}$ or 2 $\overline{STB}$ pulses. This counter is unconditionally cleared either when $\overline{CS}$ = high or when RESET = high.

Accordingly, if either $\overline{CS}$ or RESET signal is high during a byte-data transfer, the byte-data transfer will not be achieved.

In the serial interface mode, the process is made an 8-bit serial data, and when eight pulses of serial clocks ($\overline{SCK}$) are input in the chip selection state, the internal process is initiated as this is considered as the end of input or output of one byte data. In so doing, the $\overline{BUSY}$ signal is brought low at the rising edge of the 8th $\overline{SCK}$, thereby warning the CPU the busy state. When the internal process ends, the $\overline{BUSY}$ signal is made high, to indicate to the CPU that the transfer of the next byte can now be made possible.

Serial data are input or output sequentially as from MSB. (See Fig. 3-1, Fig. 3-2)

In the serial interface mode with the chip addressing function, after $\overline{CS}$ has fallen, first of all, 8-bit serial data for chip addressing should be written (the lower-order 2 bits are latched as chip address data).

And then the addressed chip can perform the command input or data I/O operation.

In the parallel interface mode, data is processed as parallel data of 4 bits x 2 for data bus is 4-bit configuration, and when two pulses of parallel data strobe signal ($\overline{STB}$) are input in the chip selection state, the internal process is made with it as being the end of data input or output.

In so doing, the $\overline{BUSY}$ signal is made low at the rising edge of the 2nd $\overline{STB}$, to indicate to the CPU the $\overline{BUSY}$ state.

When the internal process ends, the $\overline{BUSY}$ signal is forced high to indicate to the CPU that the transfer of the next byte can now be made possible.

The parallel data of both input and output corresponds to high-order 4 bits of the 1st $\overline{STB}$ and the low-order 4 bits of the 2nd $\overline{STB}$, respectively.

The parallel interface of μPD7228 is compatible with the 8243 I/O expander, and parallel data input to μPD7228 can be performed by the way that 4-bit data is output to the 8243 two times.

Also, 8-bit data of μPD7228 is read in 4 bits x 2 times by following the procedure in which data read of the 8243 is made twice consecutively.

In the parallel interface mode, the chip addressing function is always used.

After $\overline{CS}$ has fallen, the data on the D1 and D0 lines is read out at the first falling edge of $\overline{STB}$, and this data is used for chip addressing.

The chip addressing data is the lower-order 2 bits of the command code, which is output from the CPU for selection of the 8243's ports 4–7.

After $\overline{CS}$ has fallen, the command code which is output at the falling edge of the 2nd $\overline{STB}$ and after is invalid. (See Fig. 3–3, 3–4)

Fig. 3-1 SERIAL INPUT TIMING (WITHOUT CHIP ADDRESS SECTION FUNCTION)

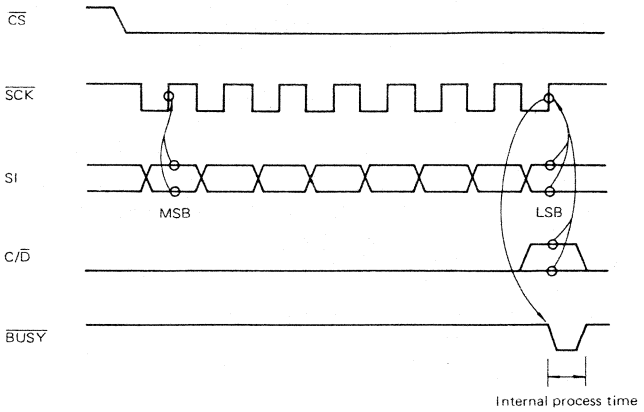


Fig. 3-2 SERIAL OUTPUT TIMING

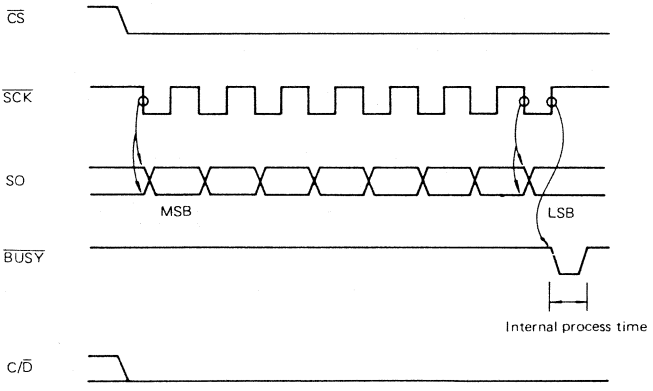


Fig. 3-3 PARALLEL INPUT TIMING

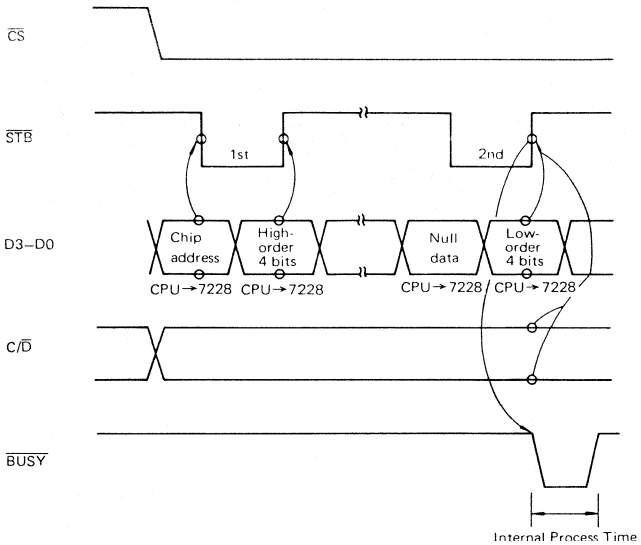
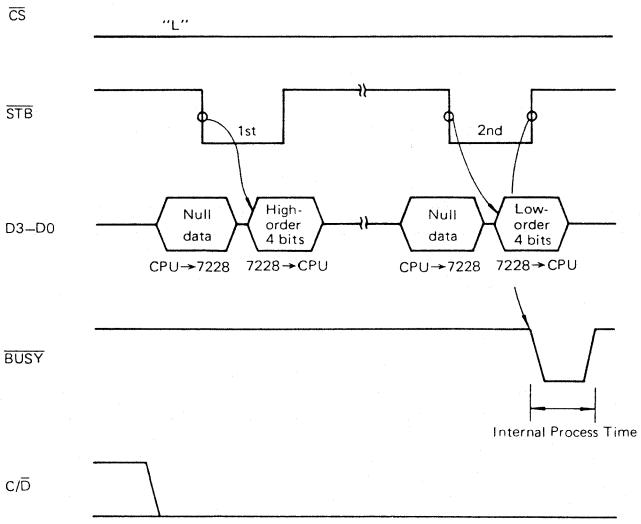


Fig. 3-4 PARALLEL OUTPUT TIMING



4. SELECTION OF INTERFACE BETWEEN μPD7228 AND CPU

Data length of the command/data of μPD7228 are 8 bits, however the μPD7228 is interfaced with the CPU in 8-bit serial or 4-bit parallel x2 configuration. Also, the μPD7228 is provided with the chip address selection function for multi-chip configuration purposes.

Designation of as to whether serial or parallel interface, and that of as to whether the chip address selection function is to be used or not, depends upon the data sent over D2/(CAE), D1/(P/$\overline{S}$) at the release timing (falling edge) of the RESET signal of the μPD7228.

Fig. 4-1 INTERFACE DESIGNATION TIMING

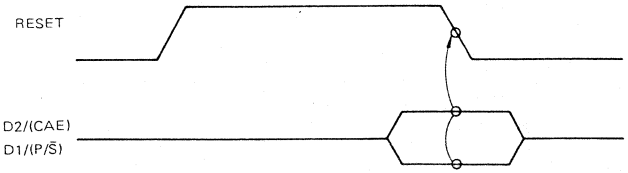


Table 4-1 INTERFACE DESIGNATION CODE

D2/(CAE)	D1/(P/$\overline{S}$)	Serial/Parallel Designation	Chip Address Selection Function
0	0	Serial	Not provided
1	0		Provided
0/1	1	Parallel	

4.1 FUNCTION OF COMMON PINS

The function of common pins $\overline{STB}$/$\overline{SCK}$, D3/S0, D0/SI used for clock input and data input/output varies as shown in Table 4-2, depending upon whether the serial interface or parallel interface is designated.

Table 4-2 FUNCTION OF COMMON PINS

Pin Name	Serial (P/$\overline{S}$=0)	Parallel (P/$\overline{S}$=1)
$\overline{STB}$/$\overline{SCK}$	$\overline{SCK}$ input	$\overline{STB}$ input
D3/S0	S0 output	D3—D0 input and output (4-bit parallel data bus)
D2/(CAE)	—	
D1/(P/$\overline{S}$)	—	
D0/SI	SI input	

4.2 CHIP ADDRESS SLECTION FUNCTION

The chip address selection function compares the chip address assigned (by CA0, CA1 input) to each μPD7228 chip with chip address data (2 bits) sent from the CPU side in the serial or parallel data format and selects only the matched chips (this makes input and output of command/data possible). This function eliminates the need for sending a plurality of chip select signals ($\overline{CS}$) from the CPU side when employing multi-chip configuration.

Parallel interface mode is unconditionally with chip address selection function, but serial interface mode is with chip address selection function only D2/(CAE)=1 at the release timing of the RESET signal of the μPD7228G.

(1) **Parallel Interface** (See Fig. 3-5, 3-6)

After falling edge of $\overline{CS}$, data to be read in D1 (corresponding to CA1) and D0 (corresponding to CA0) at the first falling edge of $\overline{STB}$ becomes 2-bit chip address data.

In actuality, parallel interface is similar to that for the 8243 I/O Expander, connection should be made with the μPD7228 by using the 8243 interface function such as in the μPD7500 or μPD80C48, and the output instruction is executed for ports 4–7 of the 8243. In so doing, it is possible to obtain chip address data (0–3) of the μPD7228 at the falling edge of $\overline{STB}$ on D1, D0.

(2) **Serial Interface** (See Fig. 3-3, 3-4)

After falling edge of $\overline{CS}$, data read in SI by 7th pulse of $\overline{SCK}$ (corresponding to CA1) and 8th pulse there of (corresponding to CA0), that is, the low-order 2 bits of the first 8-bit serial data, becomes the 2-bit chip address data.

Note: In multi-chip configuration, the internal chip-address-comparison data is cleared to 00 by RESET input. Accordingly, if $\overline{CS}$ is made low just after release of RESET input, $\overline{BUSY}$ = high is output by the chip of CA1, 0 = 00, in order to inform the CPU that the μPD7228s are ready to be accessed.
And the CPU starts to access the μPD7228s by detecting $\overline{BUSY}$ = high.
However, the first chip to be accessed is determined by the chip address information (i.e., the chip of CA1, 0 = 00 is not always necessary to be accessed first.).
In the multi-chip system using the parallel interface, just after $\overline{CS}$ signal has been made low, if a read operation is wanted to perform for the chip that is specified in the read mode, the data pointer load command should be executed before the read operation. (i.e., the read operation must not be done during the first a couple of $\overline{STB}$ signals just after $\overline{CS}$ signal has been made low.)

5. SUPPLY OF LCD DRIVE REFERENCE VOLTAGE

The value of LCD drive reference voltage to μPD7228 differs depending upon the number of multiplexings – 8-line multiplexng or 16-line multiplexing. These are shown in Fig. 5-1 and Fig. 5-2.

Fig. 5-1 8-LINE MULTIPLEXING

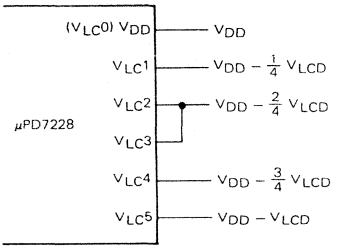
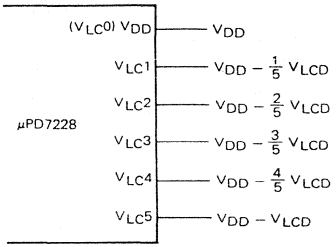


Fig. 5-2 16-LINE MULTIPLEXING



Note: LCD drive voltage (V_{LCD}) should be below V_{DD} ($V_{LCD} \leq V_{DD}$) in both cases of 8-Line multiplexing and 16-line multiplexing.

5.1 SUPPLY OF LCD DRIVE REFERENCE VOLTAGE BY RESISTOR DIVISION

An example of circuit for supplying the LCD drive reference voltage shown in Fig. 5-1 and Fig. 5-2 with the potential between $V_{DD} - V_{SS}$ divided by resistors is shown in Fig. 5-3 and Fig. 5-4.

Fig. 5-3 8-LINE MULTIPLEXING

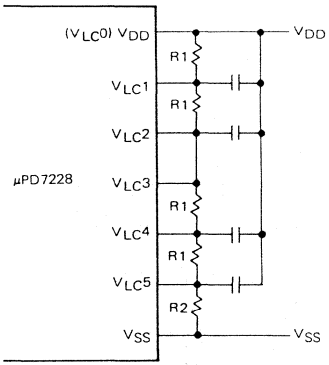
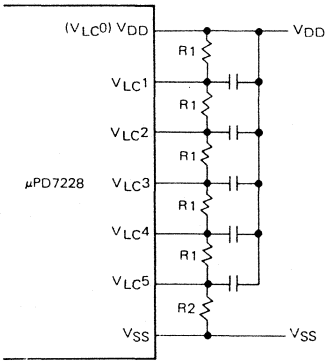


Fig. 5-4 16-LINE MULTIPLEXING



The values of dividing resistors R1, R2 in case of 8-line multiplexing and 16-line multiplexing are determined by the equation below.

$$R1 = \frac{V_{LCD}}{4\,(V_{DD}-V_{LCD})} \times R2 \quad : \text{8-line multiplexing}$$

$$R1 = \frac{V_{LCD}}{5\,(V_{DD}-V_{LCD})} \times R2 \quad : \text{16-line multiplexing}$$

The μPD7228A can drive LCD voltages up to 12.5V. In this case V_{SS} becomes −7.5V.

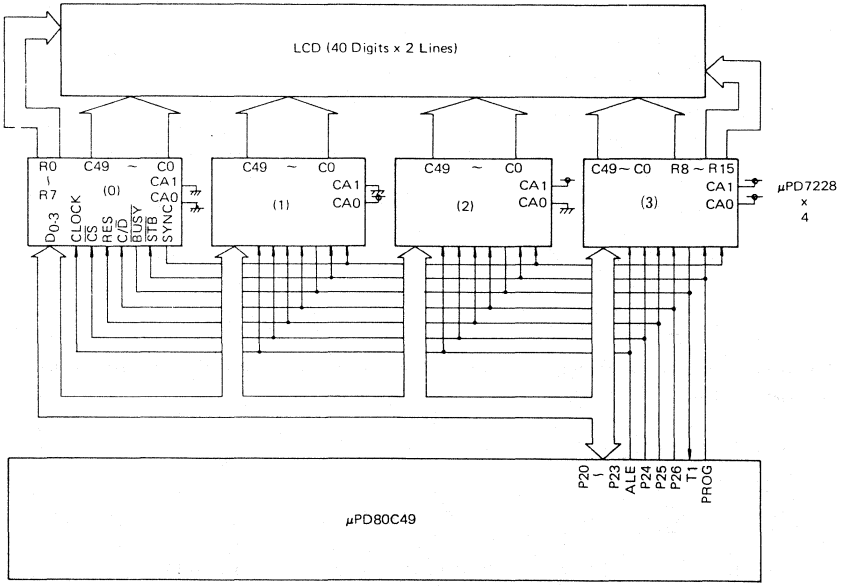
COMMANDS OF μPD7228

The μPD7228 is provided with sixteen types of commands, each command consisting of one byte (8 bits).

LIST OF COMMANDS

Mnemonic	Operation	Hexadecimal Code
SFF	Set Frame Frequency	10 – 14
SMM	Set Multiplexing Mode	18 – 1F
DISP OFF	Display Off	08
DISP ON	Display On	09
LDPI	Load Data Pointer with Immediate	80 – B1 C0 – F1
SRM	Set Read Mode	60 – 63
SWM	Set Write Mode	64 – 67
SORM	Set OR Mode	68 – 6B
SANDM	Set AND Mode	6C – 6F
SCML	Set Character Mode with Left entry	71
SCMR	Set Character Mode with Right entry	72
BRESET	Bit Reset	20 – 3F
BSET	Bit Set	40 – 5F
CLCURS	Clear Cursor	7C
WRCURS	Write Cursor	7D
STOP	Set Stop Mode	01

TYPICAL SYSTEM CONFIGURATION (REFERENCE ONLY)



ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Supply Voltage	V_{DD}	−0.3 to +7.0	V
Input Voltage	V_I	−0.3 to V_{DD}+0.3	V
Output Voltage	V_O	−0.3 to V_{DD}+0.3	V
Operating Temperature	T_{opt}	−10 to +70	°C
Storage Temperature	T_{stg}	−65 to +150	°C

DC CHARACTERISTICS (Ta = −10 to +70 °C, V_{DD} = +5 V ±10 %)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Input Voltage High	V_{IH1}	0.7 V_{DD}		V_{DD}	V	Except $\overline{SCK}$
	V_{IH2}	0.8 V_{DD}		V_{DD}	V	$\overline{SCK}$
Input Voltage Low	V_{IL}	0		0.3 V_{DD}	V	
Input Leakage Current High	I_{LIH}			10	μA	V_I=V_{DD}
Input Leakage Current Low	I_{LIL}			−10	μA	V_I=0 V
Output Voltage High	V_{OH1}	V_{DD}−0.5			V	$\overline{BUSY}$, D0−D3, I_{OH}=−400 μA
	V_{OH2}	V_{DD}−0.5			V	SYNC, I_{OH}=−100 μA
Output Voltage Low	V_{OL1}			0.45	V	$\overline{BUSY}$, D0−D3, I_{OL}=1.7 mA
	V_{OL2}			0.45	V	SYNC, I_{OL}=100 μA
Output Leakage Current High	I_{LOH}			10	μA	V_O=V_{DD}
Output Leakage Current Low	I_{LOL}			−10	μA	V_I=0 V
LCD Operating Voltage	V_{LCD}	3.0		V_{DD}	V	
Row Output Impedance	R_{ROW}		4	8	kΩ	
Row/Column Output Impedance	$R_{ROW/COL}$		5	10	kΩ	
Column Output Impedance	R_{COL}		10	15	kΩ	
Supply Current	I_{DD1}		200	400	μA	Operating Mode, fc=400 kHz
	I_{DD2}			20	μA	STOP Mode, CLK=0 V

CAPACITANCE (Ta = 25 °C, V_{DD} = 0 V)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Input Capacitance	C_{IN}			10	pF	f = 1 MHz
Output Capacitance	C_{OUT}			25	pF	Unmeasured pins
I/O Capacitance	C_{IO}			15	pF	returned to 0 V

AC CHARACTERISTICS (T_a = −10 to +70 °C, V_{DD} = +5 V ± 10 %)

COMMON OPERATION:

CHARACTERISTIC	SYMBOL	MIN.	TYP	MAX	UNIT	TEST CONDITIONS
Clock Frequency	f_C	100		1100	kHz	
Clock Pulse Width High	t_{WHC}	350			ns	
Clock Pulse Width Low	t_{WLC}	350			ns	
$\overline{BUSY}$ Delay Time from $\overline{CS}$↓	t_{DCSB}			2	μs	C_L=50 pF
CS↑ Delay Time to $\overline{BUSY}$ Floating	t_{DCSBF}			4	μs	C_L=50 pF
$\overline{CS}$ High Level Time	t_{WHCS}	4			μs	
SYNC Load Capacitance	C_{LSY}			100	pF	
Data Setup Time to RESET↓	t_{SDR}	0			μs	
Data Hold Time from RESET↓	t_{HRD}	4			μs	

SERIAL INTERFACE OPERATION:

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
$\overline{SCK}$ Cycle	t_{CYK}	0.9			μs	
$\overline{SCK}$ Pulse Width High	t_{WHK}	400			ns	
$\overline{SCK}$ Pulse Width Low	t_{WLK}	400			ns	
$\overline{SCK}$ Hold Time from $\overline{BUSY}$↑	t_{HBK}	0			ns	
SI Setup Time to $\overline{SCK}$↑	t_{SIK}	100			ns	
SI Hold Time from $\overline{SCK}$↑	t_{HKI}	250			ns	
SO Delay Time from $\overline{SCK}$↓	t_{DKO}			320	ns	C_L=50 pF
$\overline{BUSY}$ Delay Time from 8th $\overline{SCK}$↑	t_{KDB}			3	μs	C_L=50 pF
$\overline{BUSY}$ Low Level Time	t_{WLB}	18		64	$1/f_C$	C_L=50 pF
C/$\overline{D}$ Setup Time to 1st $\overline{SCK}$↓	t_{SDK}	0			μs	
C/$\overline{D}$ Hold Time from 8th $\overline{SCK}$↑	t_{HKD}	2			μs	
$\overline{CS}$ Hold Time from 8th $\overline{SCK}$↑	t_{HKCS}	2			μs	

PARALLEL INTERFACE OPERATION:

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Input Command Setup Time to $\overline{STB}$↓	t_A	100			ns	C_L=80 pF
Input Command Hold Time from $\overline{STB}$↓	t_B	90			ns	C_L=20 pF
Input Data Setup Time to $\overline{STB}$↑	t_C	230			ns	C_L=80 pF
Input Data Hold Time from $\overline{STB}$↑	t_D	50			ns	C_L=20 pF
Output Data Delay Time	t_{ACC}	90		650	ns	C_L=80 pF
Output Data Hold Time	t_H	0		150	ns	C_L=20 pF
$\overline{STB}$ Pulse Width Low	t_{SL}	700			ns	
$\overline{STB}$ High Level Time	t_{SH}	1			μs	
$\overline{STB}$ Hold Time from $\overline{BUSY}$↑	t_{HBS}	0			μs	
$\overline{BUSY}$ Delay Time from 2nd $\overline{STB}$↑	t_{DSB}			3	μs	
C/$\overline{D}$ Setup Time to 1st $\overline{STB}$↓	t_{SDS}	0			μs	
C/$\overline{D}$ Hold Time from 2nd $\overline{STB}$↑	t_{HSD}	2			μs	
$\overline{CS}$ Hold Time from 2nd $\overline{STB}$↑	t_{HSCS}	2			μs	

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C), μPD7228AG

Supply Voltage	V_{DD}	−0.3 to +7.0	V
Input Voltage	V_I	−0.3 to V_{DD}+0.3	V
Output Voltage	V_O	−0.3 to V_{DD}+0.3	V
Operating Temperature	T_{opt}	−10 to +70	°C
Storage Temperature	T_{stg}	−65 to +150	°C
LCD Operating Voltage	V_{LCD}	4.5 to 12.5	V

DC CHARACTERISTICS (Ta = −40 to +70°C, V_{DD} = +5V ± 10%)) %)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Input Voltage High	V_{IH1}	0.7 V_{DD}		V_{DD}	V	Except $\overline{SCK}$
	V_{IH2}	0.8 V_{DD}		V_{DD}	V	$\overline{SCK}$
Input Voltage Low	V_{IL}	0		0.3 V_{DD}	V	
Input Leakage Current High	I_{LIH}			10	μA	V_I=V_{DD}
Input Leakage Current Low	I_{LIL}			−10	μA	V_I=0 V
Output Voltage High	V_{OH1}	V_{DD}−0.5			V	$\overline{BUSY}$, D0−D3, I_{OH}=−400 μA
	V_{OH2}	V_{DD}−0.5			V	SYNC, I_{OH}=−100 μA
Output Voltage Low	V_{OL1}			0.5	V	$\overline{BUSY}$, D0−D3, I_{OL}=1.7 mA
	V_{OL2}			0.5	V	SYNC, I_{OL}=100 μA
Output Leakage Current High	I_{LOH}			10	μA	V_O=V_{DD}
Output Leakage Current Low	I_{LOL}			−10	μA	V_I=0 V
LCD Operating Voltage	V_{LCD}	3.0		V_{DD}	V	
Row Output Impedance	R_{ROW}		6	16	kΩ	
Row/Column Output Impedance	$R_{ROW/COL}$		7.5	20	kΩ	
Column Output Impedance	R_{COL}		15	30	kΩ	
Supply Current	I_{DD1}		250	600	μA	Operating Mode, fc=400 kHz
	I_{DD2}			25	μA	STOP Mode, CLK=0 V

CAPACITANCE (Ta = 25 °C, V_{DD} = 0 V)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Input Capacitance	C_{IN}			10	pF	f = 1 MHz
Output Capacitance	C_{OUT}			25	pF	Unmeasured pins
I/O Capacitance	C_{IO}			15	pF	returned to 0 V

AC CHARACTERISTICS (Ta = −40 to +85°C, V_{DD} = +5V ± 10%), μPD7228AG

COMMON OPERATION:

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Clock Frequency	f_C	100		1100	kHz	
Clock Pulse Width High	t_{WHC}	350			ns	
Clock Pulse Width Low	t_{WLC}	350			ns	
$\overline{BUSY}$ Delay Time from $\overline{CS}$↓	t_{DCSB}			3	μs	C_L=50 pF
$\overline{CS}$ ↑ Delay Time to $\overline{BUSY}$ Floating	t_{DCSBF}			5	μs	C_L=50 pF
$\overline{CS}$ High Level Time	t_{WHCS}	4			μs	
SYNC Load Capacitance	C_{LSY}			100	pF	
Data Setup Time to RESET↓	t_{SDR}	0			μs	
Data Hold Time from RESET↓	t_{HRD}	5			μs	

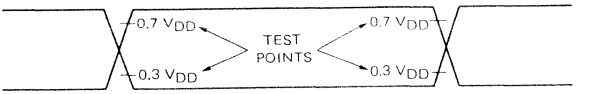
SERIAL INTERFACE OPERATION:

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
$\overline{SCK}$ Cycle	t_{CYK}	0.9			μs	
$\overline{SCK}$ Pulse Width High	t_{WHK}	400			ns	
$\overline{SCK}$ Pulse Width Low	t_{WLK}	400			ns	
$\overline{SCK}$ Hold Time from $\overline{BUSY}$↑	t_{HBK}	0			ns	
SI Setup Time to $\overline{SCK}$↑	t_{SIK}	120			ns	
SI Hold Time from $\overline{SCK}$↑	t_{HKI}	270			ns	
SO Delay Time from $\overline{SCK}$↓	t_{DKO}			320	ns	C_L=50 pF
$\overline{BUSY}$ Delay Time from 8th $\overline{SCK}$↑	t_{KDB}			3	μs	C_L=50 pF
$\overline{BUSY}$ Low Level Time	t_{WLB}	18		64	$1/f_C$	C_L=50 pF
C/$\overline{D}$ Setup Time to 1st $\overline{SCK}$↓	t_{SDK}	0			μs	
C/$\overline{D}$ Hold Time from 8th $\overline{SCK}$↑	t_{HKD}	3			μs	
$\overline{CS}$ Hold Time from 8th $\overline{SCK}$↑	t_{HKCS}	5			μs	

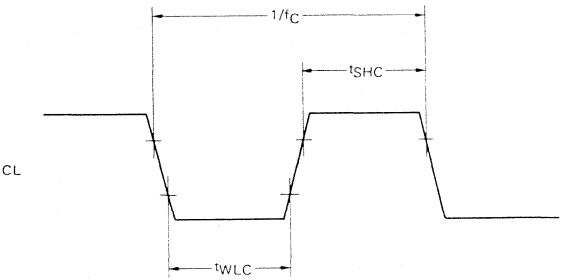
PARALLEL INTERFACE OPERATION:

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Input Command Setup Time to $\overline{STB}$↓	t_A	120			ns	C_L=80 pF
Input Command Hold Time from $\overline{STB}$↓	t_B	110			ns	C_L=20 pF
Input Data Setup Time to $\overline{STB}$↑	t_C	250			ns	C_L=80 pF
Input Data Hold Time from $\overline{STB}$↑	t_D	70			ns	C_L=20 pF
Output Data Delay Time	t_{ACC}	90		750	ns	C_L=80 pF
Output Data Hold Time	t_H	0		150	ns	C_L=20 pF
$\overline{STB}$ Pulse Width Low	t_{SL}	700			ns	
$\overline{STB}$ High Level Time	t_{SH}	1			μs	
$\overline{STB}$ Hold Time from $\overline{BUSY}$↑	t_{HBS}	0			μs	
$\overline{BUSY}$ Delay Time from 2nd $\overline{STB}$↑	t_{DSB}			4	μs	
C/$\overline{D}$ Setup Time to 1st $\overline{STB}$↓	t_{SDS}	0			μs	
C/$\overline{D}$ Hold Time from 2nd $\overline{STB}$↑	t_{HSD}	3			μs	
$\overline{CS}$ Hold Time from 2nd $\overline{STB}$↑	t_{HSCS}	3			μs	

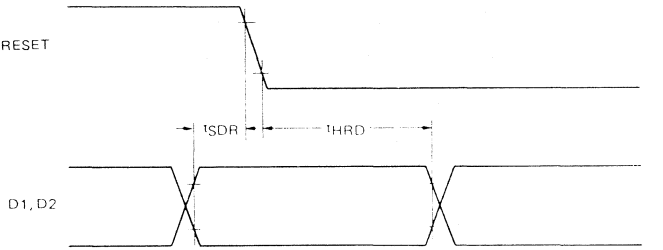
AC TEST POINTS



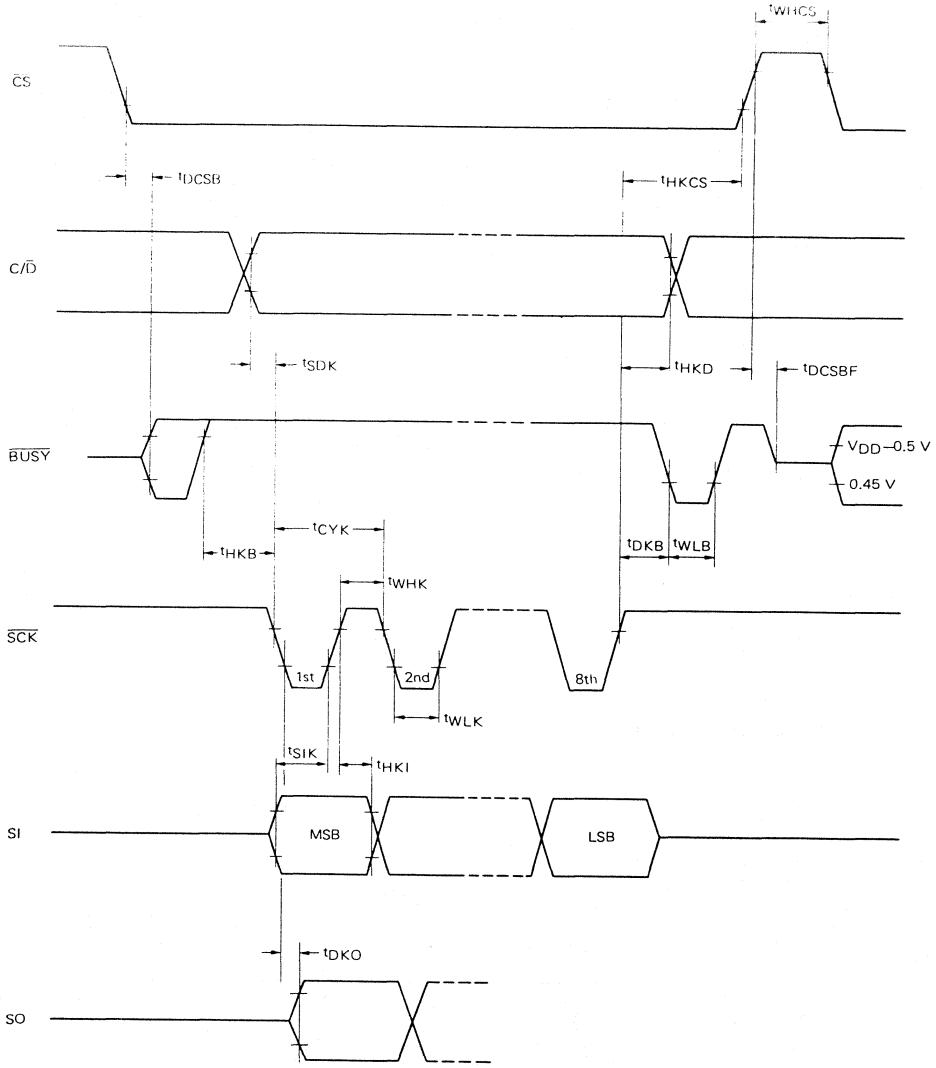
CLOCK WAVEFORM



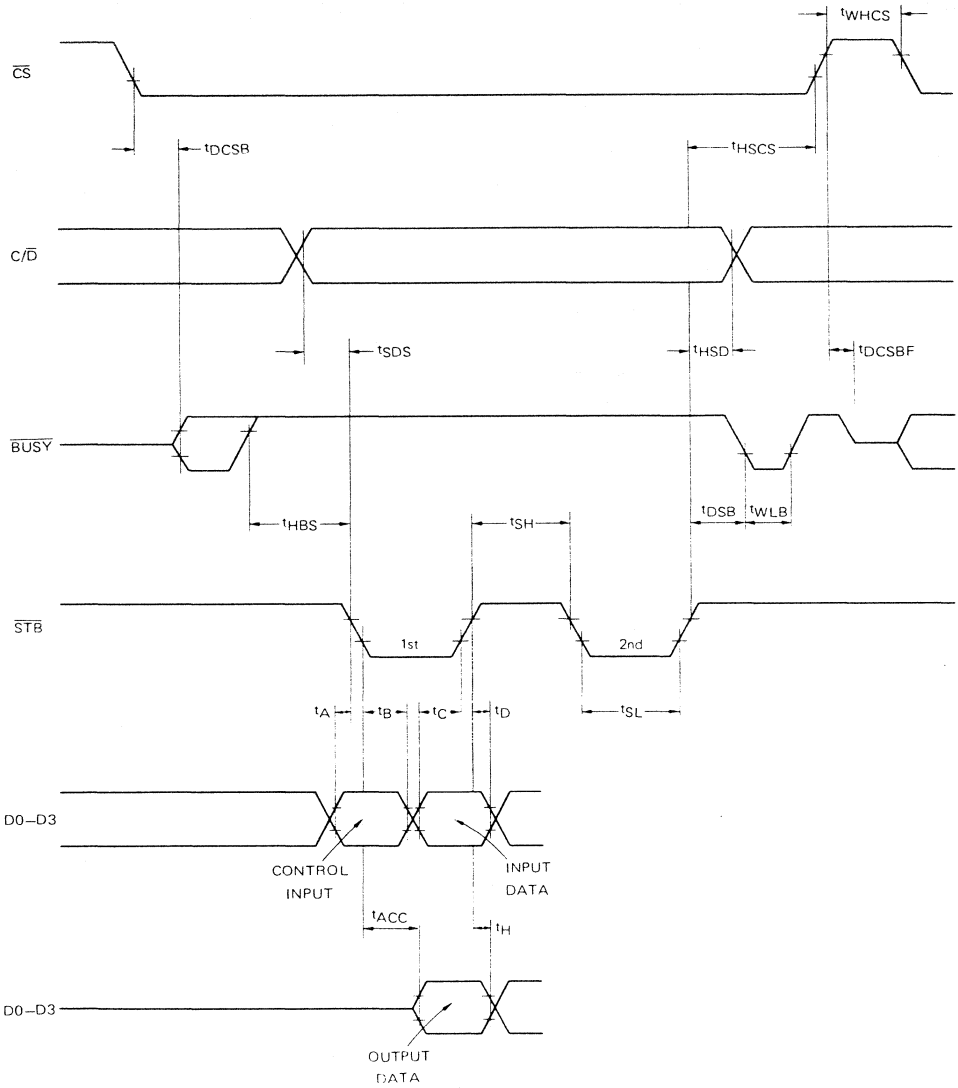
INTERFACE TIMING WAVEFORMS



SERIAL INTERFACE TIMING WAVEFORMS



PARALLEL INTERFACE TIMING WAVEFORMS



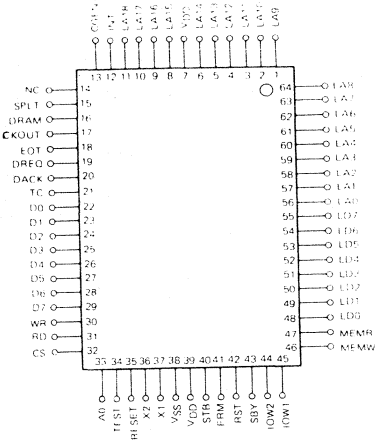
The μPD72030G is an LSI used to control the display of a heavy duty, dot-matrix LCD. Characters and graphics can be displayed on the LCD by providing commands through an 8085-compatible bus interface.

FEATURES

- Display duty 1/32 to 1/128
- Abundant functions for character display
- Internal character generator (5×7 dot matrix)
- 64 ASCII characters (alphanumeric characters and others)
- Expandable external character generator
- Use of character generator RAM possible
- Display memory: 64 KB MAX.
- Use of SRAM and DRAM possible
- Abundant control commands for easy data display
  - Cursor manipulation
- Vertical and horizontal movement
- Direct addressing
- Shift to home position
  - Editing
- Row/display screen clearing
  - Screen control
- Scrolling
  - Attribute functions
- Reverse display
- Underline
- Blinking display
- Secret
- Bus-compatible with other microcomputers such as the μCOM-87 and V series™
- Can be directly connected to the high-voltage output LCD driver μPD6307/6308G and is capable of 8-bit parallel high-speed transfer of display data.
- CMOS technology
- Single logic power supply +5 V
- 64-pin plastic flat package

Note: V series™ is a registered trademark of NEC Corporation.

PIN CONFIGURATION (Top View)



1. SYSTEM CONFIGURATION AND GENERAL FUNCTIONS

The μPD72030G is an LCD controller which can be used to configure an LCD system by connecting a μPD6307G (LCD row driver), μPD6308G (LCD column driver), and a general-purpose RAM as the display memory to the μPD72030G. An external character generator may be connected as necessary.

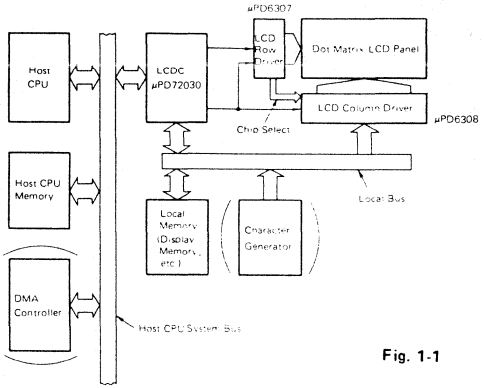
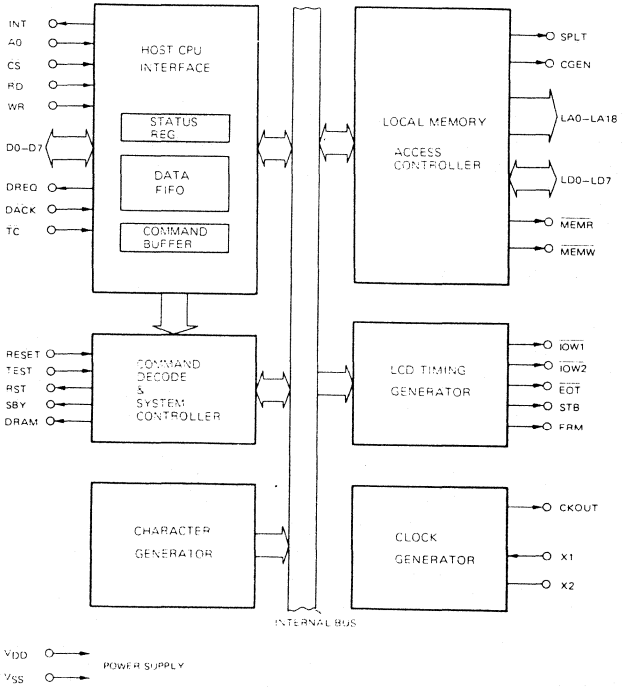


Fig. 1-1

BLOCK DIAGRAM

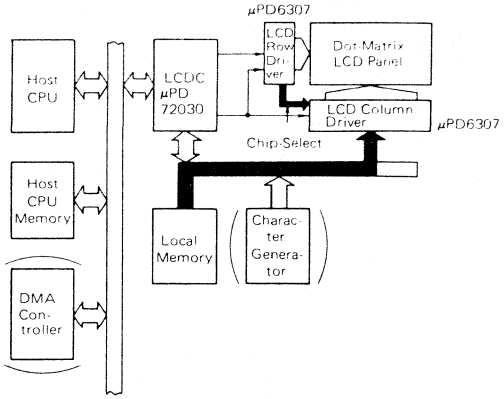


The μPD72030G carries out two processes: display and command. In the display process, the μPD72030G drives an LCD panel by sending display memory data to the column driver and timing signals to the row and column drivers. In the command process, the μPD72030G manipulates the display memory contents by commands sent from the host CPU.

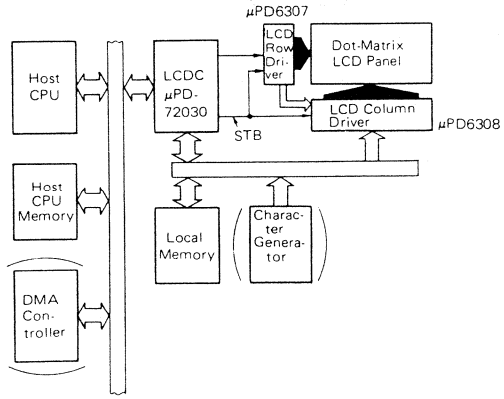
The follwoing discusses these two processes in greater detail.

1.1 Display Process

(1) The display memory contents are transferred directly to the column driver via the local bus at fixed timing intervals generated by the LCDC. When two or more column drivers are connected to the system, the chip select signal generated by the row driver determines the column driver to which the data are to be written.

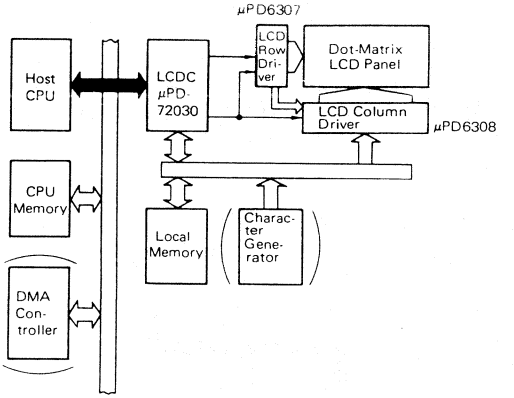


(2) After display data are stored in each column driver, the STB signal is output. Then, one line of display data is output to the LCD panel. The row signals are scanned, and the above sequence is repeated to drive the LCD panel using the time-division method.

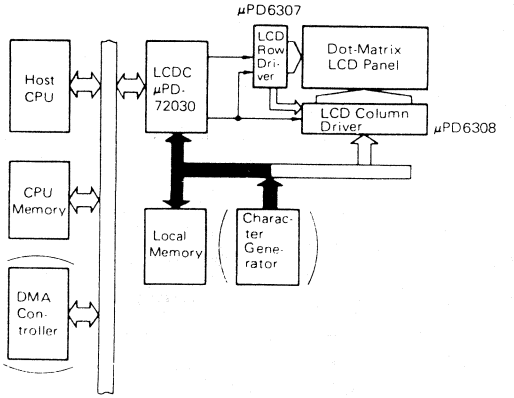


1.2 Command Process

(1) The host CPU reads and checks* the status of the LCDC, then sends it an appropriate command.
(* An interrupt may instead be used.)



(2) The LCDC interprets the given command, then executes it. To manipulate display data, the LCDC checks data such as those provided by the character generator, then manipulates the local memory contents.



2. PIN FUNCTIONS

2.1 D0 to D7 (Data Bus): Input/Output

This is the data bus for interfacing the host CPU. Writing commands, parameters, and data, or reading status and data are performed through this bus.

These pins connect the host CPU data bus.

2.2 A0 (Address 0) . . . Input

This pin inputs commands and signals for function of the data bus (D0 to D7).

A0 = 0: data, parameter

A0 = 1: command, status

This pin connects the host CPU address bus.

2.3 $\overline{CS}$ (Chip Select) . . . Input

This pin inputs the host CPU interface-enable signal. $\overline{CS}$ = 0 enables the read/write function of the data bus.

This pin connects the host CPU address decode signal.

2.4 $\overline{RD}$ (Read Strobe) . . . Input

This pin inputs the status/data read strobe signal to the data bus. When the host CPU interface is enabled, with $\overline{RD}$ = 0, status and data are read to the data bus.

This pin connects the host CPU read strobe signal.

2.5 $\overline{WR}$ (Write Strobe) . . . Input

This pin inputs the command/parameter write strobe signal from the data bus.

When the host CPU interface is enabled with $\overline{WR}$ = 0, command/data on the data bus are written to the LCDC.

This pin connects the host CPU write strobe signal.

2.6 DREQ (DMA Request) . . . Output

This pin outputs a DMA service request signal for data block transfer.

When data block transfer is required between the host CPU memory and the LCDC local memory, if the data transfer is possible, DREQ is set to 1 to request DMA service.

This pin connects service request input of the DMA controller. If the block transfer function is not to be used, this pin should be left open.

2.7 $\overline{DACK}$ (DMA Acknowledge) . . . Input

This pin inputs an acknowledge signal for DMA service requests made when DREQ = 1.

When $\overline{DACK}$ is set to 0, $\overline{CS}$ and A0 are internally set to 0 regardless of their input level.

This pin connects the service acknowledge output of the DMA controller. If the block transfer function is not used, this pin should be pulled up to high level.

2.8 $\overline{TC}$ (Terminal Count) . . . Input

This pin inputs a termination signal for data block transfer.

When $\overline{TC}$ is set to 0, termination of data block transfer is indicated.

This pin connects to the DMA transfer termination output of the DMA controller. If the block transfer function is not used, this pin should be pulled up to high level.

2.9 LD0 to LD7 (Local Data Bus) . . . Input

These pins are the data bus to access the local memory. The display memory and external character generator are connected to the LCDC as local memories.

Communication with these memories is made through the local data bus.

2.10 LA0 to LA18 (Local Address Bus) . . . Output

These pins are the address bus to provide access to the local memory.

LA0 – 15: These pins are used for addressing the display memory and external character generator.

LA16 – 18: These pins are used for addressing the external character generator.

2.11 CGEN (Character Generator Enable) . . . Output

This is the external character generator enable signal output.

When CGEN = 1, the character address and scan address are output onto LA0 to LA18.

When CGEN = 0, the address to the display memory is output onto LA0 to LA15; LA16 and LA17 become don't care.

When the external generator is not used, this pin should be left open.

By combining with SPLT output, $\overline{RFSH}$ output for a pseudo SRAM can be externally generated.

2.12 SPLT (Split Screen Select) . . . Output

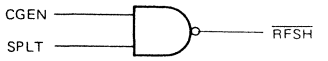
This pin is for the memory refresh select signal for the LCD screen partitioning matrix display.

SPLT = 0: Accesses the refresh memory for the upper portion of the screen.

SPLT = 1: Accesses the refresh memory for the lower portion of the screen.

Refer to 7.1 for details.

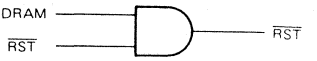
By combining with CGEN output, $\overline{RFSH}$ output for a pseudo SRAM can be externally generated.



Output from the controller

3.13 DRAM (DRAM Reset Enable) . . . Output

When the DRAM (Dynamic RAM) is connected to the local memory, the DRAM reset enable signal and AND signal of $\overline{RST}$ are input to the RST pin of the row driver. This prevents the loss of the display memory contents without refreshing the DRAM while the display is off.



Output from the controller Input to the row driver

2.14 $\overline{MEMR}$ (Local Memory Read) . . . Output

This is the read strobe to the local memory.

Pulses are output when the display memory contents are directly written to the display driver, with $\overline{MEMR}$, $\overline{IOW1}$, and $\overline{IOW2}$ set to low level. Pulses are also output when the LCDC reads the local memory contents, but with only $\overline{MEMR}$ set to low level.

2.15 $\overline{MEMW}$ (Local Memory Write) . . . Output

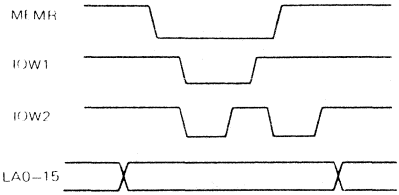
This is the write strobe to the local memory.

A low level pulse is output during data write to the local memory.

2.16 IOW1, IOW2 (LCD Driver Write Strobe) . . . Output

These are the data write strobes to the LCD column (segment) driver.

$\overline{IOW1}$ generates one pulse and $\overline{IOW2}$ generates two pulses for each $\overline{MEMR}$ pulse. Therefore, these are selected according to how the LCD column driver is used.



2.17 STB (Strobe) . . . Output

This is the row drivers signal strobe output.

One pulse is output at the timing interval for display of one row.

The display duty is determined by the number of STB pulses output during each frame interval.

2.18 FRM (Frame) . . . Output

This is an AC-converted signal output to drive the LCD.

If it is high, a positive frame is displayed, and if it is low, a negative frame is displayed.

2.19 $\overline{EOT}$ (End of Transfer) . . . Output

This output indicates the end of display data transfer for one row.

When the display data transfer for one row is complete, a low-level pulse is output. This is used as clear signal for the chip select signal generator counter of the row driver.

2.20 $\overline{RST}$ (LCD Driver Reset) . . . Output

This is the LCD driver reset output.

When the LCD driver is being reset, a low-level signal is output at this pin.

For normal display, this is set to high level.

2.21 $\overline{SBY}$ (LCD Standby) . . . Output

This output sets the LCD driver to the standby state.

To stop the LCD display and put the LCD in the standby state, a low level signal is output during execution of the STOP command.

This is set to high level for normal display, and when a $\overline{RESET}$ signal is input.

2.22 CKOUT (Clock Out) . . . Output

This is the divided output of the internal oscillator.

A clock whose frequency was divided down to 1/15 from the original oscillator is output. This is set to high level during execution of the STOP command.

2.23 X1, X2 (Xtal1, Xtal2) . . . Output

These pins are used to connect an external crystal.

The μPD72030G has a built-in high-gain amplifier. Thus, a functional clock can be generated simply by connecting a crystal or ceramic resonator and two capacitors to X1 and X2 pins.

When an external clock is used, X1 and X2 function as clock input pins.

2.24 $\overline{\text{RESET}}$ (Reset Input) . . . Input

This is the reset input for the μPD72030G.

When a low-level signal is input to this pin, the μPD72030G is initialized.

2.25 $\overline{\text{INT}}$ (Interrupt Request) . . . Output

This pin outputs an interrupt service request to the host CPU.

$\overline{\text{INT}}$ = 1: Indicates a command is being processed.

$\overline{\text{INT}}$ = 0: Indicates a command process is complete and the μPD72030G is ready to request a new command to the host CPU. $\overline{\text{INT}}$ can be conveniently used as an interrupt signal to the host CPU.

2.26 TEST (Test Input) . . . Input

A high-level input sets the μPD72030G in test mode.

The input to the TEST pin should be fixed to low level for normal use.

To achieve this, this pin can be directly connected to the V_{SS}.

3. GENERAL DESCRIPTION OF INTERNAL BLOCK

3.1 Host CPU Interface Circuit

The μPD72030G sends/receives commands, parameters, status, data, etc., to/from the host CPU through an 8-bit data bus.

In addition, a DMA controller can be connected through a host CPU interface circuit. The data bus functions as follows:

	$\overline{\text{CS}}$	$\overline{\text{DACK}}$	A0	$\overline{\text{RD}}$	$\overline{\text{WR}}$	STATUS OF D0 TO D7 PINS	HOST CPU INTERFACE OPERATION
	1	1	X	X	X	Z	No operation
	X	X	X	1	1	Z	No operation
Command input	0	1	1	1	0	Z	Fetches data on D0 to D7 into command buffer
Status output	0	1	1	0	1	A	Places status on D0 to D7
Parameter input	0	1	0	1	0	Z	Fetches data on D0 to D7 into data FIFO
Data output	0	1	0	0	1	A	Places data on D0 to D7 from contents of data FIFO
Data block input	X	0	X	1	0	Z	Fetches data on D0 to D7 into data FIFO
Data block output	X	0	X	0	1	A	Places data on D0 to D7 from conents of data FIFO

Z: High impedance

A: Active

3.2 Command Decoder and System Controller

The internal circuit of the μPD72030G is controlled according to the command and/or parameter. This circuit provides reset and standby functions to the system, and generates reset and standby signals to the LCD driver.

3.3 Character Generator

This is a ROM in which 64 ASCII characters (5X7 dot) are stored. The character fonts are shown in Fig. 3-1.

3.4 Local Memory Access Controller

This circuit generates a memory read signal for read, write, and display of the local memory contents.

3.5 LCD Timing Generator

This circuit generates display timing and data latch signals to the LCD driver.

3.6 Clock Generator (Oscillator)

The clock generator generates a clock signal used in the μPD72030G through an external crystal or ceramic resonator by inputting an external clock signal.

	X0	X1	X2	X3	X4	X5	X6	X7	X8	X9	XA	XB	XC	XD	XE	XF
2X	Space	!	"	#	$	%	&	'	(	)	*	+	,	-	.	/
3X	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4X	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5X	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
6X	`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
7X	p	q	r	s	t	u	v	w	x	y	z	{	|	}	~	

Fig. 3-1 Internal Character Generator Code and Font Reference Table

4. CONNECTION TO THE HOST COMPUTER

Connecting the host CPU is easily done using an 8-bit parallel data bus in the same manner as other general-purpose peripherals. (See Fig. 4-1)

The following registers can be accessed depending on the data bus interfaced to the host CPU.

(1) Command buffer (write only) A0 = 1
(2) Data FIFO (read/write) A0 = 0
(3) Status (read only) A0 = 1

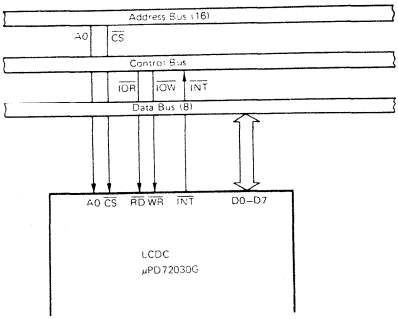


Fig. 4-1 Host CPU Connection

4.1 Command Buffer

The command buffer is an 8-bit register in which a command to be given to the LCDC is stored. Although a value can be set in the command buffer, the host CPU cannot read the value once it is set. When the command is written to the command buffer, CBF of the status flag is set to 1; when the LCDC receives the command and starts command execution, CBF is set back to 0.

Note that CBF = 0 does not mean that command process is terminated. The section 4.4 describes how to perform flag checks.

4.2 Data FIFO

For communication between the host CPU and the LCDC, an 8-byte bidirectional FIFO is used. The LCDC changes the FIFO direction depending on the command.

The status of the FIFO can be checked by the two flags IBR and OBR in the status register.

IBR: The master CPU can write the parameter and data to the LCDC's data FIFO only when this flag is set to 1.

When this is 0, write to the data FIFO should not be attempted.

OBR: The master CPU can read data from the LCDC's data FIFO only when this flag is set to 1.

If data are read from the data FIFO when this flag is 0, the data read out will be undefined.

> **FIFO** (First In, First Out)
>
> When a buffer register for two or more bytes of data exists between a data sender and receiver, after the sender writes the data to the buffer, the receiver reads the data in the same order they were written. This method is known as FIFO.
>
> The opposite of this is called LIFO, Last In, First Out

4.3 Status

This is a register that indicates the functional status of the LCDC.

7	6	5	4	3	2	1	0
WRN	SBY	ERR	BSY1	CBF	BSY0	IBR	OBR

OBR: Output Buffer Ready (bit 0)

When the data FIFO direction is changed from the LCDC to the direction of the master CPU, and output data of one or more bytes exist in the data FIFO, this is set to 1. That is, if OBR is 1, data can be read from the data FIFO.

IBR: Input Buffer Ready (bit 1)

When the data FIFO direction is changed from the master CPU to the direction of the LCDC, and room for one or more bytes exists in the data FIFO, this is set to 1. That is, if IBR is 1, data can be written to the data FIFO.

BSY0: Busy 0 (bit 2)

When a command is given, this flag is set to 1 after a specific period of time. Then the LCDC provides its command and parameter to the internal command decoder and system controller. When command execution starts, this flag is set to 0.

If BSY0 = 0, the next command and parameter can be input from the master CPU.

CBF: Command Buffer Full (bit 3)

This flag indicates the status of the command buffer.

When CBF = 1: Indicates a command exists in the command buffer.

When CBF = 0: Indicates the command buffer is empty.

BSY0 and BSY1 require a certain period of time to be set to 1 after a command is written. However, CBF is set to 1 immediately after the command is written. Therefore, when giving a command, confirm that CBF = BSY0 = 0, or CBF = BSY1 = 0.

BSY1: Busy 1 (bit 4)

When a command is given, this flag is set to 1 after a specific period of time. When the LCDC completes execution of the command, this flag is set to 0. Note that Busy 0 is set to 0 when command execution starts. When Busy 1 is changed from 1 to 0, WRN and ERR flags can be checked.

ERR: Error (bit 5)

When there is an error in the parameter value, this flag is set to 1. When BSY1 = 0 or $\overline{INT}$ pin is set to 0, the ERR flag can be checked.

This flag is automatically cleared upon start of the next command execution.

SBY: Standby (bit 6)

When the STOP command is executed and the μPD72030G enters the standby state, this flag is set to 1.

This flag is set to 0 when the μPD72030G leaves the standby state after the START command is given.

WRN: Warning (bit 7)

This flag is set to 1 if no memory exists to be cleared when the CLR LN, CLR FRM, or CLR GRP command is executed or no character code memory exists, when the TRNS command is executed. When BSY1 = 0 or $\overline{INT}$ pin is set to 0, the WRN flag can be checked.

This flag is automatically cleared upon starting execution of the next command.

5. COMMANDS

Because the μPD72030G is an intelligent LCD controller, functions such as clearing of the display screen and scroll-up can be executed using simple commands issued by the host CPU. Consequently, the host CPU can perform other tasks while these functions are executed. The result is an increase in overall system efficiency and a reduction in host CPU overhead.

The commands are 1 byte in length. Data written to the command buffer register inside the LCDC are received by the LCDC and the corresponding process is executed.

After the process is over, another command can be given to the LCDC.

Fig. 6-1 shows command code table. Command codes are allocated in the non-character portion of the character code. All codes input to the buffer that are not commands are processed as character codes for display. That is, a character can be displayed by simply writing its code to the command buffer.

Commands are divided into the following four groups according to their function:

(1) Initialization commands

These commands specify the LCDC's functional mode corresponding to the LCD display system configuration.

(2) Function specifying commands

These commands specify functions such as temporary halt of the display, restart, and standby.

(3) Display control commands

These commands specify such things as cursor position and display mode.

(4) Display data manipulation commands

These commands manipulate display data and their attributes.

For execution, one or more parameters may be required depending on the command. These parameters are sent to the data FIFO.

When the display data are to be read upon command execution, the data are sent to the host CPU from the LCDC, again using the data FIFO.

80	START	(0)	8F	CURLT	(0)	9F	BLKTOT	(x)	EE	CLRCHR	(2)
81	STOP	(0)	90	CURON	(0)	E0	BLINK0	(0)	EF	CLRGRP	(1)
82	DSPLY1	(0)	91	CUROFF	(0)	E1	BLINK1	(0)	F0	DSPPOS	(1)
83	BLANK	(0)	92	SELECT0	(0)	E2	BLINK2	(0)	F1	MEMADR	(8)
84	DSPLY2	(0)	93	SELCT1	(0)	E3	BLINK3	(0)	F2	MEMSIZ	(8)
85	DSPLY3	(0)	94	CURDR	(2)	E4	CURSOR	(1)	F3	SELECTCG	(1)
86	CLRLN	(0)	95	ATTR	(1)	E5	MODEC	(0)	F4	DISPL	(0)
87	CLRFRM	(0)	96	SYNC	(5)	E6	MODEG	(0)	20~7F,	A0~DF	
88	DSPLY4	(0)	97	DSPDEF	(7)	E7	MODEM	(0)		CHRDSP	(1)
89	STOP2	(0)	98	DIVIDN	(0)	E8	READ	(x)	1B	ESC	(0)
8A	ATTROF	(0)	99	DIVIDU	(4)	E9	WRITE	(x)	0A	LF	(0)
8B	CURHM	(0)	9A	DIVIDD	(4)	EA	DRESET	(7)	0D	CR	(0)
8C	CURUP	(0)	9B	DIVIDB	(8)	EB	DSET	(7)	08	BS	(0)
8D	CURDN	(0)	9C	TRANS	(2)	EC	GET	(7)			
8E	CURRT	(0)	9E	BLKTIN	(x)	ED	COMP	(7)			

Note: Parentheses indicate the number of parameters.

Fig. 5-1 Command Code Table

6. LOCAL MEMORY

The LCDC has a function to control the memory used for LCD display in accordance with the commands received from the host CPU. This is the local memory of the LCDC. This memory is independent of the main CPU, which means CPU memory is not sacrificed for display. If direct manipulation of the display memory from the main CPU is required, this can be realized by allocating the local memory as part of the memory space of the main CPU. This can be done by adding a switching circuit between the local memory's address and data buses and the main CPU's address and data buses. Either SRAM or DRAM can be used as local memory. Type of memory to be used can be selected using the SYNC command.

The local memory consists of the display memory and the character generator. The display memory is divided into the following four memories:

(1) Refresh memory
(2) Character code memory
(3) Character attribute memory
(4) Graphics memory

The allocation of these memory spaces in the local memory is specified by the two commands, MEMADR and MEMSIZ. MEMADR specifies the start address and MEMSIZ specifies the byte length. Consequently, each memory can be independently allocated in the local memory in a desired manner. If a memory of sufficient capacity is mounted, the display of several pages can be easily switched by issuing the Display Modify command which modifies the start address.

In addition, the character generator also is connected to the local memory. However, by switching memory banks to separate the memory space from the display memories, a high capacity character generator for character sets such as Kanji can be connected. This character generator space is allocated by an address fixed by the hardware. Therefore, allocation by command is not necessary. The method of connection is discussed in section 6.5.

6.1 Refresh Memory

Data stored in the refresh memory are automatically transferred to the LCD driver periodically and displayed. The refresh memory stores data that is the logical sum (OR) of character display expanded to bit-image data and graphic display data.

The size of the refresh memory space is based on the number of pixels of the LCDC panel to be controlled.

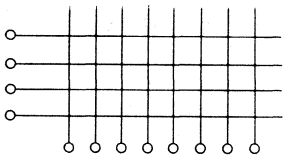
As was required for a 200×640 display with 1/100 duty, to perform a partitioned matrix display with a pixel number of twice the display duty, two refresh memories are necessary. One is for the upper screen and the other is for the lower screen. These two refresh memories simultaneously transfer display data for the two screens to each LCDC driver. The LCDC constructs the data so that character and graphics display assumes a continuous appearance between the upper and lower screens. Therefore, it is of no consequence to the host CPU that the screen is partitioned into upper and lower portions when commands are given.

Memories other than the refresh memory are not required to be partitioned into upper and lower portions.

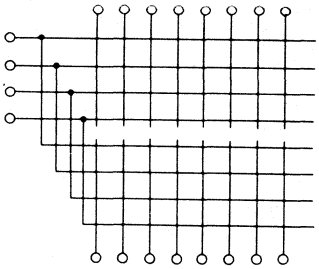
The SYNC command specifies whether or not a partitioned matrix is used.

Partioned Matrix Display

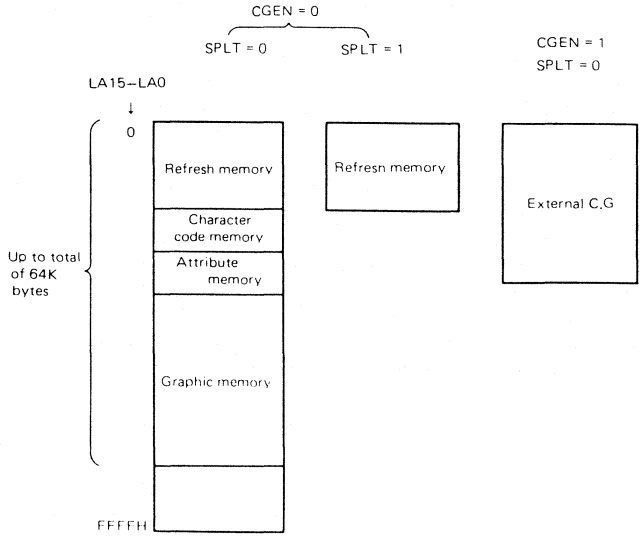
The number of pixels in the vertical direction on the LCD panel is limited by the number of time divisions of the display. While the number of time divisions has been increased with improved materials used for liquid crystal display, limitations are still imposed due to display quality. In partitioned matrix display, the number of pixels in the vertical direction can be twice the display duty; however, this requires that the number of pins for display in the column (segment) direction be twice the number of pixels in the horizontal direction.



Single Matrix



Partitioned Matrix



Typical Allocation of Local Memory

6.2 Character Code Memory

Either 8-bit or 16-bit character codes for character display can be stored in the character code memory. Whether the character code is to be 8-bit or 16-bit should be preset by DSPDEF command. This means that 1-byte and 2-byte codes cannot be mixed. When characters are not displayed, if FFFFH is specified as the start address of the character code memory, the LCDC interprets this as meaning that the character code memory does not exist.

The character memory can have a larger number of rows than that of the actual screen (up to 255 rows as set by MEMSIZ command.)

< Character code memory and scroll processing >

Fig. 6-3 below shows the relation between character code memory and LCD panel in scroll processing (screen movement in vertical direction).

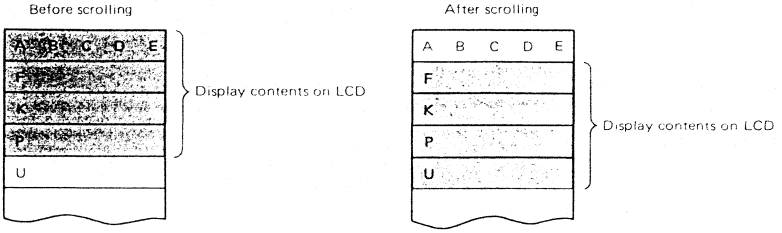


Fig. 6-3 Character Code Memory and Scroll Processing (I)

Fig. 6-4 below shows the relation between character code memory and LCD panel when the character code memory is scrolled up to the final line of the character code memory.

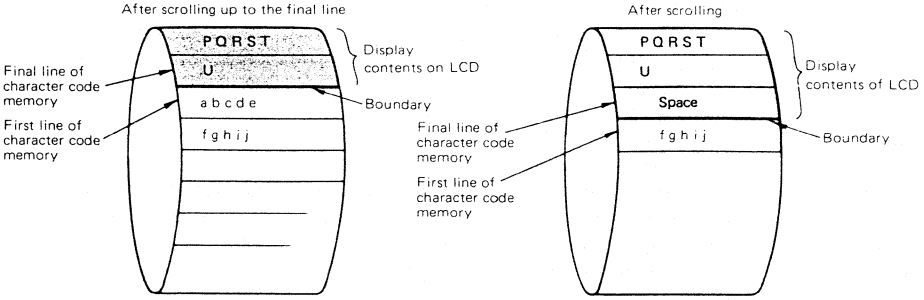
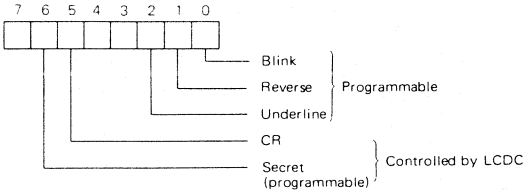


Fig. 6-4 Character Code Memory and Scroll Processing (II)

After scrolling, the LCD returns to the first line (next line down from the final line). At this time, the previous data is erased (a space code is written) and a blank line is displayed. This line is the final line of the character code memory. In this manner, although the addresses are non-continuous, the LCDC controls them as if they were continuous. The portion between the final line of the memory and the first line is called boundary.

6.3 Attribute Memory

This attribute memory is paired with the character code memory character by character, and stores attribute data (such as reverse display and underline) for each character. A byte of attribute memory is required for the display of each character. A single byte of the attribute memory stores the following information.



These attributes can be set by ATTR command. However, because the LCDC controls the screen, the attributes of CR and space are automatically attached when the character code is stored. (For the WRITE command, these are not automatically attached.)

Blink ..... This blinks the character at an interval specified by BLINK command. However, when the character is in the fixed row, the blink attribute is invalid and the character does not blink.
The blinking function has the following constraints:
- No blink takes place during the command process.
- The number of characters that can blink is limited due to the amount of process time required for blinking.

Reverse ..... This reverses the black and white portions of the character specified by the reverse attribute.

Underline ..... This draws an underline one pixel thick under the font of the specified character.

CR ..... This indicates the logical line end and is used for screen editing. When CR is input, the LCDC sets to 1 the CR bit of the attribute memory corresponding to the cursor location at CR input.

Secret ..... This indicates that the corresponding code is secret and no character is displayed on the display. When data is cleared by pressing the space key using CLRCHR, CLRLN, or CLRFRM command, the LCDC automatically adds a space.

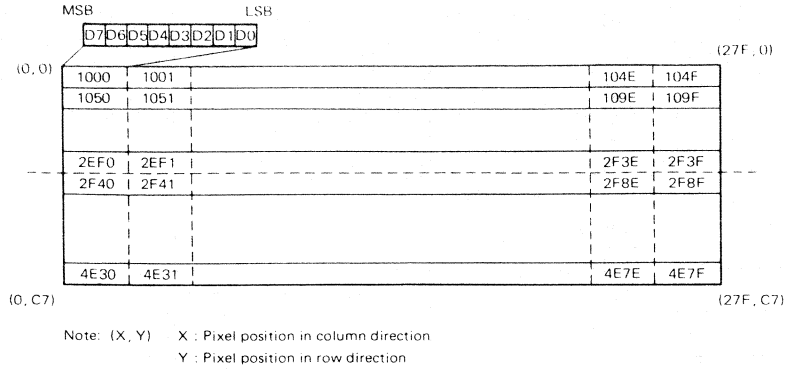
6.4 Graphics Memory

Pixel data for graphics display are stored in this memory.

Manipulations of set, reset, and reverse for each pixel are performed to this memory. After DISPLAY1 command is executed, the character display is overlapped with the data in the graphics memory, then transferred to the refresh memory. The graphics display then changes (display-ON mixed mode).

When the graphics display is not needed, if FFFFH is specified as the start address, the LCDC interprets this as meaning the graphics memory does not exist.

One pixel on the LCD panel corresponds to one bit of the graphics memory. Fig. 6-5 shows the relation between the graphics memory addresses and LCD panel when the start address of the graphics memory is 1000H.



Note: (X, Y) X : Pixel position in column direction
Y : Pixel position in row direction

Fig. 6-5 Relation between LCD Panel and Graphics Memory

6.5 Character Generator

A 5X7-pixel font character generator for 64 characters is internally provided. In addition to this, a row scan-type external character generator (up to 16X16 pixels) can be externally connected.

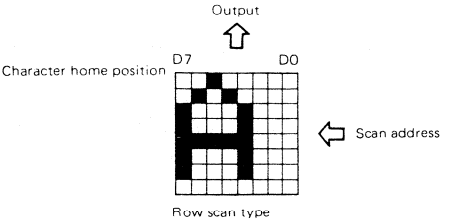
The LCDC references the character generator table according to the character code data in the character code memory, converts the data to bit image, then stores the bit image data in the refresh memory from the MSB.

Connections of the external character generator are shown in Figs. 6-7 and 6-8.

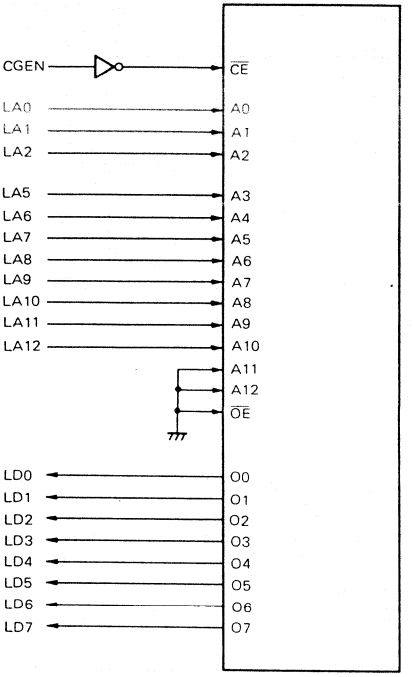
Row Scan-Type Character Generator

This generator is often used for CRT display. For it, character font data are divided and read out a portion at a time. If the font data simultaneously output in parallel are horizontal slices, it is called the row scan type.

If the slicing is done in the vertical direction, it is known as a column scan type. The latter type is used for printers.

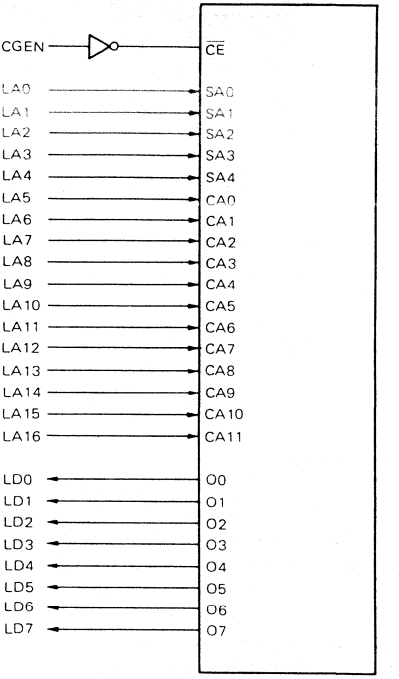


Relation among local address output when CGEN=1 and scan address, and character address is as shown below:



Row scan Character generator μPD27C64, etc.

Fig. 6-7 Typical Connection of Character Generator (1) (8×8 pixels)



μPD24C1000D/D-1-X01

Fig. 6-8 Typical Connection of Character Generator (2) (16×16 pixels)

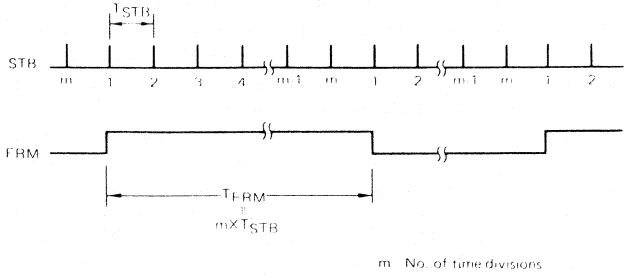
The μPD27C64 is a CMOS EPROM. To use this as a character generator, the user should write the character font before use.

The μPD24C1000D/D-1X01 is a standard 16X16-pixel character generator. The chip contains 453 JIS non-Kanji characters and 2,965 JIS Kanji characters of the first level conforming to JIS C 6226.

7. FUNCTIONAL TIMING

7.1 LCD Drive Timing

The LCD driver is controlled so that an LCD of up to a 1/128 duty cycle can be driven. The timing for this is as shown below.



T_{STB} and T_{FRM} can be specified by SYNC command. See the chapter on commands for details.

T_{STB}: $(\frac{1}{f_{osc}} \times 15) \times n$ ... (f_{osc} is the original frequency of the oscillator; n is an integer 1 to 256.)

T_{FRM}: $T_{STB} \times m$ ..... (m is the number of time divisions, expressed as any integer from 1 to 128.)

n: STB interval setting value

Here, value m is determined by the LCD panel used for display; however, n should be a value which satisfies the following condition:

$$t_{FRM} \leqq \frac{1}{f_{FRM}\ (MIN.)} \quad \ldots\ldots\ldots\ldots\ (A)$$

The minimum display frame frequency (f_{FRM} (MIN.)) is determined according to the LCD panel to be used. However, lowering to too low a frequency causes flicker on the LCD display. Normally, 50 to 60 Hz is the minimum frequency. Data for one row (common) should be transferred to the column (segment) driver during T_{STB}. If T_{STB} is shortened, display may move to the next row before completion of display data transfer, and thus disturb the LCD display.

Display data transfer is discussed in Section 7.2; n should be a value which satisfies the formula in 7-2 (c). The SYNC command sets the values of m and n.

7.2 Local Memory Access Timing

The LCD performs the following three types of access to the local memory.

(1) Display
(2) Data read
(3) Data write

When the STB pulse is output, display access begins so that data in the refresh memory are transferred to the LCD column (segment) driver. Once display access has been repeated for the number of bytes specified by the SYNC command, the $\overline{EOT}$ pulse is output, and display data transfer for one row terminates. The next display access is not performed until the next STB pulse is output. While the LCDC is displaying a particular display and no command is executed (that is, during the command wait state), the LCDC performs the above functions.

However, once command execution begins, data read access and data write access are performed to modify display and to read from the external character generator. These two types of access are executed through interrupts to the display access. Therefore, when data read and data write access are made, the interval between the STB pulse and $\overline{EOT}$ pulse is increased by the number of required interrupts. This is shown in Fig. 7-1. As the command is being processed, data read and data write access may be executed as necessary (even between the $\overline{EOT}$ pulse and the next STB pulse). That is, execution of these two accesses has highest priority.

However, if a command is not being processed, and the LCDC is in command wait state, the LCDC does not access the local memory between the $\overline{EOT}$ pulse and the next STB pulse. It is possible to use this timing to access the display memory directly from the host CPU by providing an external bus switching circuit.

During execution of the BLKTIN and BLKTOT commands, the frequency of the data read accesses and data write accesses will be at its highest. There is a 1:3 ratio between these two accesses and the display access.

Therefore, the time required to transfer data for one row (that is, the time (T_{TRNS}) between the STB pulse and the $\overline{EOT}$ pulse) is:

$$T_{TRNS} < \frac{4}{3}\ell \cdot T_{MCY} = \frac{10\ell}{f_{osc}}$$

To perform display normally:

$$T_{TRNS} < \frac{10\ell}{f_{osc}} \leqq T_{STB}$$

$$\frac{10}{f_{osc}} \cdot \ell \leqq T_{STB} \quad \text{..... (B)}$$

Where ℓ : Number of display data bytes in the column direction
f_{osc} : Original frequency of the oscillator
T_{MCY} : Time for one memory cycle $T_{MCY} = 7.5/f_{osc}$

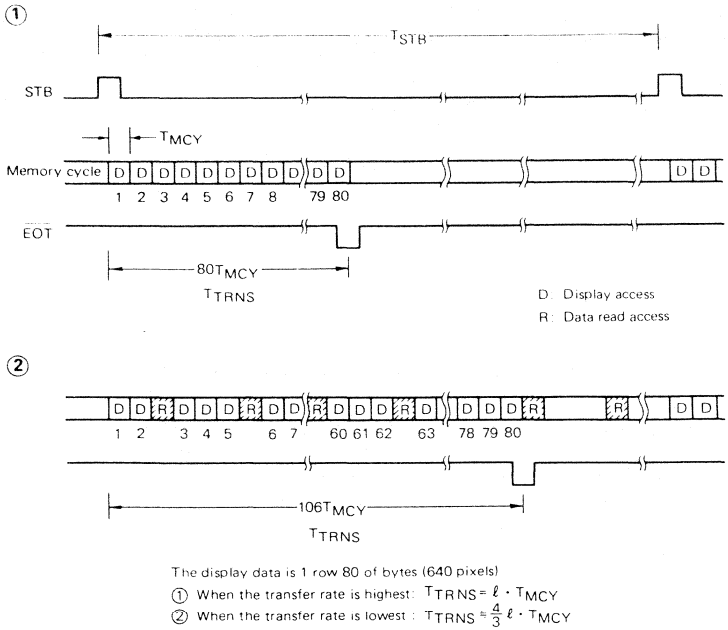


Fig. 7-1

Set the following values as the STB interval of the SYNC command according to the formulas given in 7-1 (A) and 7-2 (B).

If these values are not satisfied, the display may be disturbed or flicker will occur on the screen. This should be noted when setting the SYNC command.

$$\frac{2}{3}\ell < n \leqq \frac{f_{osc}}{15 \cdot m \cdot f_{FRM(MIN.)}} \quad \cdots\cdots\cdots \text{(C)}$$

where,

ℓ	: Display data byte length in the column direction
n	: Frequency dividing ratio to determine the STB pulse interval
m	: Number of time divisions for the display
f_{osc}	: Original frequency of the oscillator
$f_{FRM(MIN.)}$	: Minimum display frame frequency

Example:

To drive 200X640 pixels using the partitioned matrix method at 1/100 duty, when f_{osc} = 6.0 [MHz].

$f_{FRM(MIN.)}$ = 60 [Hz]:

1 byte = 8 bits

$\ell = 640 \div 8 = 80$, $m = 100$

$$\frac{2}{3}\ell = 53.3, \frac{f_{osc}}{15mf_{FRM(MIN.)}} = 66.6$$

n = 54 to 83 (decimal) is specified.

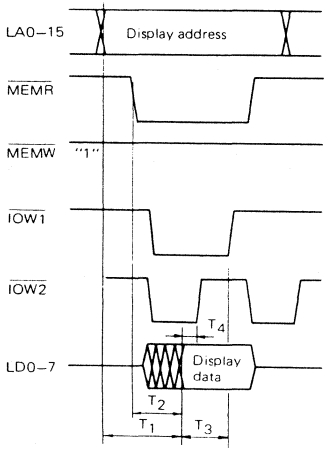
The frame frequency (f_{FRM}) is:

$$f_{FRM} = \frac{f_{osc}}{15 \cdot m \cdot n} \text{ [Hz]}$$

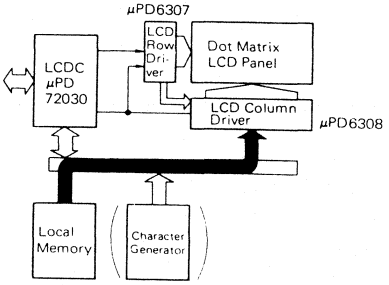
7.2.1 Display access

For display access, the display data in the refresh memory within the local memory is transferred to the LCD column driver.

The LCDC outputs the refresh memory address onto LA0 to LA15, then outputs a low level signal to $\overline{MEMR}$ to output the display data onto LD0 to LD7. Thereafter, the LCDC outputs $\overline{IOW1}$ and $\overline{IOW2}$, and directly writes the display data placed onto LD0 to LD7 to the LCD column driver. In this case, the LCDC only outputs the address and the control pulse; the LCDC does not read the display data. This can be thought of as a type of DMA transfer.



Display access timing



Data flow

T_1: Address access time
T_2: Read access time
T_3: LCD driver data set-up time (for $\overline{IOW1}$)
T_4: LCD driver data set-up time (for $\overline{IOW2}$)

The access time to the refresh memory (T_1 and T_2) should be set to correspond with the data setup time of the LCD column driver (T_3 and T_4.)

The following is why two types of write signals to the LCD column driver ($\overline{IOW1}$ and $\overline{IOW2}$) are provided:

The display data are output in 8-bit units from the refresh memory. However, the LCD column driver (μPD6308G) accepts these data only in 4-bit units. Therefore,

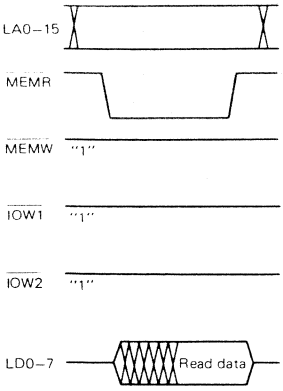
(1) $\overline{IOW1}$ is input as the LCD driver write pulse ($\overline{IOW}$) when an 8-bit display data is divided into two 4-bit units and written to the two μPD6308Gs simultaneously,

(2) $\overline{IOW2}$ is input as the LCD driver divided write pulse ($\overline{IOW}$) when an 8-bit display data is divided into its upper and lower 4 bits, and written to one μPD6308G.

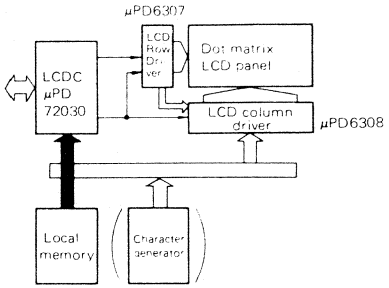
See the circuit shown in Figs. 11-2 and 11-5.

7.2.2 Data read access

During data read access, data in the local memory are read into the LCDC.



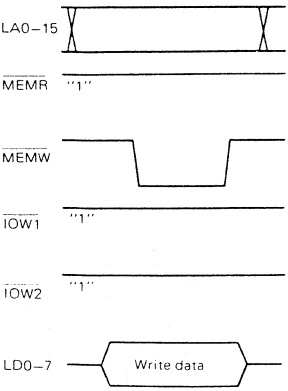
Data read access timing

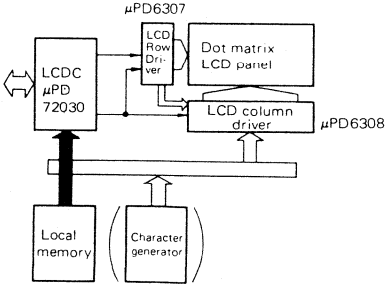


Data flow

7.2.3 Data write access

During data write access, data are written to the local memory from the LCDC.





8. OSCILLATOR

The oscillator generates a reference clock for operation of the LCDC.

As shown in Fig. 8-1, a high gain amplifier for serial resonance is internally provided. A functional clock can be generated to the LCDC by connecting to the X1 and X2 pins a resonator (crystal or ceramic), and load capacitors. The inverter and amplifier inside the LCDC create self-oscillation. An external clock can be used; however, because V_{IH} of X1 and X2 are very high, the normal TTL level cannot drive this. In addition, when an external clock is used, caution should be taken concerning standby operation.

A crystal or ceramic resonator can be used as an external resonator for self-oscillation (see Fig. 8-2).

Since the oscillator is a high frequency analog circuit operating at a frequency in the range of several megahertz, take particular care in its wiring. The resonator and load capacitors should be located very close to the X1 and X2 pins, and wiring should be as short as possible. Grounding wire for the load capacitors (C1 and C2) should be a minimum length to the V_{SS} of the LCDC. By taking these points into consideration, adverse effects to the oscillator caused by inductance and capacitance of wiring can be minimized.

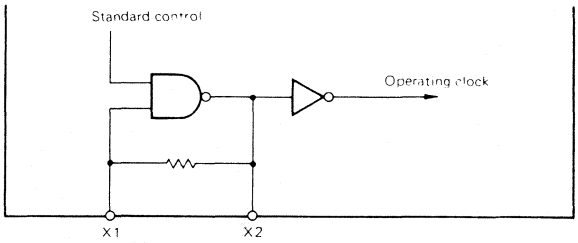


Fig. 8-1 Internal Equivalent Circuit of Oscillator

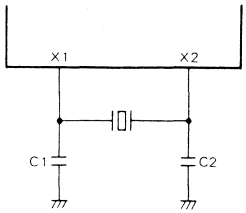


Fig. 8-2 When a Crystal or Ceramic Resonator is Used

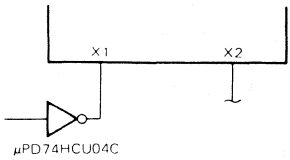


Fig. 8-3 An External Clock Input

The following crystals can be used:

External capacity: C1 = C2 $\leqq$ 50 pF

Equivalent series resistor : $R_L < 100\ \Omega$

The ceramic resonators listed below can be used.

MANUFACTURER	PRODUCT NAME	C1	C2
Murata Mfg. Co., Ltd.	CSA5.50M CSA6.0MT	30 pF ±5 %	30 pF ±5 %
Kyocera Corporation	KBR-5.5M KBR-6.0M	33 pF ±5 %	33 pF ±5 %

Note: When using a ceramic resonator, an externally connected return resistor is required. Stop current in this case increases by the portion of current that flows through the externally connected return resistor in addition to the rated value. When V_{DD}=5.5 V, the stop current increases by 5.5 μA with R_f=1 MΩ.

ELECTRICAL CHARACTERISTICS

ABSOLUTE MAXIMUM RATINGS (T_a = 25 °C)

Supply voltage	V_{DD}	V_{SS}−0.3 to +7	V
Input voltage	V_I	V_{SS}−0.3 to V_{DD}+0.3	V
Output voltage	V_O	V_{SS}−0.3 to V_{DD}+0.3	V
Operating temperature	T_{opt}	−10 to +70	°C
Storage temperature	T_{stg}	−65 to +125	°C

OPERATING CONDITIONS

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	CONDITION
Supply voltage	V_{DD1}	4.75	5.0	5.25	V	
Operating frequency	f_{opt1}			6	MHz	−10 °C ≦ T_a ≦ +70 °C
Supply voltage	V_{DD2}	4.5	5.0	5.5	V	
Operating frequency	f_{opt2}			6	MHz	−10 °C ≦ T_a ≦ +50 °C

DC CHARACTERISTICS (T_a = −10 to +70 °C, V_{DD} = 5 V ±5 %; T_a = −10 to +50 °C, V_{DD} = 5 V ±10 %)

CHARACTERISTIC	SYMBOL	RATED VALUE			UNIT	CONDITION
		MIN.	TYP.	MAX.		
Low-level input voltage	V_{IL}	−0.3		0.7	V	
High-level input voltage	V_{IH1}	2.2		V_{DD}+0.3	V	Other than $\overline{RESET}$, X1
	V_{IH2}	V_{DD}−1		V_{DD}+0.3	V	$\overline{RESET}$, X1
Low-level output voltage	V_{OL}	0		0.45	V	$\overline{IOW1}$, $\overline{IOW2}$, LD0 to 7 CKOUT, $\overline{MEMR}$, $\overline{MEMW}$ LA0 to 18, D0 to 7, $\overline{INT}$, CGEN. SPLT, DRAM, DREQ FRM, STB, $\overline{RST}$, $\overline{EOT}$, $\overline{SBY}$ I_{OL}= 1.8 mA
High-level output voltage	V_{OH}	4.0			V	$\overline{IOW1}$, $\overline{IOW2}$, LD0 to 7 CKOUT, $\overline{MEMR}$, $\overline{MEMW}$ LA0 to 18, D0 to 7, $\overline{INT}$, CGEN. SPLT, DRAM, DREQ FRM, STB, $\overline{RST}$, $\overline{EOT}$, $\overline{SBY}$ I_{OH}=−0.4 mA
Input current	I_I	−25		−3	μA	$\overline{RESET}$, $V_{IN} \leqq V_{IL}$
Input leakage current	I_{IL1}	−3		+3	μA	$\overline{TC}$, $\overline{DACK}$, $\overline{CS}$, AO, $\overline{RD}$, $\overline{WR}$ V_{IN} = 0 to V_{DD}
Output leakage current	I_{LO}	−3		+3	μA	D0 to 7, LD0 to 7 at high impedance
Current when stopped (1)	I_{STP1}		1	12.0	μA	XTAL oscillation, no load, STOP command
Current when stopped (2)	I_{STP2}		3	10	mA	f_{osc}=6.0 MHz, no load, STOP2 command
Operating current	I_{SS}		5	14	mA	f_{osc}=6.0 MHz, no load

CAPACITY (T_a = 25 °C)

CHARACTERISTIC	SYMBOL	RATED VALUE			UNIT	CONDITION
		MIN.	TYP.	MAX.		
Input capacity	C_I		7	12	pF	f_{osc}=1 MHz
Input/Output capacity	C_{IO}		7	12	pF	V_{osc}=0.1 V

AC CHARACTERISTICS FOR MPU (T_a = −10 to +70 °C, V_{DD} = 5 V ±5 % / T_a = −10 to +50 °C, V_{DD} = 5 V ±10 %)

CHARACTERISTIC	SYMBOL	RATED VALUE			UNIT	CONDITION
		MIN.	TYP.	MAX.		
$\overline{DACK}$, $\overline{CS}$, A0 setup time for $\overline{RD}$↓	t_{AR}	0			ns	
$\overline{DACK}$, $\overline{CS}$, A0 hold time for $\overline{RD}$↑	t_{RA}	0			ns	
$\overline{RD}$ pulse width	t_{RR}	250			ns	
$\overline{DACK}$, $\overline{CS}$ A0→Data output delay	t_{AD}			300	ns	C_L=150 pF
$\overline{RD}$→Data output delay	t_{RD}			250	ns	
$\overline{RD}$↑→Data floating delay	t_{DF}	10		120	ns	(Note)
$\overline{DACK}$, $\overline{CS}$, A0 setup time for $\overline{WR}$↓	t_{AW}	0			ns	
$\overline{DACK}$, $\overline{CS}$, A0 hold time for $\overline{WR}$↑	t_{WA}	0			ns	
$\overline{WR}$ pulse width	t_{WW}	160		$15/f_{osc}$	ns	
Data setup time for $\overline{WR}$↑	t_{DW}	100			ns	
Data hold time for $\overline{WR}$↑	t_{WD}	70			ns	
$\overline{TC}$ pulse width	t_{TC}	100			ns	
$\overline{TC}$↓→D R E Q clear	t_{CDQ}			200	ns	C_L=80 pF
$\overline{RD}$, $\overline{WR}$↓→$\overline{TC}$↑	t_{RT}	100			ns	
$\overline{TC}$↓→$\overline{RD}$, $\overline{WR}$↑	t_{TR}	100			ns	
DREQ↑→$\overline{DACK}$	t_{DD}	0			ns	C_L=80 pF
$\overline{DACK}$ pulse width	t_{DACK}	300			ns	

Note: Measuring point

V_{OH}=V_{DD}−0.5 V

V_{OL}=0.5 V

FOR LOCAL BUS

CHARACTERISTIC	SYMBOL	RATED VALUE			UNIT	CONDITION
		MIN.	TYP.	MAX.		
LA setup time for $\overline{MEMR}\downarrow$ *1	t_{LMR}	60			ns	C_L=100 pF
LA hold time for $\overline{MEMR}\uparrow$ *1	t_{MRL}	100			ns	
$\overline{MEMR}$ pulse width	t_{MRR}	660			ns	
$\overline{MEMR}$ cycle	t_{CYM}		1250		ns	
$\overline{MEMR}\uparrow$ → $\overline{MEMR}\downarrow$	$t_{MR(H)}$	250			ns	
LA → $\overline{IOW1}\uparrow$	$t_{AD(1)}$	610			ns	
$\overline{MEMR}\uparrow$ → $\overline{IOW1}\uparrow$	$t_{MRD(1)}$	400			ns	
$\overline{MEMR}$ hold time for $\overline{IOW1}\uparrow$	t_{MRI1}	50			ns	
$\overline{MEMR}$ setup time for $\overline{IOW1}\downarrow$	t_{IMR1}	160			ns	
$\overline{IOW1}$ pulse width	t_{II1}	240			ns	
$\overline{IOW1}$ cycle	t_{CY1}	1100			ns	
CKOUT pulse width	t_{FF}	130			ns	
CKOUT cycle	t_{CY3}		2500		ns	
$\overline{MEMR}\downarrow$ → CKOUT↓	t_{MRF}	450			ns	
CKOUT↑ → $\overline{MEMR}\downarrow$	t_{FMR}	200			ns	
$\overline{MEMR}\downarrow$ → data delay time	t_{MRD}			430	ns	C_{LBUS}=200 pF, C_L=100 pF
$\overline{MEMR}\uparrow$ → data hold time	t_{MH}	0			ns	
Data delay time for LA*	t_{AD1}			500	ns	
LA setup time for $\overline{MEMW}\downarrow$*	t_{LMW}	200			ns	C_L=100 pF
LA hold time for $\overline{MEMW}\uparrow$*	t_{MWL}	190			ns	
$\overline{MEMW}$ pulse width	t_{MWW}	400			ns	
Data delay time for LA*	t_{AD2}			270	ns	C_{LBUS}=200 pF, C_L=100 pF
Data setup time for $\overline{MEMW}\downarrow$	t_{DMW1}	10			ns	
Data setup time for $\overline{MEMW}\uparrow$	t_{DMW2}	580			ns	
Data hold time for $\overline{MEMW}\uparrow$	t_{MWD}	85			ns	C_L=100 pF *2
STB pulse width	t_{STB}	360			ns	C_L=100 pF
STB↑ → $\overline{IOW1}\downarrow$	t_{SW1}	530			ns	
$\overline{IOW1}\uparrow$ → $\overline{EOT}$	t_{W1E}	0			ns	
$\overline{EOT}$ pulse width	t_{EOT}	360			ns	
FRM ($\overline{SBY}$, $\overline{RST}$) → STB↓	t_{FS}	720			ns	
LA → $\overline{IOW2}\uparrow$	$t_{AD(2)}$	400			ns	
$\overline{MEMR}\downarrow$ → $\overline{IOW2}\uparrow$	$t_{MRD(2)}$	220			ns	
$\overline{MEMR}\downarrow$ → $\overline{IOW2}\downarrow$	t_{MRI2}	0			ns	
$\overline{IOW2}\uparrow$ → MEMR↓	t_{IMR2}	140			ns	
$\overline{IOW2}$ pulse width	t_{II2}	150			ns	
$\overline{IOW2}$ cycle	t_{CY2}	500			ns	
$\overline{IOW1}\uparrow$ → $\overline{IOW2}\downarrow$	t_{I12}	50			ns	
$\overline{IOW2}\uparrow$ → $\overline{IOW1}\uparrow$	t_{I21}	70			ns	
STB↑ → $\overline{IOW2}\downarrow$	t_{SW2}	450			ns	

*1: Includes CGEN and SPLT pins

*2: Measuring point $V_{OH}=V_{DD}-0.5$ V
$V_{OL}=0.5$ V

TIMING DEFINITION OF BUS DEPENDIENT ON t_{CY}

CHARACTERISTIC	SYMBOL	RATED VALUE			UNIT	CONDITION
		MIN.	TYP.	MAX.		
LA setup time for $\overline{MEMW}\downarrow$ *	t_{LMR}	$1/f_{osc}-106$			ns	C_L=100 pF
LA hold time for $\overline{MEMR}\uparrow$ *	t_{MRL}	$1.5/f_{osc}-150$			ns	
$\overline{MEMR}$ pulse width	t_{MRR}	$5/f_{osc}-170$			ns	
$\overline{MEMR}$ cycle	t_{CYM}		$7.5/f_{osc}$		ns	
$\overline{MEMR}\uparrow$ → $\overline{MEMR}\downarrow$	$t_{MR(H)}$	$2.5/f_{osc}-166$			ns	
LA → $\overline{IOW1}\uparrow$	$t_{AD(1)}$	$5/f_{osc}-223$			ns	
$\overline{MEMR}\uparrow$ → $\overline{IOW1}\uparrow$	$t_{MRD(1)}$	$4/f_{osc}-266$			ns	
$\overline{MEMR}$ setup time for $\overline{IOW1}\downarrow$	t_{MRI1}	$1.5/f_{osc}-200$			ns	
$\overline{MEMR}$ hold time for $\overline{IOW1}\uparrow$	t_{IMR1}	$1/f_{osc}-13$			ns	
$\overline{IOW1}$ pulse width	t_{II1}	$2.5/f_{osc}-176$			ns	
$\overline{IOW1}$ cycle	t_{CY1}	$7.5/f_{osc}-150$			ns	
CKOUT pulse width	t_{FF}	$1.5/f_{osc}-120$			ns	
CKOUT cycle	t_{CY3}		$15/f_{osc}$		ns	
MEMR↓ → CKOUT↓	t_{MRF}	450			ns	
CKOUT↑ → $\overline{MEMR}\downarrow$	t_{FMR}	200			ns	
$\overline{MEMR}\downarrow$ → Data delay time	t_{MRD}			$5/f_{osc}-400$	ns	C_{LBUS}=200 pF, C_L=100 pF
$\overline{MEMR}\uparrow$ → Data hold time	t_{MH}	0			ns	
Deta delay time for LA*	t_{AD1}			$7/f_{osc}-666$	ns	
LA setup time for $\overline{MEMR}\downarrow$ *	t_{LMW}	$2.5/f_{osc}-216$			ns	C_L=100 pF
LA hold time for $\overline{MEMW}\uparrow$ *1	t_{MWL}	$1.5/f_{osc}-60$			ns	
$\overline{MEMW}$ pulse width	t_{MWW}	$3.5/f_{osc}-183$			ns	
Data delay time for LA *1	t_{AD2}			$1.5/f_{osc}+20$	ns	C_{LBUS}=200 pF, C_L=100 pF
Data setup time for $\overline{MEMW}\downarrow$	t_{DMW1}	$1/f_{osc}-166$			ns	
Data setup time for $\overline{MEMW}\uparrow$	t_{DMW2}	$4.5/f_{osc}-170$			ns	
Data hold time for $\overline{MEMW}\uparrow$	t_{MWD}	$1/f_{osc}-81$			ns	C_L=100 pF
STB pulse width	t_{STB}	$3/f_{osc}-140$			ns	
STB↑ → $\overline{IOW1}\downarrow$	t_{SW1}	$4/f_{osc}-136$			ns	
$\overline{IOW1}\uparrow$ → $\overline{EOT}$	t_{W1E}	$1/f_{osc}-166$			ns	
$\overline{EOT}$ pulse width	t_{EOT}	$3/f_{osc}-140$			ns	
FRM ($\overline{SBY}$, $\overline{RST}$) → STS↓	t_{FS}	$6/f_{osc}-280$			ns	
LA → $\overline{IOW2}\uparrow$	$t_{AD(2)}$	$4/f_{osc}-266$			ns	
$\overline{MEMR}\downarrow$ → $\overline{IOW2}\uparrow$	$t_{MRD(2)}$	$3/f_{osc}-280$			ns	
$\overline{MEMR}\downarrow$ → $\overline{IOW2}\downarrow$	t_{MRI2}	$1.5/f_{osc}-250$			ns	
$\overline{IOW2}\uparrow$ → $\overline{MEMR}\downarrow$	t_{IMR2}	$1/f_{osc}-26$			ns	
$\overline{IOW2}$ pulse width	t_{II2}	$1.5/f_{osc}-100$			ns	
$\overline{IOW2}$ cycle	t_{CY2}	$3.5/f_{osc}-83$			ns	
$\overline{IOW1}\uparrow$ → $\overline{IOW2}\downarrow$	t_{I12}	$1/f_{osc}-116$			ns	
$\overline{IOW2}\uparrow$ → $\overline{IOW1}\uparrow$	t_{I21}	$1/f_{osc}-96$			ns	
STB↑ → $\overline{IOW2}\downarrow$	t_{SW2}	$4/f_{osc}-216$			ns	

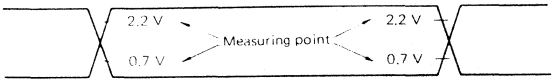
*1: Includes CGEN and SPLT pins

*2: $f_{osc}=f_{opt1}=f_{opt2}$

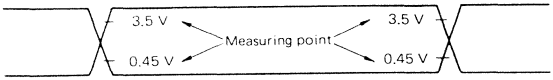
FOR CLOCK

CHARACTERISTIC	SYMBOL	CALCULATION FORMULA			UNIT	CONDITION
		MIN.	TYP.	MAX.		
X 1 cycle time	t_{CY}	166			ns	
X 1 pulse width (H)	t_{CH}	50			ns	
X 1 pulse width (L)	t_{CL}	80			ns	
X 1 rise time	t_{CR}			20	ns	
X 1 fall time	t_{CF}			20	ns	

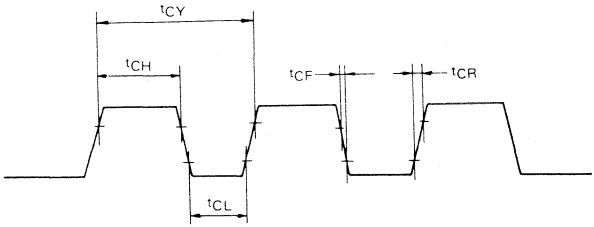
Test Input Measuring Point (excluding X1)



Test Output Measuring Point

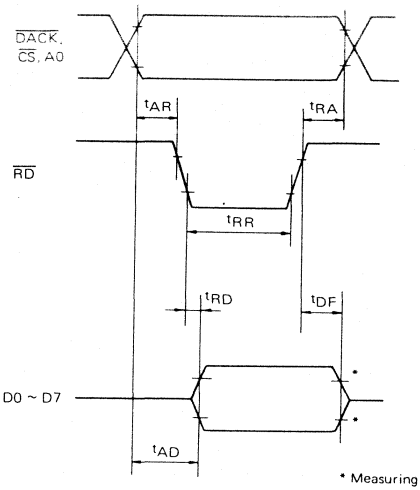


Clock Timing



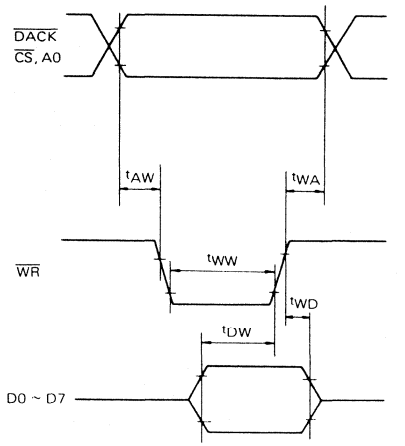
System Bus Timing

Read timing

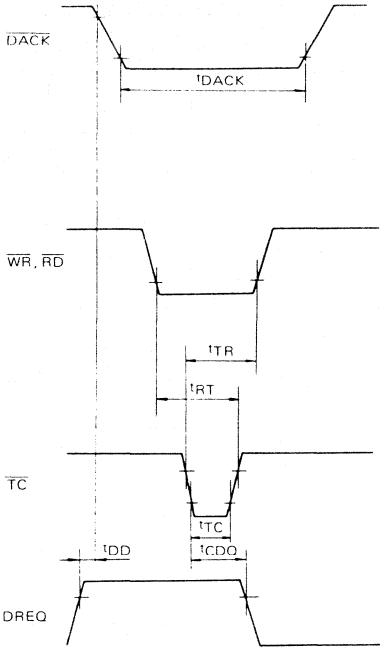


* Measuring point $V_{OH}=V_{DD}-0.5$ V
$V_{OL}=0.5$ V

Write timing

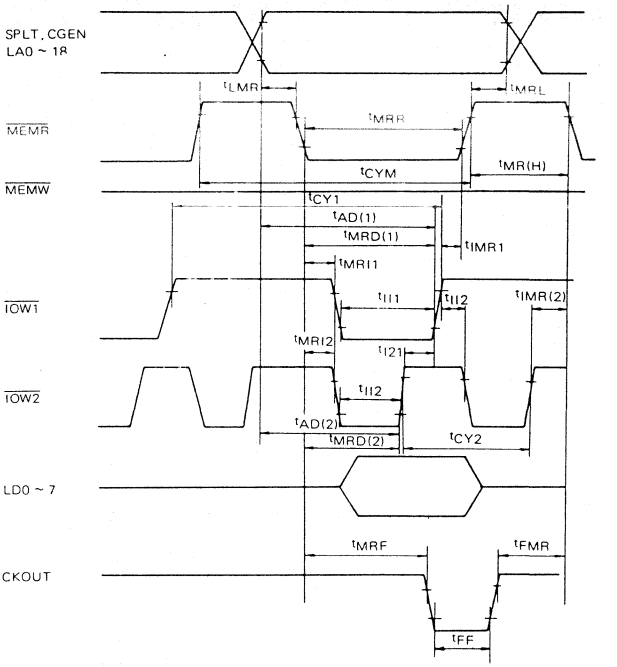


DMA timing

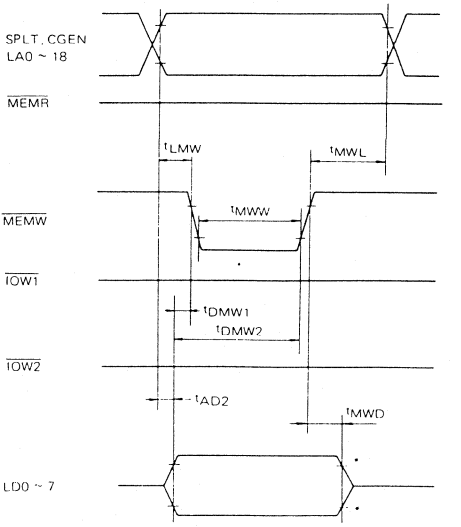


Local Bus Timing

Display timing (1)



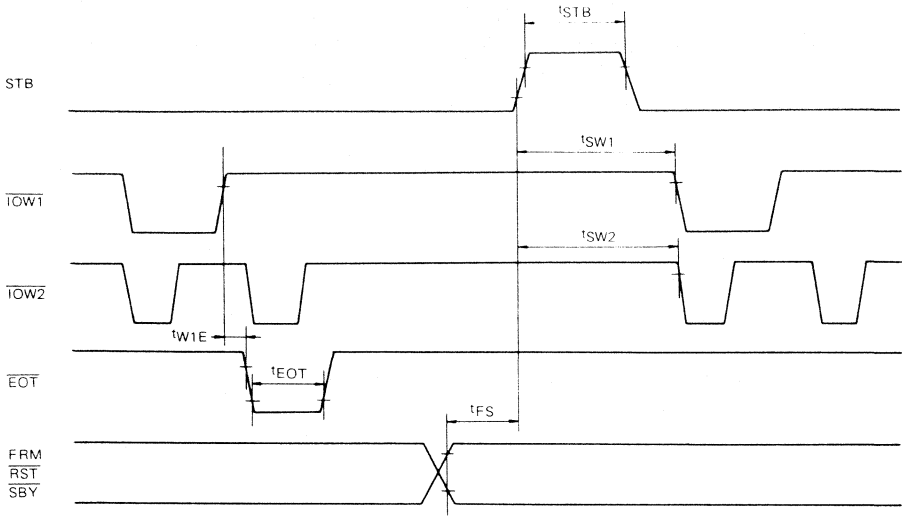
Write timing



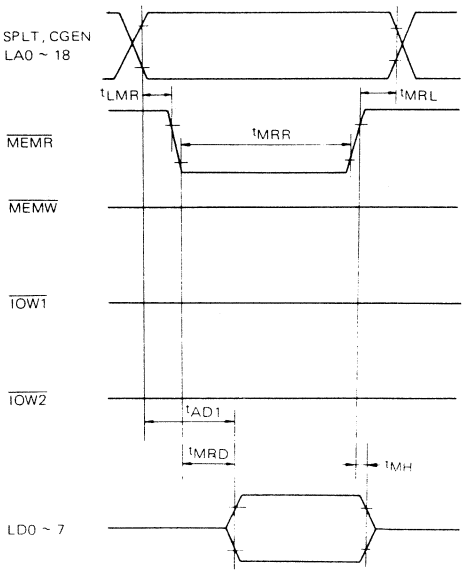
* Measuring point $V_{OH}=V_{DD}-0.5$ V
$V_{OL}=0.5$ V

Note: Since this product is MOS IC, do not use in such environment with high charging property.

Display timing (II)



Read timing

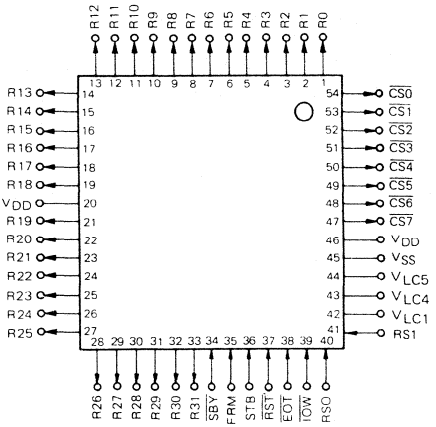


The μPD6307G is an IC for driving row signals of a heavy-duty, dot-matrix LCD. It is provided with 32 high-voltage outputs per package and is capable of driving up to a 128-row LCD by cascading four packages.

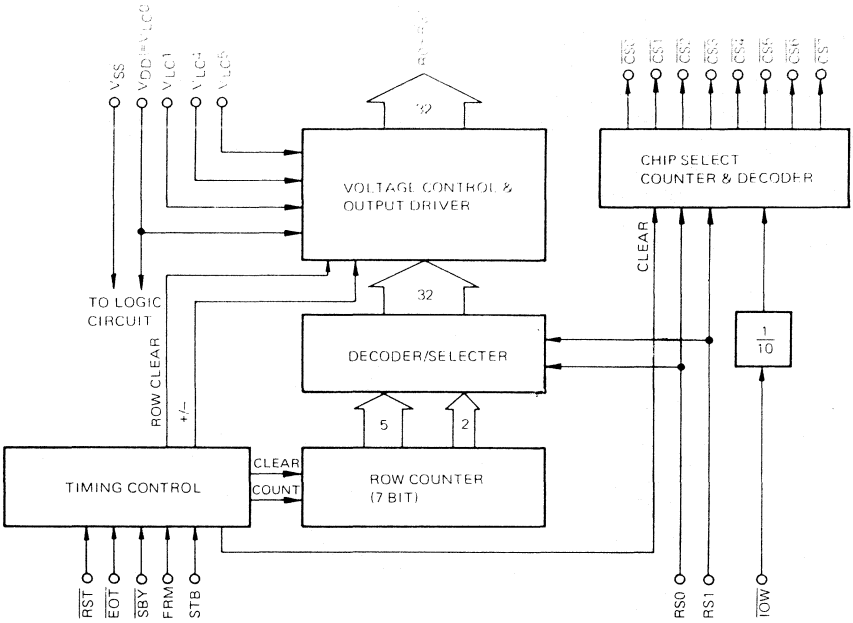
FEATURES

- High-voltage output: +20 V MAX.
- Up to four packages that can be cascaded to drive a 128-row LCD
- Generates chip-select signal for column driver: 8 outputs/chip
- Can be directly controlled by LCD controller μPD72030G
- CMOS technology
- Single +5 V logic power supply
- 54-pin plastic flat package (0.65-mm pitch)

PIN CONFIGURATION (TOP VIEW)



BLOCK DIAGRAM



1. PIN DESCRIPTION

1.1 FRM (Frame) . . . Input

This pin inputs row-drive AC signals. "H" displays the positive frame and "L" displays the negative frame. At the "H" to "L" or "L" to "H" transition, the row counter is cleared and the row-drive is started from row 0 (R0).

1.2 STB (Strobe) . . . Input

This pin inputs the row-drive signal strobe. Advances one row-drive signal at each leading edge of the STB input.

1.3 $\overline{IOW}$ (I/O Write) . . . Input

This pin inputs the chip-select count up signal. Advances one chip-select count after each group of 10 $\overline{IOW}$ pulses input.

1.4 $\overline{EOT}$ (End of Transfer) . . . Input

This pin inputs chip-select counter clear signal. Clears the chip-select counter by a low-level input.

1.5 RS0, RS1 (Row Select) . . . Input

This pin inputs row-driver cascade-connected select signals. Expandable up to 128 row-drive signal outputs and 32 chip-select outputs.

RS1	RS0	Row signal input	Chip-select output
0	0	R0 – R31	$\overline{CS0}$ – $\overline{CS7}$
0	1	R32 – R63	$\overline{CS8}$ – $\overline{CS15}$
1	0	R64 – R95	$\overline{CS16}$ – $\overline{CS23}$
1	1	R96 – R127	$\overline{CS24}$ – $\overline{CS31}$

1.6 $\overline{CS0}$ to $\overline{CS7}$ (Chip Select) . . . Output

This pin outputs chip-select signals for the column driver. These outputs are generated by the chip-select counter and RS0, RS1.

1.7 $\overline{RST}$ (Reset) . . . Input

This pin inputs the row-driver reset signal. When a low-level signal is input, the internal counter is cleared, all the row outputs R0 to R31 become non-select, and $\overline{CS0}$ to $\overline{CS7}$ outputs are set to high level.

1.8 $\overline{SBY}$ (Stand-by) . . . Input

This pin inputs the stand-by signal. When a low-level signal is input, the row outputs R0 to R31 are set to $V_{LC}0$. It is necessary to set all column-driver display data to 1 before entering the stand-by mode.

1.9 R0 to R31 (Row-Drive Outputs) . . . Output

This pin outputs row-drive signals. This is the LCD panel row (common) line-drive output.

1.10 $V_{LC}1$, $V_{LC}4$, $V_{LC}5$ (LCD Drive Supply) . . . Power supply

The LCD reference voltages reference the V_{DD} pin. These pins provide drive voltages for row-drive outputs.

1.11 V_{DD} (=$V_{LC}0$) (Logic Supply and LCD Drive Supply) . . . Power supply

This is a pin common to the logic power supply and LCD reference voltage. Connect the power supply (+5 V) across pins V_{DD} and V_{SS} for logic circuit operation. This pin is also used for the row-drive signal output-drive voltage.

1.12 V_{SS} (Logic Ground) . . . GND

This is logic ground pin.

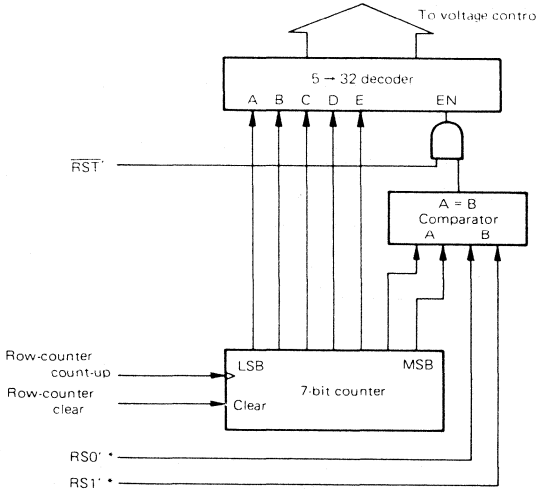
2. INTERNAL BLOCK FUNCTIONS

2.1 Timing Control Circuit

This circuit controls the timing necessary to operate each of the internal blocks. FRM, RS0, RS1, $\overline{RST}$, and $\overline{SBY}$ are sampled by this circuit at the leading edge of the STB, then supplied to the internal circuits.

2.2 Row-Counter, Decoder/Select Circuit

This circuit has a 7-bit counter to accommodate up to 128 segments. R0 to R31 become non-selected if the upper 2 bits of the counter do not match RS0 and RS1. If they match, one of R0 to R31, which is indicated by the lower 5 bits of the row counter, is selected. The remaining 31 outputs remain non-selected.



EN	E	D	C	B	A	Selected row signal
1	0	0	0	0	0	R0
1	0	0	0	0	1	R1
			⋮			
1	1	1	1	1	0	R30
1	1	1	1	1	1	R31
0	X	X	X	X	X	None

*** RS0', RS1', and $\overline{RST}$' are obtained by synchronizing RS0, RS1, and $\overline{RST}$ with STB.**

The rows become active in the order of R0, R1, R2, . . . R31.

2.3 Voltage-Control Driver Circuit

This circuit generates the row (common) signals for driving the LCD panel with AC. The following levels are output on R0 to R31.

	+ (FRM*'=1)	− (FRM'=0)
Select	$V_{LC}0$	$V_{LC}5$
Non-select	$V_{LC}4$	$V_{LC}1$

$\overline{RST}$ = Low level sets the output as non-select.

$\overline{SBY}$ = Low level sets the output $V_{LC}0$.

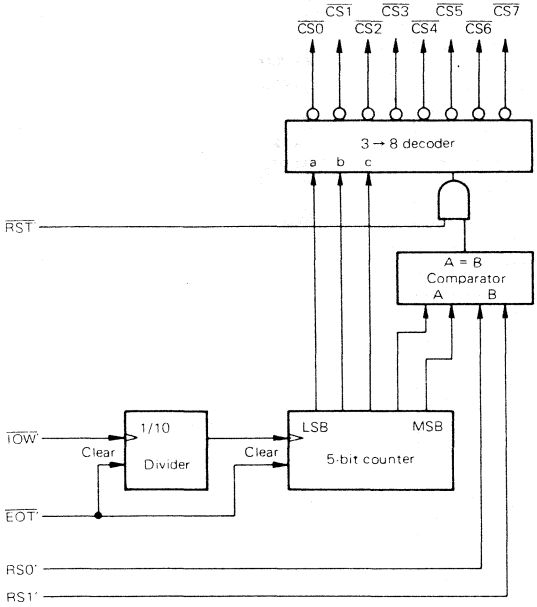
FRM' are obtained by internally synchronizing the FRM signal with the leading edge of the STB signal.

2.4 Chip-select Counter, Decoder Circuit

This circuit is the column-driver chip-select signal. It has a 5-bit counter so that up to 32 chip-select signals can be generated. A count signal of this counter obtained by dividing $\overline{IOW}$ by the 1/10 divider.

If the upper 2 bits of the chip-select counter do not match $\overline{RS0}$ and $\overline{RS1}$, all the outputs $\overline{CS0}$ to $\overline{CS7}$ are set to high level. If they match, one of $\overline{CS0}$ to $\overline{CS7}$ (indicated by the lower 3 bits of the chip-select counter) becomes low level.

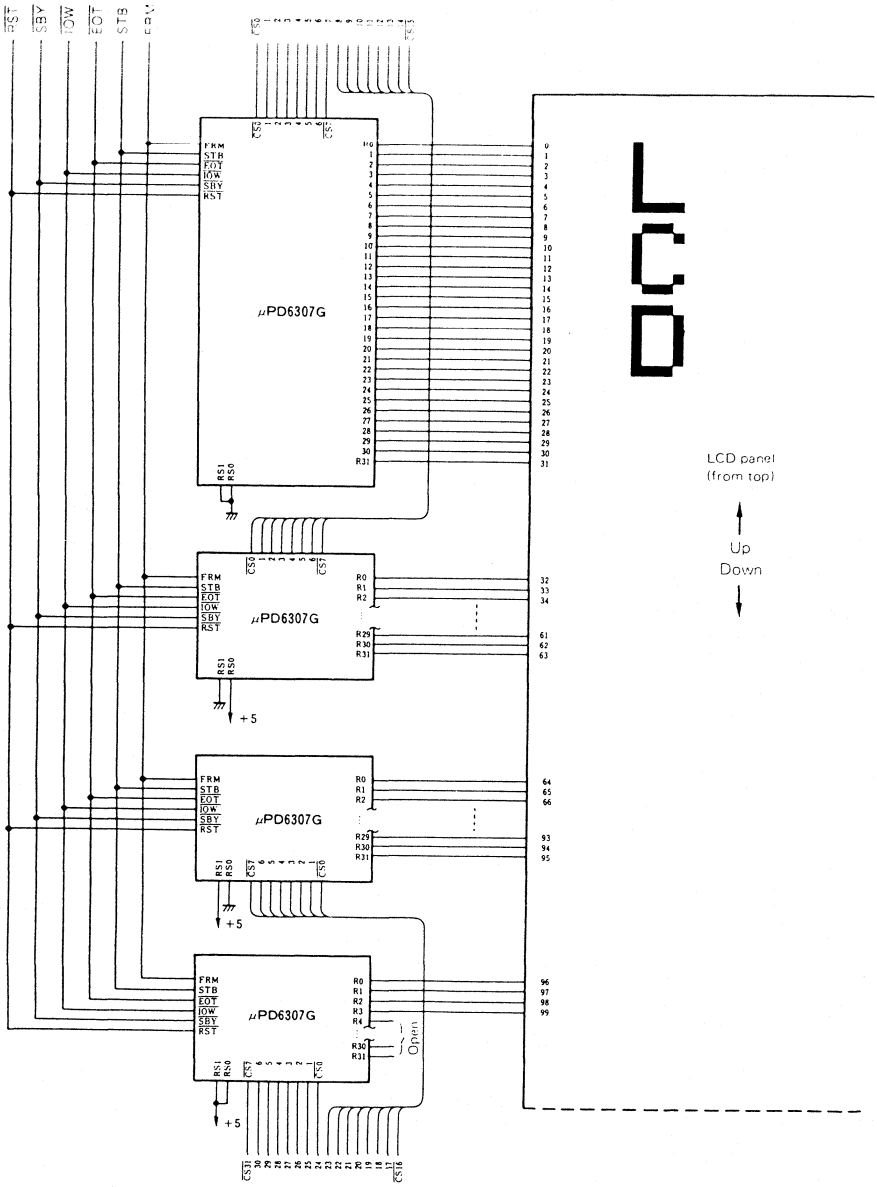
If $\overline{RST}$ is low level, all $\overline{CS0}$ to $\overline{CS7}$ become high level.



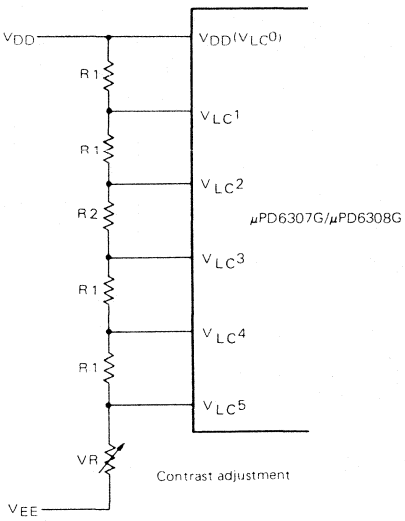
EN				Active chip select
	c	b	a	
1	0	0	0	$\overline{CS0}$
1	0	0	1	$\overline{CS1}$
1	0	1	0	$\overline{CS2}$
1	0	1	1	$\overline{CS3}$
1	1	0	0	$\overline{CS4}$
1	1	0	1	$\overline{CS5}$
1	1	1	0	$\overline{CS6}$
1	1	1	1	$\overline{CS7}$
0	X	X	X	None

3. APPLICATION EXAMPLE

3.1 Row (common) Signal Driver Circuit (1/100 duty)



3.2 Example of LCD Drive Power Supply Circuit (with split resistors)



NOTE: 1. R1 and R2 differ depending on the LCD panel to be used. For example, at 1/128 duty, R2 becomes 8 · R1

2. It is necessary to keep the following relation: $V_{DD} \geq V_{LC1} \geq V_{LC2} \geq V_{LC3} \geq V_{LC4} \geq V_{LC5} \geq V_{EE}$

4. ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATING

CHARACTERISTIC	SYMBOL	CONDITION	RATING	UNIT	REMARK
Supply voltage (1)	$V_{DD}-V_{SS}$		7	V	
Supply voltage (2)	$V_{DD}-V_{LC5}$		23	V	
Output voltage (1)	V_O1		$V_{LC5}-0.3\sim V_{DD}+0.3$	V	1
Output voltage (2)	V_O2		$V_{SS}-0.3\sim V_{DD}+0.3$	V	2
Input voltage (1)	V_I1		$V_{LC5}-0.3\sim V_{DD}+0.3$	V	3
Input voltage (2)	V_I2		$V_{SS}-0.3\sim V_{DD}+0.3$	V	4
Operating temperature	T_{opt}		$-10\sim+70$	°C	
Storage temperature	T_{stg}		$-65\sim+125$	°C	

Note: (1) Applies to output pins R0 to R31

(2) Applies to output pins other than R0 to R31

(3) Applies to input pins $V_{LC}0$, $V_{LC}1$, $V_{LC}4$, $V_{LC}5$

The following relation must be kept

$V_{LC}0 \geq V_{LC}1 \geq V_{LC}2 \geq V_{LC}3 \geq V_{LC}4 \geq V_{LC}5$

(4) Applies to input pins other than $V_{LC}0$, $V_{LC}1$, $V_{LC}4$, $V_{LC}5$

DC CHARACTERISTICS ($T_a=-10\sim+70$ °C, $V_{DD}-V_{SS}=5$ V ± 10 %, $V_{DD}-V_{LC5}=8\sim20$ V)

CHARACTERISTIC	SYMBOL	CONDITION	RATING			UNIT
			MIN.	TYP.	MAX.	
High-level input voltage	$V_{IH}1$	Excluding FRM	0.7 V_{DD}		V_{DD}	V
High-level input voltage	$V_{IH}2$	FRM	3.8		V_{DD}	V
Low-level input voltage	V_{IL}		V_{SS}		0.3 V_{DD}	V
High-level output voltage	V_{OH}	$\overline{CS}$, $I_{OH}=-500$ μA	4.0			V
Low-level output voltage	V_{OL}	$\overline{CS}$, $I_{OL}=500$ μA			0.5	V
Output-on resistor (R0~R31)	R_{ON}	Load=±100 μA, $V_{DD}-V_{LC5}=20$ V $V_{Bias}=\frac{1}{2}(V_{DD}-V_{LC5})$			0.8	kΩ
Input leakage current	$I_{L}1$	$V_{IN}=V_{DD}$, V_{SS}	−3		+3	μA
ROW output leakage current	I_{EL}	$V_{DD}=5$ V, $V_{DD}-V_{LC5}=20$ V			5	μA
Power consumption	P	No load			5	mW
Input capacity	C_{IN}	$V_{DD}=5$ V, f=1 MHz, $T_a=25$ °C			4	pF

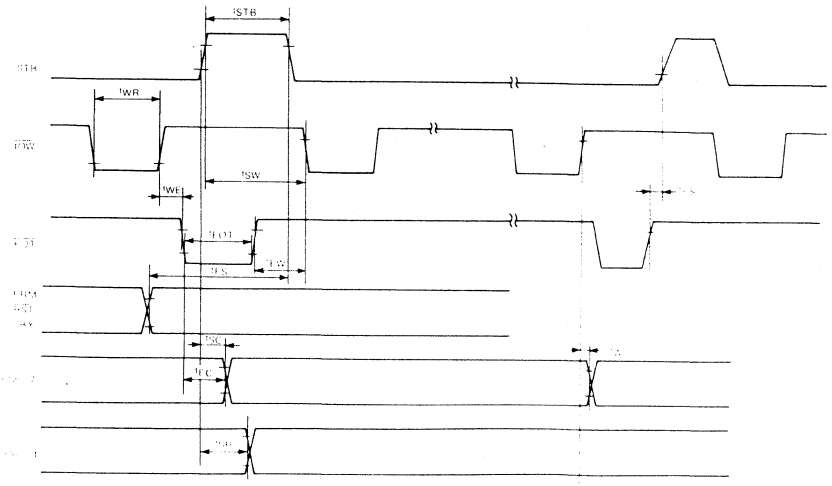
AC CHARACTERISTICS (T_a = −10 ~ +70 °C, $V_{DD}-V_{SS}$ = 5 V ± 10 %, $V_{DD}-V_{LC5}$ = 8 ~ 20 V)

CHARACTERISTIC	SYMBOL	CONDITION	RATING			UNIT	RE-MARK
			MIN.	TYP.	MAX.		
Operating frequency	f_C	$\overline{IOW}$ cycle			2.5	MHz	1
STB pulse width	t_{STB}		250			ns	
FRM, $\overline{RST}$, $\overline{SBY}$ → STB ↓	t_{FS}		500			ns	
$\overline{IOW}$ pulse width	t_{WR}		150			ns	
$\overline{IOW}$ ↑ → $\overline{EOT}$ ↓	t_{WE}		0			ns	
$\overline{EOT}$ pulse width	t_{EOT}		250			ns	
$\overline{EOT}$ ↓ → $\overline{CS0}$ ↓	t_{EC}	C_L = 25 pF			850	ns	
STB ↑ → R0~R31 outputs	t_{SR}	No load $V_{DD}-V_{LC5}$ = 20 V			2.5	μs	
STB ↑ → $\overline{CS0}$ ↓	t_{SC}	C_L = 25 pF			330	ns	
$\overline{IOW}$ ↑ → $\overline{CS0}$~$\overline{CS7}$ outputs	t_{WC}	C_L = 25 pF	100		850	ns	
STB ↑ → $\overline{IOW}$ ↓	t_{SW}		300			ns	
$\overline{EOT}$ ↑ → $\overline{STB}$ ↑	t_{ES}		350			ns	
$\overline{EOT}$ ↑ → $\overline{IOW}$ ↓	t_{EW}		500			ns	

Note:

(1) When using $\overline{IOW2}$ of the LCD controller μPD72030G, use μPD72030G at its operating frequency f_{OSC} = 3.0 MHz or lower.

Timing Waveform

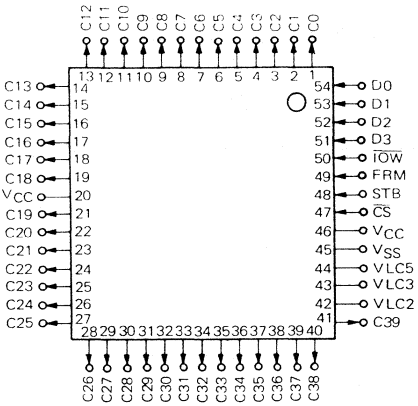


The μPD6308G LCD Column driver can drive multiplexed Dot-matrix LCD. It can directly drives any multiplexed LCD organized as up to 40 columns, and easily cascadable fitting to the user's system.

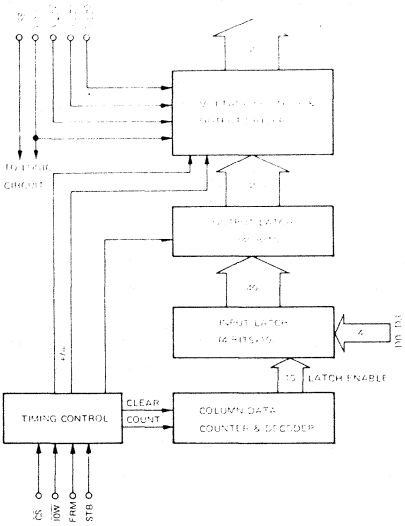
FEATURES

- High voltage output 21V max
- 40-column (segment) output and cascadable
- Can be directly controlled by the LCD controller, μPD72030G
- CMOS technology
- Single +5V logic power supply
- 54-pin plastic flat package (0.65 mm pitch)

PIN CONNECTION (Top View)



μPD6308G BLOCK DIAGRAM



1. PIN FUNCTIONS

1.1 FRM (Frame) . . . . . input

The frame signal input: "H" displays the positive frame and "L" displays the negative frame.

1.2 STB (Strobe) . . . . . input

The column-drive signal strobe input: At the leading edge of the STB input, the 40-bits display data in the input latch is transferred to the output latch to appear in the column-dirve output.

1.3 $\overline{IOW}$ (I/O Write) . . . . . input

The data-write signal: If the $\overline{CS}$ is low-level, the data on D0—D3 is written into the input latch at the low-level of $\overline{IOW}$.

1.4 $\overline{CS}$ (Chip Select) . . . . . input

The chipselect signal: It is connected to the chipselect output of the μPD6307G row driver as the $\overline{IOW}$-enable signal.

1.5 D0—D3 (Data Input) . . . . . input

The display-data input bus: The data in the 40-bits input latch is written via this data bus 4bits at a time (a total of 10 times).

1.6 C0—C39 (Column-drive Output) . . . . . output

The column-drive output, i.e., LCD panel column (segment) line-drive output.

1.7 $V_{LC}2$, $V_{LC}3$, $V_{LC}5$ (LCD-Drive Supply) . . . . . power supply

LCD reference voltages: These voltages drive the column-drive outputs.

1.8 V_{CC} (= $V_{LC}0$) (Logic supply and LCD-drive supply) . . . . . power supply

The logic power supply and LCD reference voltage. Connect the power supply (+5 V) between V_{CC} and V_{SS}. It is also used for the column-drive voltage input.

1.9 V_{SS} (Logic Ground) . . . . . GND

Logic GND pin.

2. INTERNAL BLOCK FUNCTIONS

2.1 Timing Control Circuit

This circuit controls the timing necessary to operate each internal block.

2.2 Column-Data Counter/Decoder Circuit

This decimal counter/decoder circuit generates latch pulses to send to the input-latch circuit which latches 40-bits data, 4bits at a time (total of 10 times). Since one of the decoder output becomes active only when the $\overline{CS}$ is at a low-level, the number of outputs can be increased by the control of the $\overline{CS}$ by cascading the μPD6308G chips. The counter value is counted up at leading edge of the $\overline{IOW}$, and cleared when the $\overline{CS}$ goes high-level.

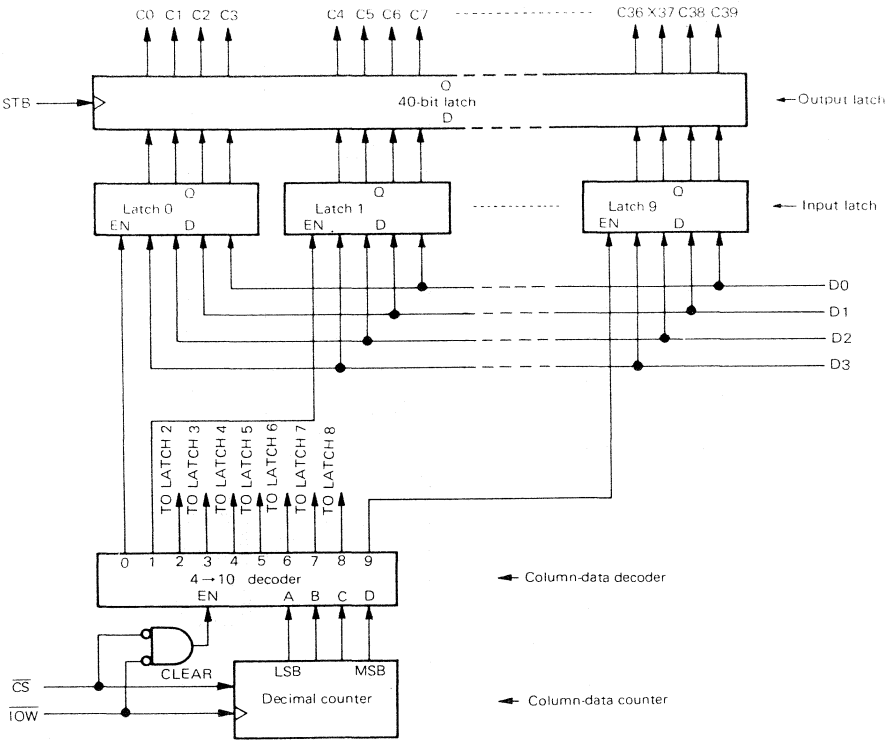
2.3 Input Latch Circuit

This circuit latches display data 4-bits at a time to obtain 40-bits display data. Data on data bus D0–D3 is latched in the order of latch 0, latch 1, . . . , latch 9 by the latch signal generated by the column-data counter/decoder each time the IOW is inputted if the CS is low-level. Therefore, the 40-bits display data is latched by the input latch circuit, sending 10 write pulses (active low) to IOW after setting the CS to low-level.

2.4 Output Latch Circuit

After all the 40-bits display data is latched by the input latch circuit, the output latch circuit output the display data to the drive circuit in sync with the STB signal.

The 40 bits outputs from the input latch circuit are transferred to the output latch circuit at the leading edge of the STB signal and appear on the column drive outputs. Note that D0 is to be C3, D3 to be C0, and so on.

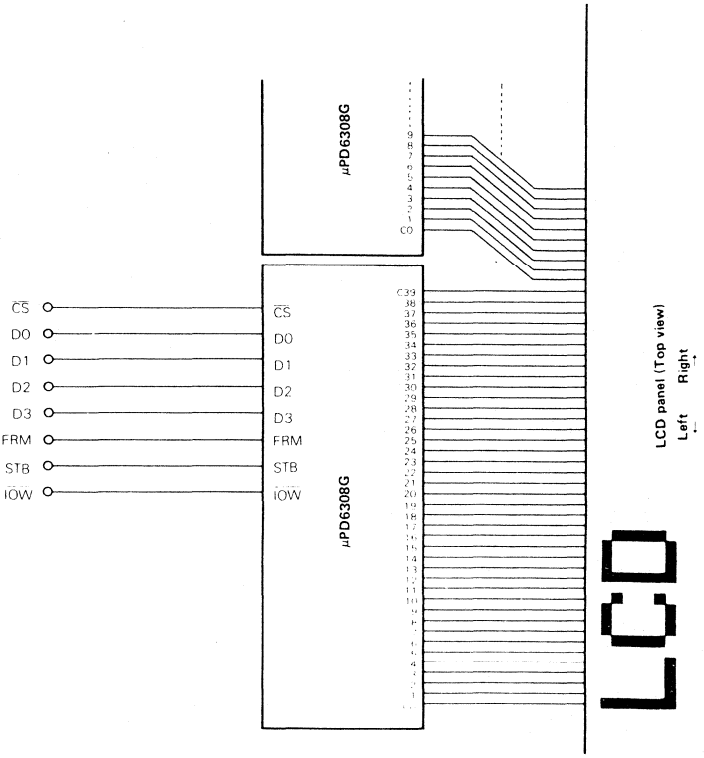


2.5 Voltage Control, Driver Circuit

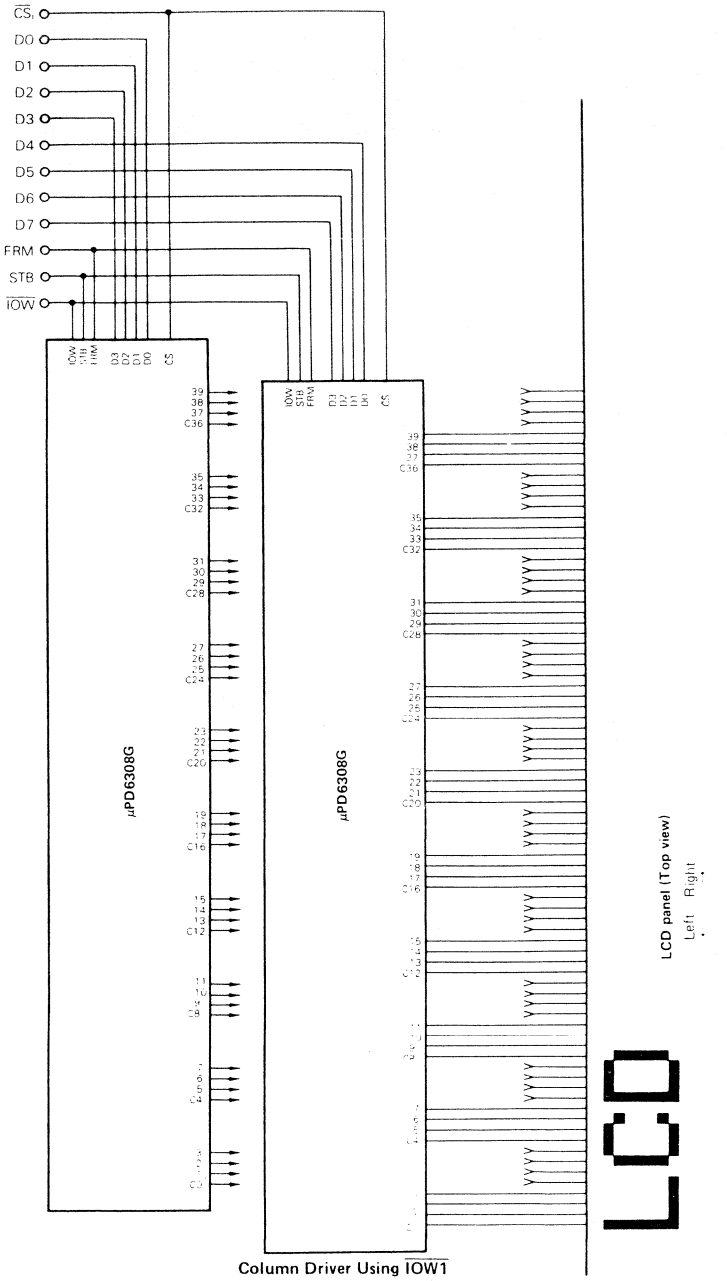
Generates the column (segment) signals for the AC drive of the LCD panel. The level of outputs to C0–C39 are as follows:

	+(FRM′ = 1)	−(FRM′ = 0)
Select (Data = 1)	V_{LC5}	V_{LC0}
Nonselect (Data = 0)	V_{LC3}	V_{LC2}

FRM′ is obtained by internally synchronizing the FRM signal with the leading edge of the STB signal.



Connection to Column Driver Using $\overline{IOW}2$



Column Driver Using IOW1

Description

The NEC μPD7281 Image Pipelined Processor is a high-speed digital signal processor specifically designed for digital image processing such as restoration, enhancement, compression, and pattern recognition. The μPD7281 employs token-based data-flow and pipelined architecture to achieve a very high throughput rate. A high-speed on-chip multiplier speeds calculations. More than one μPD7281 can easily be cascaded with a minimum amount of interface hardware to increase the throughput rate even further. The μPD7281 is designed to be used as a peripheral processor for minicomputers or microcomputers, thereby relieving the host processor from the burden of time-intensive computations. The μPD7281 has a very powerful instruction set designed specifically for digital image processing algorithms. The Image Pipelined Processor can also be used as either a general purpose digital signal processor or a numeric processor.

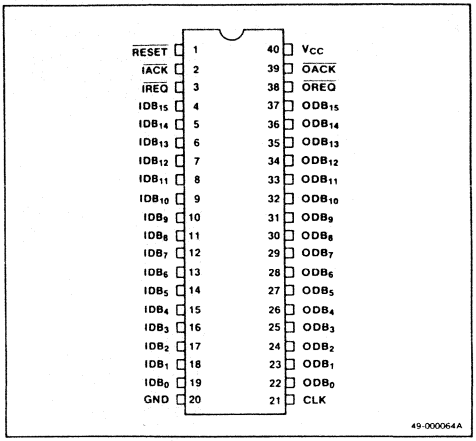
Features

- ☐ Token-based data-flow architecture
- ☐ Internal pipelined ring architecture
- ☐ Powerful instruction set for image processing
- ☐ 17 x 17-bit (including sign bits) fast multiplier: 200 ns (target spec)
- ☐ High-speed data I/O handling
  - — Asynchronous two-wire handshaking protocols
  - — Separate data input and output pins
- ☐ Easy multiple-processor configuration
- ☐ Rewritable program stores
- ☐ On-chip memories:
  - — Link Table (LT): 128 x 16 bits
  - — Function Table (FT): 64 x 40 bits
  - — Data Memory (DM): 512 x 18 bits
  - — Data Queue (DQ): 32 x 60 bits
  - — Generator Queue (GQ): 16 x 60 bits
  - — Output Queue (OQ): 8 x 32 bits
- ☐ NMOS technology
- ☐ Single +5 V power supply
- ☐ 40-pin DIP

Applications

- ☐ Digital image restoration
- ☐ Digital image enhancement
- ☐ Pattern recognition
- ☐ Digital image data compression
- ☐ Radar and sonar processing
- ☐ Fast Fourier Transforms (FFT)
- ☐ Digital filtering
- ☐ Speech processing
- ☐ Numeric processing

Pin Configuration



Performance Benchmarks

(Subject to change without notice.)

Operation	1 μPD7281	3 μPD7281s	Note
Rotation	1.5 sec	0.6 sec	512 x 512 binary image
1/2 Shrinking	80 ms	30 ms	512 x 512 binary image
Smoothing	1.1 sec	0.4 sec	512 x 512 binary image
3x3 Convolution	3.0 sec	1.1 sec	512 x 512 grey scale image
64-stage FIR Filter	50 μs	18 μs	17-bit fixed point
cos(x)	40 μs	15 μs	33-bit fixed point

Pin Identification

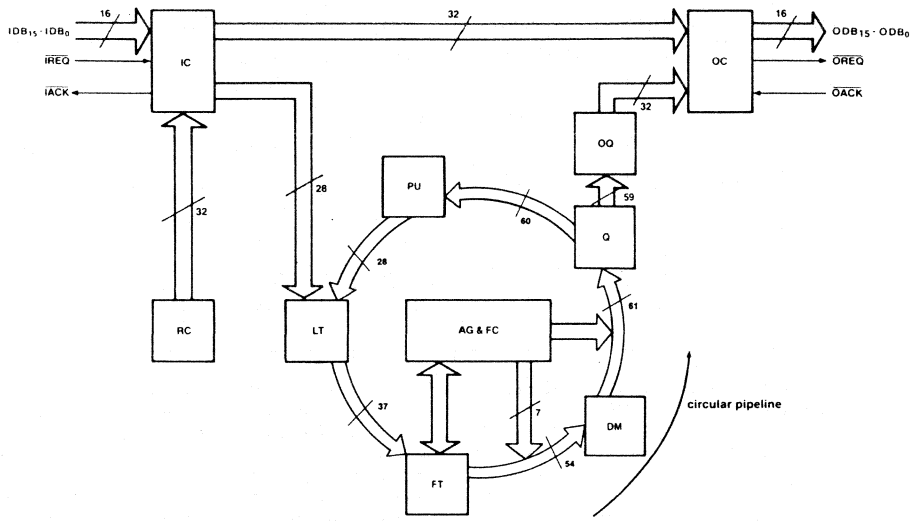
No.	Signal	I/O	At RESET	Description
1	$\overline{RESET}$	In		System Reset: A low signal on this pin initializes μPD7281. During the reset, a 4-bit module number should be placed on IDB_{15} - IDB_{12}.
2	$\overline{IACK}$	Out	High	Input Acknowledge: This acknowledge signal is output by the μPD7281 to notify the external data source that a 16-bit data transfer has been completed.
3	$\overline{IREQ}$	In		Input Request: This input signal requests a data transfer from an external device to μPD7281.
4-19	IDB_{15} - IDB_0	In		16-bit input data bus: 32-bit input data tokens are input to the Input Controller as two 16-bit words.
20	GND			Power ground
21	CLK	In		System clock input (10 MHz: target spec)
22-37	ODB_{15} - ODB_0	Out	High Impedance	16-bit output data bus: 32-bit output data tokens are output by the Output Controller as two 16-bit words.
38	$\overline{OREQ}$	Out	High	Output Request: This signal informs an external device that a 16-bit data word is ready to be transferred out of μPD7281.
39	$\overline{OACK}$	In		Output Acknowledge: This acknowledge signal input by the external data destination notifies μPD7281 that a 16-bit data transfer may occur.
40	V_{CC}			+5 V power supply

Architecture

The μPD7281 utilizes a token-based, data-flow architecture. This novel architecture not only provides multiprocessing capability without complex external hardware, but also offers high computational efficiency within each processor. Taking advantage of the multi-processing capability of data-flow architecture, almost any processing speed requirements can be satisfied by using as many μPD7281s as needed in the system. Within each μPD7281, the data-flow architecture provides high computational efficiency through concurrent operations. For example, while the Processing Unit (or ALU) spends its time for actual computations only, the internal memory address calculations, internal memory read and write operations and input/output operations are all being done concurrently. Furthermore, in contrast to conventional von Neumann processors, a data-flow processor doesn't fetch instructions, perform subroutine stack operations or do data transfers between registers. Therefore, it does not spend the time required for these operations.

The μPD7281 also utilizes an internally pipelined architecture. As shown in the block diagram, a circular pipeline is formed by five functional blocks: the Link Table (LT), the Function Table (FT), the Data Memory (DM), the Queue (Q), and the Processing Unit (PU). A token entered through the Input Controller (IC) is passed on to the Link Table to be processed around the pipelined ring as many times as needed. When a token is finished being processed, it is queued into Output Queue (OQ) and then output via the Output Controller (OC).

Block Diagram



IC: Input Controller. Controls input data tokens and determines whether or not an input data token should be sent to the circular pipeline for processing.

OC: Output Controller. Controls output data tokens.

LT: Link Table (128 words x 16 bits). Stores instruction parameters.

FT: Function Table (64 words x 40 bits). Stores instruction parameters.

DM: Data Memory (512 words x 18 bits). Stores constants or temporary data.

Q: Queue (48 words x 60 bits). FIFO queue. Data Queue: 32 words x 60 bits. Generator Queue: 16 words x 60 bits.

PU: Processing Unit. Executes logical, arithmetic and bit operations.

OQ: Output Queue (8 words x 32 bits). FIFO queue for the output tokens.

AG/FC: Address Generator and Flow Controller. Generates addresses for DM and controls the flow of tokens.

RC: Refresh Controller. Generates refresh tokens for internal DRAMs.

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Functional Description

As shown in the block diagram, the μPD7281 consists of 10 functional blocks. Before any processing occurs, the host processor down-loads the object code into the Link Table and the Function Table of the μPD7281 by using specially formatted input tokens. At this time, constants may also be sent to the Data Memory to be stored. The contents of the Link Table and the Function Table are closely related to a computational graph. When a computational process is represented graphically, it usually forms a directed data-flow graph. In such a graph, the arcs (or edges, links, etc.) represent the entries in the Link Table and the nodes represent the entries in the Function Table. An arc between any two nodes has a data value, called a "token", and is identified by a corresponding entry in the Link Table. A node in the directed data-flow graph signifies an operation, and the type of operation is logged into the Function Table along with the identification information about the outgoing arc.

A minimal amount of interface hardware is required to configure μPD7281s in a multiprocessor system. As many as 14 μPD7281s can be cascaded together, as shown in figure 1. Each μPD7281 must be assigned a Module Number (MN) during reset. Figure 2 shows the timing diagram for assigning the module number.

Figure 1. Connecting Multiple μPD7281s

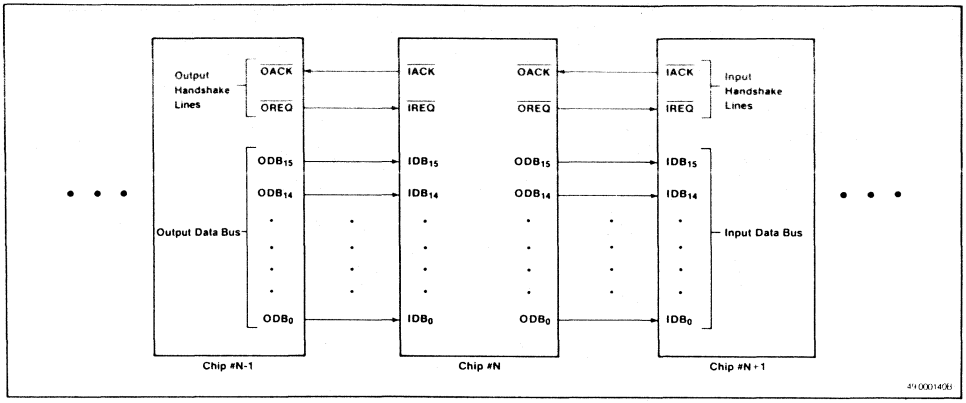
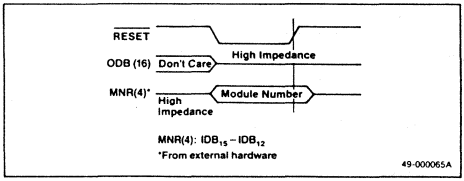


Figure 2. Timing Diagram for Assigning Module Numbers During RESET

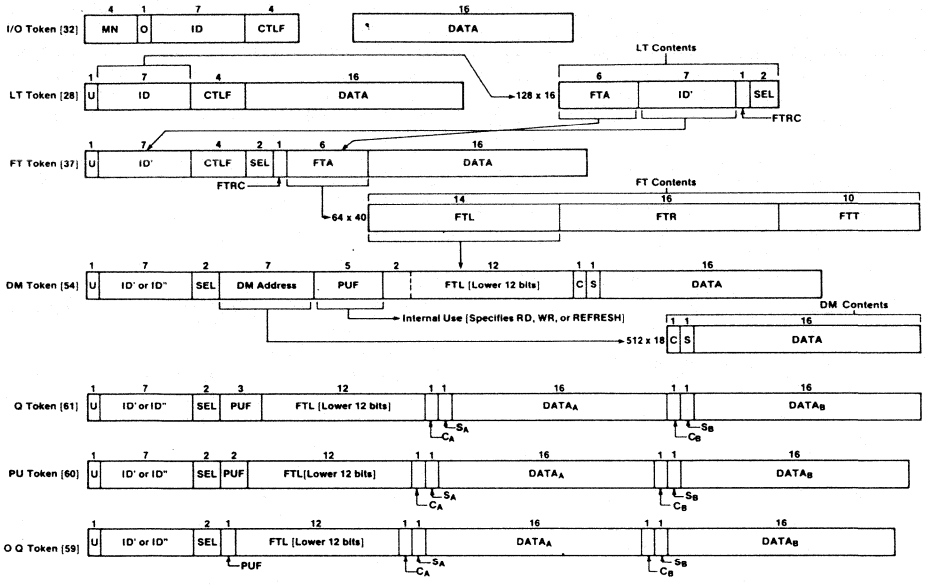


When any token enters a μPD7281, regardless of the total number of μPD7281s used in the system, the Input Controller of that μPD7281 discerns whether or not the entering token is to be processed by checking the Module Number (MN) field of the token. If the Module Number is not the same as the Module Number assigned during reset, the token is passed to the Output Controller so that it can be sent out via the Output Data Bus. However, if the token has the same Module Number, then the Input Controller strips off the MN field and sends the remaining part of the token to the Link Table for processing.

Once a token enters the circular pipeline by accessing the Link Table, it requires seven pipeline clock cycles for the token to fully circulate around the ring. One pipeline clock cycle is needed for the Link Table, the Function Table, or the Data Memory to process an incoming token, and two pipeline clock cycles are needed for the Queue or the Processing Unit to process a token. The Queue requires one pipeline clock cycle to write and one cycle to read. Similarly, the Processing Unit requires one pipeline clock cycle to execute and one clock cycle to output the result. In other words, both the Processing Unit and the Queue are made of two-stage pipelines. Therefore, when seven tokens exist simultaneously in the circular pipeline, the pipeline is full and full parallel processing is achieved.

When a data token flows through each functional block in a given μPD7281, the format of the token changes significantly. The actual transitions of a token format through different functional blocks are shown in figure 3. A data token flowing within the circular pipeline must have at least a 7-bit Identifier (ID) field and an 18-bit data field. The ID field is used as an address to access the Link Table memory. When a token accesses the LT memory, the ID field of the token is replaced by a new ID (shown as ID' in figure 3) previously stored in the LT memory. As a result, every time a data token accesses LT memory, its ID field is renewed. The data field of a token consists of a control bit, a sign bit and a 16-bit data. A token may have up to two data fields, as well as other fields (OP code, control, etc.) if necessary.

Figure 3. Token Formats and Transitions



I/O Token	Input or Output Token
LT Token	A token accessing the Link Table
FT Token	A token accessing the Function Table
DM Token	A token accessing the Data Memory
Q Token	A token accessing the Queue
PU Token	A token accessing the Processing Unit
OQ Token	A token accessing the Output Queue

MN	Modulo Number
ID	Identifier for an input or output token
ID'	Identifier for a token which exits LT for the first time
ID"	Identifier for a token which exits LT for the second time
CTLF	Control field
DATA	16-bit data field
FTA	Function Table Address

SEL	SELection field
FTRC	Function Table Right field Control bit
FTL	Function Table Left field
FTR	Function Table Right field
FTT	Function Table Temporary field
PUF	Processing Unit Flags
C	Control bit for a 16-bit data
C_A	Control bit for a 16-bit data from A side
C_B	Control bit for a 16-bit data from B side
S	Sign-bit for a 16-bit data
S_A	Sign-bit for a 16-bit data from A side
S_B	Sign-bit for a 16-bit data from B side
$DATA_A$	16-bit data from A side
$DATA_B$	16-bit data from B side

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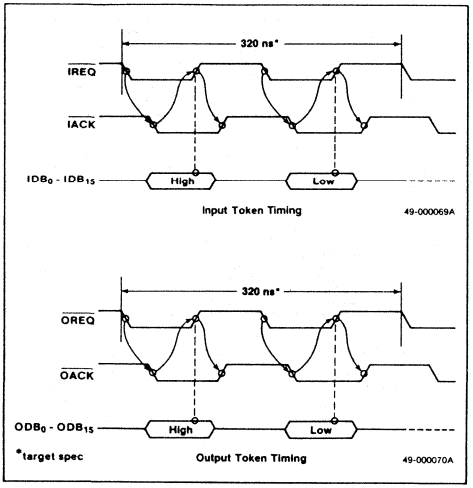
Input Controller [IC]

A 32-bit token is entered into a μPD7281 in two 16-bit halves using a two-signal request/acknowledge handshake method, as shown in figure 4. The input/output token format is shown in figure 7. After a token is accepted by the IC, the MN field of the token is compared to the Module Number of μPD7281 which was assigned at reset. If the Module Number of the accepted token is not the same, the IC passes the token directly to the Output Controller. If the MN field of the accepted token is the same, then the IC strips off the Module Number and sends the remaining part of the token to the Link Table. The IC also monitors the status of the Processing Unit. If it is busy, the IC delays accepting another token until it is no longer busy. The IC also accepts the refresh tokens from the Refresh Controller (RC) and sends them to the Link Table.

Figure 4. Handshake Timing Waveforms



Output Controller [OC]

The OC outputs 32-bit tokens in two 16-bit halves using a two-signal request/acknowledge handshake method, as shown in figure 4. The types of tokens output by the OC are as follows: output data tokens from the Output Queue, error status data tokens generated internally by OC, DUMP tokens, and passing data tokens from the Input Controller.

Link Table [LT]

The LT is a 128 x 16-bit dynamic RAM. The ID field of an incoming LT token is used to access the LT memory. The contents of an LT memory location consist of a 6-bit Function Table Address (FTA), a 7-bit ID, a 1-bit Function Table Right Field Control (FTRC), and a 2-bit Selection (SEL) field. When a token accesses LT memory, its ID field is replaced by the new ID field contained in the memory location being accessed. Therefore, every time a token accesses LT memory, it is given a new ID. The FTA field is used to access FT memory locations. The FTRC bit and the SEL field are used to specify the type of instruction. By using specially formatted tokens, the contents of the LT can either be set during a program download or be read during a diagnosis.

Function Table [FT]

The FT is a 64 x 40-bit dynamic RAM. As for the case of the Link Table, the contents can either be set during a program download or be read during a diagnosis by using specially formatted tokens.

Each FT memory location consists of a 14-bit Function Table Left field (FTL), a 16-bit Function Table Right field (FTR), and a 10-bit Function Table Temporary field (FTT). These fields contain control information for different types of instructions.

Address Generator and Flow Controller [AG/FC]

The AG/FC generates the addresses to access the Data Memory (DM) and controls the writing of data to and the reading of data from the Data Memory. AG/FC determines whether the incoming token contains a one-operand instruction or a two-operand instruction. One-operand instruction tokens can be sent directly to the Queue. However, if the token contains a two-operand instruction, then both operands must be available before they can be sent to the Queue. For a two-operand instruction, the token which arrives at the Data Memory first is temporarily stored until the second operand token arrives. When the second operand token exits the Function Table, the AG/FC generates the Data Memory address which contains the first operand. Then, the second operand token and the first operand data read out from the Data Memory are sent to the Queue together.

Data Memory [DM]

The DM is a 512 x 18-bit dynamic RAM which is used to queue the first operand for a two-operand instruction until the second operand arrives. DM can also be used as a temporary memory or as a buffer memory for I/O data.

Queue [Q]

The Q is a FIFO memory configured with a 48 x 60-bit dynamic RAM. The Q is used to temporarily store the Processing Unit-bound and the Output Queue-bound tokens. The Q is further divided into two different FIFO memories: a 32 x 60-bit Data Queue (DQ) and a 16 x 60-bit Generator Queue (GQ). The DQ is used for the

PU, OUT and AG/FC instructions. The DQ temporarily stores the PU and AG/FC tokens before they are sent to the Processing Unit for processing. The DQ also temporarily stores the Output Queue tokens before they are sent to the Output Queue. The GQ is used for Generate (GE) instructions only. The DQ will not output tokens to the Output Queue if it is full, and the DQ or GQ will not output tokens to the Processing Unit if the Processing Unit is busy.

In order to control the number of tokens in the circular pipeline to prevent Q overflow, the Q is further restricted by the following two situation rules: when the DQ has eight or more tokens stored, the read from the GQ is inhibited, and when the DQ has fewer than eight tokens stored, the read from the GQ has a higher priority than the read from the DQ. Since instructions stored in the GQ generate tokens, restricting the number of GQ tokens is important in order to keep the Q from overflowing. In case the internal processing speed is slower than the rate of incoming data tokens, the DQ posseses a potential overflow condition. To prevent overflow, the processor is put into restrict/inhibit mode when the DQ reaches a level greater than 23.

Output Queue [OQ]

The OQ is a first-in first-out (FIFO) memory configured in an 8 x 32-bit static RAM. The OQ is used to temporarily store the output data tokens from the Data Queue so that they can be output by the Output Controller via the output data bus. When OQ is full, it sends a signal to the Data Queue to delay accepting further tokens.

Processing Unit [PU]

The PU executes two types of instructions: PU and GE. PU instructions include logical, arithmetic (add, subtract and multiply), barrel-shift, compare, data-exchange, bit-manipulation, bit-checking, data-conversion, double-precision adjust, and other operations. The control information for a PU instruction is contained in the Function Table Left field of the PU token. The GE instructions are used to generate a new token, multiple copies of a token, or block copies of a token. They can also be used to set the Control field (CTLF) of a token and to generate external memory addresses. If the current PU operation cannot be completed within a pipeline clock cycle, the PU sends a signal to the Queue and the Input Controller to prevent them from releasing any more tokens.

Refresh Controller [RC]

The RC automatically generates refresh tokens for the dynamic RAMs used in the circular pipeline, i.e. the LT, FT, DM, and Q. Each RC token, generated periodically, is sent to the Input Controller and is propagated through the LT, FT, DM and Q, in that order. The RC tokens are deleted after reaching the Q.

Operation Modes

There are three different modes in which the μPD7281 can operate: Normal, Test, and Break (see figure 5). After an external hardware reset, the μPD7281 is in the Normal mode of operation. The μPD7281 can enter the Test mode for program debugging by inputting a SETBRK token (see figure 6) while the processor is in the Normal mode. If an overflow occurs in the Data Queue or the Generator Queue, the processor enters into the Break mode so that the internal contents of the processor can be examined; see table 1. Table 2 describes the effects of software and hardware resets.

Table 1. DUMPD Output Token Format

MN	Z	ID	CTLF	DATA (16-bit field)
0000	0	0000 000	0111	xxxxx(5) GQ Size(5 bits) DQ Size(6 bits)
0000	0	0000 001	0111	xxxx(4) u(1) ID(7) CTLF(4)
0000	0	0000 010	0111	DATA(16)
0000	0	0000 011	0111	xxx (3) u(1) ID(7) x(1) C_B, S_B, C_A, S_A
0000	0	0000 100	0111	xx(2) FTL (Lower 12 bits) xx(2)
0000	0	0000 101	0111	$DATA_A$(16)
0000	0	0000 110	0111	$DATA_B$(16)
0000	0	0000 111	0111	xxxxxxxxx(9) ID(7)

x: Don't care u: Unused

Table 2. Effects of Reset Operation

	Hardware Reset	Software Reset
MN	μPD7281 reads in MN	No Change
High/Low Word Flip-flop	Reset	No Change
Input Inhibit Control	Reset (No constraint)	No Change
LT Break State	Reset	Reset
Internal Operation	Stopped	Stopped
DQ, GQ, and OQ Pointers	Set to 0	Set to 0

Figure 5. μPD7281 Operation Modes

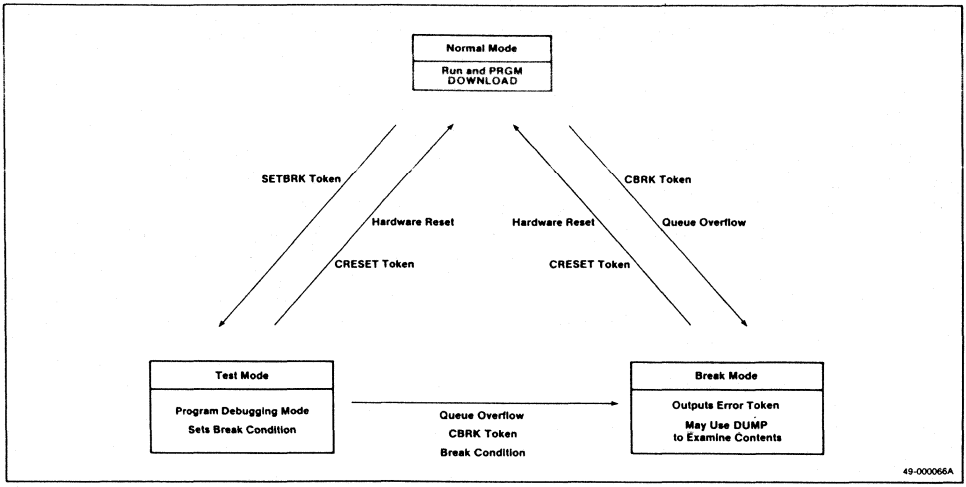
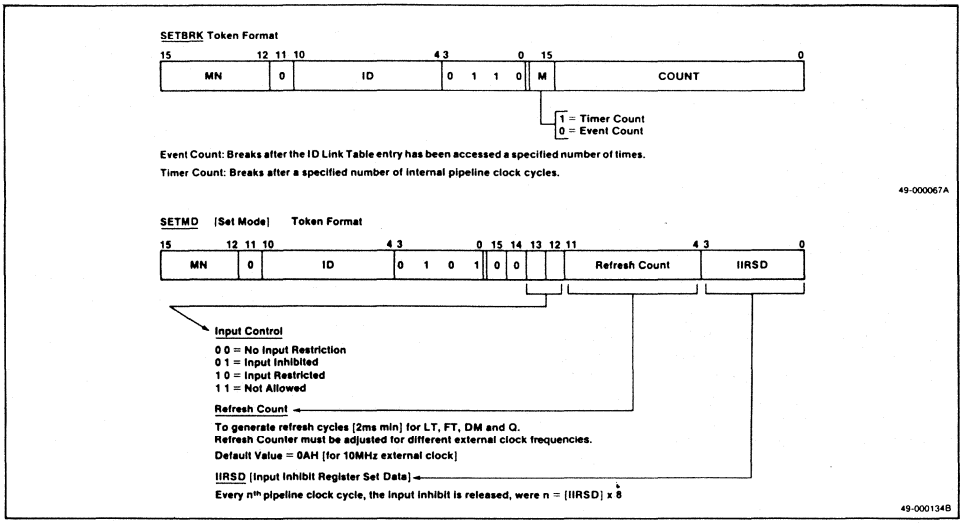


Figure 6. SETBRK (Set Break Condition) and SETMD (Set Mode) Token Formats



Input/Output Tokens

The only way any external device can communicate with the μPD7281 is by using the I/O tokens (see figure 7). Both the input and the output tokens have the same format so that a token may flow through a series of multiple processors without a format change. A 32-bit I/O token is divided into upper and lower 16-bit words and input to or output from the μPD7281 a 16-bit word at a time. Object code is down-loaded into the Link Table and the Function Table using SETLT, SETFTR, SETFTL and SETFTT input tokens. The contents of the Function Table and the Link Table can also be read using RDLT, RDFTR, RDFTL and RDFTT tokens. In order to write or read a value to and from the Data Memory, a program must be down-loaded and executed. Once object code is down-loaded into the μPD7281, data tokens are input to the processor, thereby initiating the processing. For a description of the input and output tokens, see tables 3 and 4.

Figure 7. Input/Output Token Format

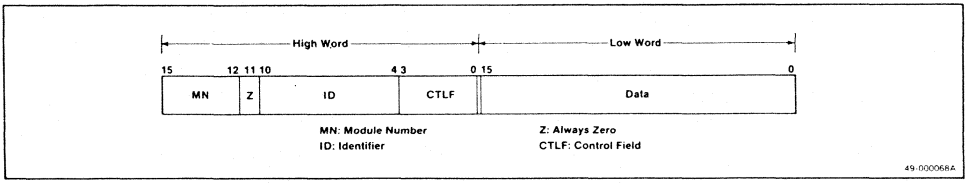


Table 3. Input Token Format

Input Token	High Word (16)				Low Word (16)		Remarks
	MN (4) 15 12	Z (1) 11	ID (7) 10 4	CTLF (4) 3 0	DATA (16) 15 0		
SETLT	MN	0	LT address	1 1 0 0	Data to be set in LT		Set LT
SETFTR	MN	0	FT address	1 1 0 1	Data to be set in FTR		Set FT Right Field
SETFTL	MN	0	FT address	1 1 1 0	Data to be set in FTL		Set FT Left Field
SETFTT	MN	0	FT address	1 1 1 1	Data to be set in FTT		Set FT Temporary Field
RDLT	MN	0	LT address	1 0 0 0			Read LT
RDFTR	MN	0	FT address	1 0 0 1			Read FT Right Field
RDFTL	MN	0	FT address	1 0 1 0			Read FT Left Field
RDFTT	MN	0	FT address	1 0 1 1			Read FT Temporary Field
CRESET	MN	0		0 1 0 0			Command Reset
SETMD	MN	0		0 1 0 1	Mode set data		Set Operation Mode
SETBRK	MN	0	ID	0 1 1 0	M (1)	Count (15)	Set Break Condition
DUMP	MN	0	xxxx(4) DUMP (3)	0 1 1 1			Dump
CBRK	0 0 0 0	0		0 1 0 0			Command Break
VAN	1 1 1 1	0					Vanish Data
PASS	MN*	0					Pass Data
EXEC	MN	0	ID	0 0 C S	Data		Normal Execution Data

* When MN is not the current module number
x: Don't care

Table 4. Output Token Format

Output Token	Upper-Order Word (16)				Lower-Order Word (16)		Remarks
	MN (4) 15 12	Z (1) 11	ID (7) 10 4	CTLF (4) 3 0	DATA (16) 15 0		
LTRDD	0 0 0 0	0	LT address	1 0 0 0	Data read from LT		FT Read Data
FTRRDD	0 0 0 0	0	FT address	1 0 0 1	Data read from FTR		FT Right Field Read Data
FTLRDD	0 0 0 0	0	FT address	1 0 1 0	Data read from FTL		FT Left Field Read Data
FTTRDD	0 0 0 0	0	FT address	1 0 1 1	Data read from FTT		FT Temporary Field Read Data
PASSD	MN	0	ID	CTLFD	Data		Pass Data
ERR	0 0 0 0	0	0 0 0 0 0 0 0	0 1 0 0	MN(4)	MODE(4) 0 0 0 STATUS(5)	Error Data
DUMPD	0 0 0 0	0	0 0 0 0 DUMP(3)	0 1 1 1	Dump data		Dumped Data
OUTD	MN	0	ID	0 0 C S	Data		Output Data

Instruction Set Summary

Tables 5 through 8 summarize the instruction set.

Table 5. AG/FC Instructions

Mnemonic	Instruction
QUEUE	Queue
RDCYCS	Read cyclic short
RDCYCL	Read cyclic long
WRCYCS	Write cyclic short
WRCYCL	Write cyclic long
RDWR	Read/Write Data Memory
RDIDX	Read Data Memory with index
PICKUP	Pickup data stream
COUNT	Count data stream
CONVO	Convolve
CNTGE	Count generation
DIVCYC	Divide cyclic
DIV	Divide
DIST	Distribute
SAVE	Save ID
CUT	Cut data stream

Table 6. PU Instructions

Mnemonic	Instruction
OR	Logical OR
AND	Logical AND
XOR	Logical EXCLUSIVE-OR
ANDNOT	Logical INVERT an operand then AND: ($\bar{A}$•B)
NOT	Invert
ADD	Add
SUB	Subtract

Table 6. PU Instructions (cont)

Mnemonic	Instruction
MUL	Multiply
NOP	No operation
ADDSC	Add and shift count
SUBSC	Subtract and shift count
MULSC	Multiply and shift count
NOPSC	NOP and shift count
INC	Increment
DEC	Decrement
SHR	Shift right
SHL	Shift left
SHRBRV	Shift right with bit reverse
SHLBRV	Shift left with bit reverse
CMPNOM	Compare and normalize
CMP	Compare
CMPXCH	Compare and exchange
GET1	Get one bit
SET1	Set one bit
CLR1	Clear one bit
ANDMSK	Mask a word with logical AND
ORMSK	Mask a word with logical OR
CVT2AB	Convert 2's complement to sign-magnitude
CVTAB2	Convert sign-magnitude to 2's complement
ADJL	Adjust long (for double precision numbers)
ACC	Accumulate
COPYC	Copy control bit

Table 7. GE Instructions

Mnemonic	Instruction
COPYBK	Copy block
COPYM	Copy multiple
SETCTL	Set control field

Table 8. OUT Instructions

Mnemonic	Instruction
OUT1	Output 1 token
OUT2	Output 2 tokens

There are four different types of instructions which can be specified by the SEL field of an FT token. See table 9.

Table 9. SEL Field of an FT Token

SEL	Type	Description
11	AG/FC	Executes instructions specified by the Function Table Right field while monitoring the Function Table Temporary field.
01	PU	Performs arithmetic, logical, barrel-shift, bit-manipulation, data-conversion, etc.
10	GE	Generates a block or multiple new tokens from a token. Sets the control field of a token. Increments or decrements the data field of a token.
00	OUT	Outputs data tokens from the circular pipeline to the Output Queue after the tokens are finished being processed.

AG/FC Instructions

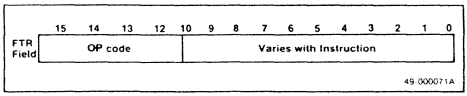
There are 16 AG/FC instructions (see table 10). They can be grouped into three types: Address Generator (AG), Flow Controller (FC), and AG/FC type.

AG type: RDCYCS, RDCYCL, WRCYCS, WRCYCL, RDWR, RDIDX

FC type: PICKUP, COUNT, CUT, DIVCYC, DIV, DIST, CONVO, SAVE, CNTGE

AG/FC type: QUEUE

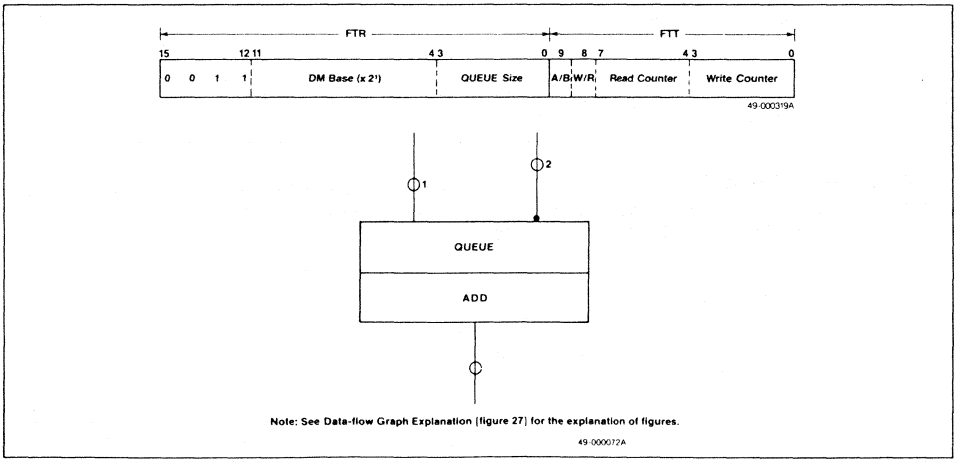
A 4-bit OP code in the Function Table right field specifies the instruction to be executed.



QUEUE

For a two-operand instruction, a QUEUE instruction is used to temporarily store the first operand token in the Data Memory until the second operand token arrives. The maximum Queue size is 16. See figure 8.

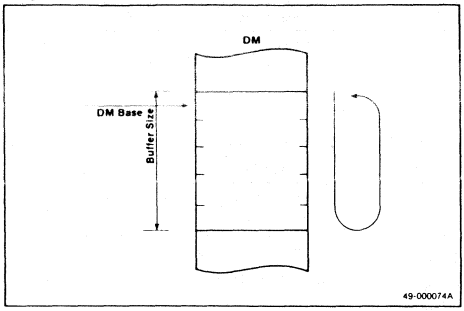
Figure 8. QUEUE Instruction

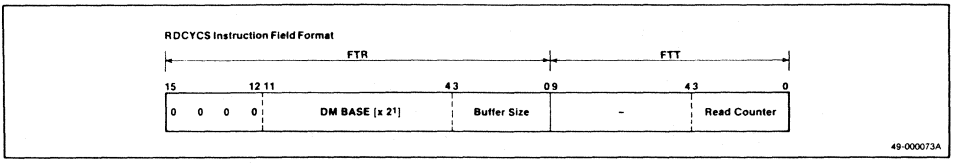


RDCYCS [Read Cyclic Short]

RDCYCS reads 18-bit data words from the Data Memory cyclically (see figure 9). The first data to be read is specified by the DM Base address. The last data to be read is specified by the buffer size. The Read Counter (RC) contains the offset address from Data Memory Base (DMB) address. It is incremented each time the Data Memory is accessed. The maximum buffer size is 16.

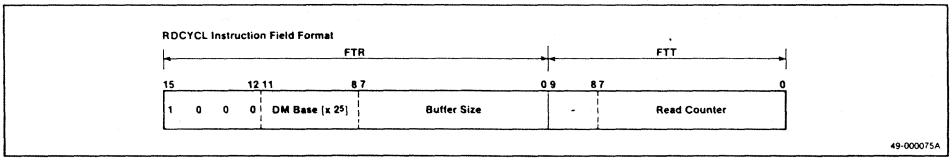
Figure 9. RDCYCS Instruction Operation





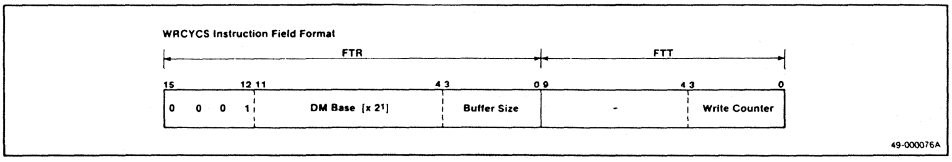
RDCYCL [Read Cyclic Long]

RDCYCL reads 18-bit data words from the Data Memory in a cyclic manner like RDCYCS but has a longer cyclic range. The first data to be read is specified by the DM Base address. The last data to be read is specified by the buffer size. The maximum buffer size is 256.



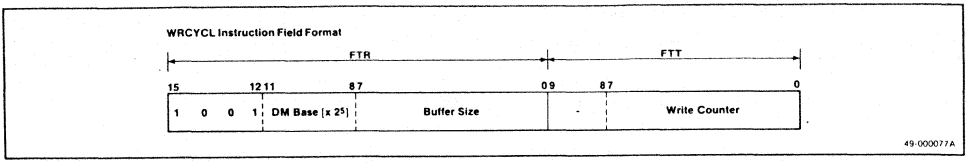
WRCYCS [Write Cyclic Short]

WRCYCS writes 18-bit data words into the Data Memory cyclically. The first the Data Memory address is specified by the DM Base address. The last address is specified by the buffer size. The maximum buffer size is 16.



WRCYCL [Write Cyclic Long]

WRCYCL writes 18-bit data words into the data memory in a cyclic manner similar to WRCYCS but has a longer cyclic range. The first DM address is specified by the DM Base address. The last address is specified by the buffer size. The maximum buffer size is 256.



RDWR [Read/Write Data Memory]

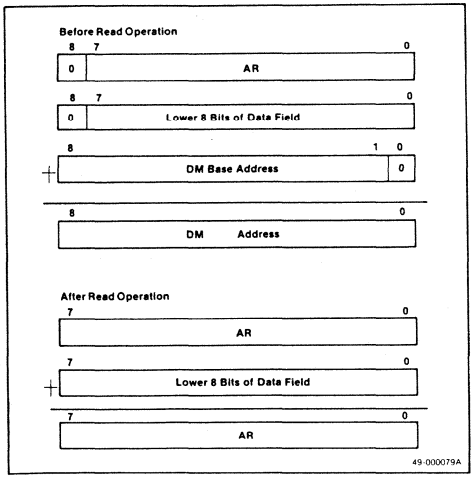
RDWR is used to write or read data to and from the Data Memory. This instruction reads/modifies/writes the Data Memory with the Address Register as index.

If a token arriving at the instruction has FTRC bit = 0, then the instruction performs a DM read operation. If it has FTRC bit = 1, then the instruction performs a DM write operation.

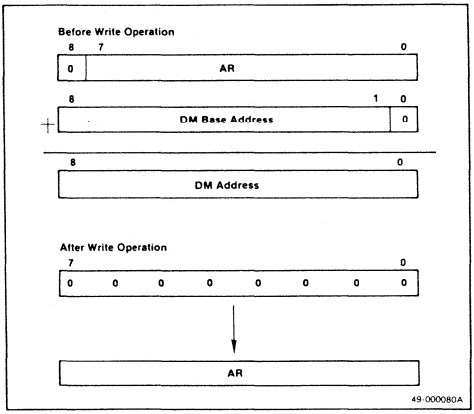
For a token with the FTRC bit = 0, the actual DM address location to be read is determined by the sum of the following three values: 8-bit Address Register (AR), the lower eight bits of the data field of the token, and the DM Base address. After the read operation, the lower eight bits of the token's data field is added to the value of AR. Additionally, the data field of the token is replaced by the contents read from the Data Memory location.

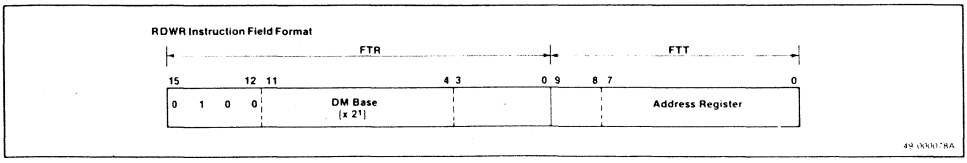
If a token with FTRC bit = 1 is used along with RDWR, a write operation is performed. The Data Memory address location is determined by the sum of 8-bit AR and DM Base address. The 18-bit data from the token is written into the DM address calculated. After the write operation, AR is reset to 00H.

FTRC = 0



FTRC = 1



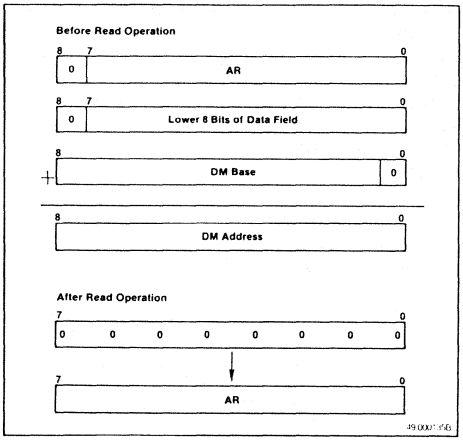


RDIDX [Read Data Memory with Index]

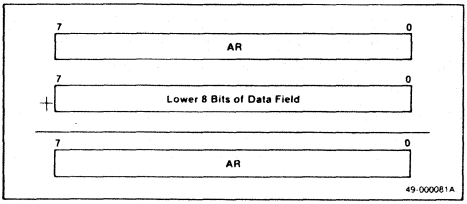
RDIDX is used to read the contents of the Data Memory. This instruction is most useful when a part of the Data Memory is used as a look-up table. The RDIDX instruction performs different operations depending upon the FTRC bit of the token using the instruction. If the FTRC bit = 0, then the instruction reads a Data Memory location. The DM address location to be read is determined by the sum of the following three values: the 8-bit AR, the lower eight bits of the token's data field, and the DM Base address. After the read operation, the data field of the token is replaced by the contents of the Data Memory location read. The value of AR is reset to zero after the operation.

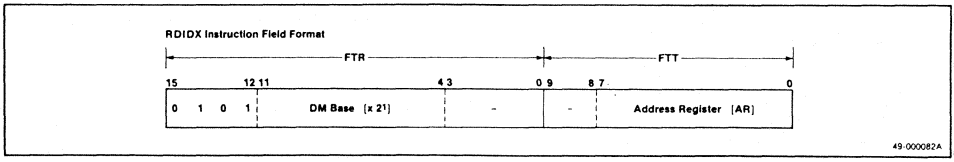
If the FTRC bit = 1, no operation is performed on the Data Memory. However, the token's AR contents are replaced by the modulo-256 sum of the lower eight bits of data field and the current contents of AR.

FTRC = 0



FTRC = 1





PICKUP [Pickup Data Stream]

This instruction picks up every $(n+1)^{th}$ token from a stream of incoming tokens and increments the $(n+1)^{th}$ token's ID field by one. The number n is specified by the Count Size (CS) of the Function Table Right field.

Figure 10 illustrates the PICKUP instruction with CS = 3.

Note: These figures use the data-flow graph convention. See figure 27, Data-flow Graph Explanation for the explanation of figures.

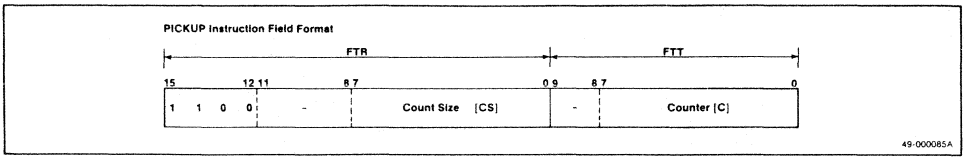
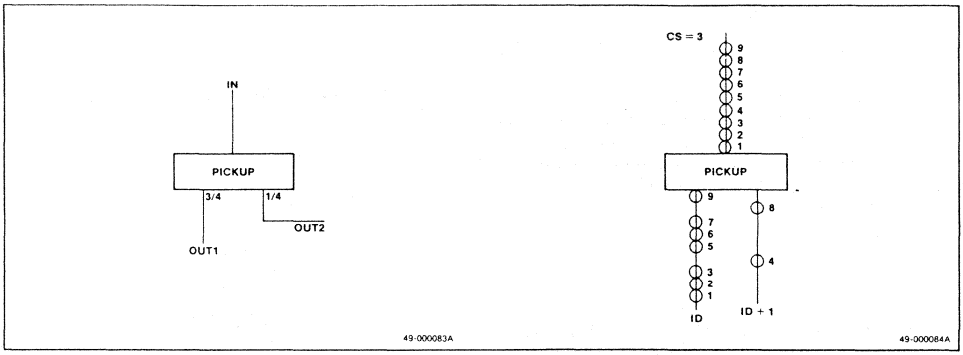


Figure 10. Pickup Instruction



COUNT [Count Data Stream]

COUNT copies every $(n+1)^{th}$ token from a stream of incoming tokens and increments the copied token's ID field by one. The number n is specified by CS of the Function Table Right field. Figure 11 illustrates the COUNT instruction with CS = 3.

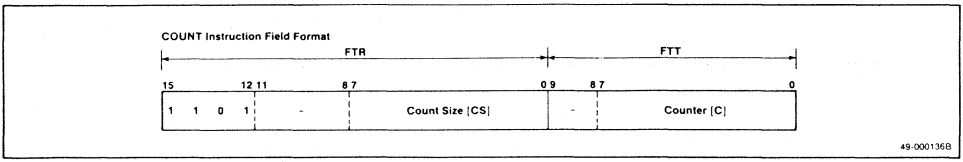
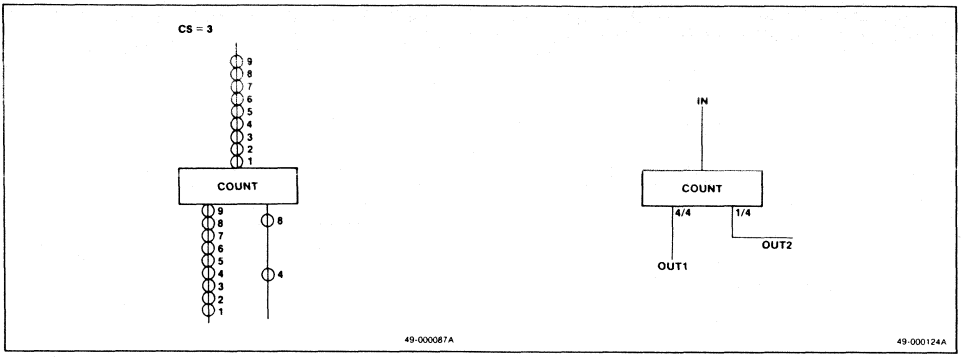


Figure 11. COUNT Instruction



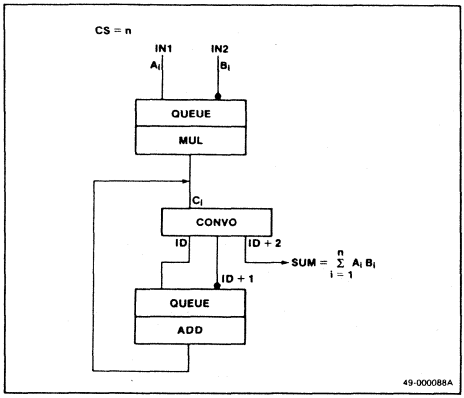
CONVO [Convolve]

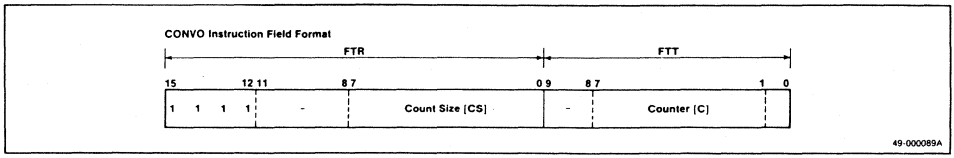
CONVO instruction is used to perform cumulative operations such as ΣA_i or ΠA_i. The CONVO instruction is best suited for convolving two sequences of the same length. Figure 12 illustrates the CONVO instruction by computing

$$SUM = \sum_{i=1}^{n} A_i B_i.$$

The A_i sequence is input to IN1 while the B_i sequence is input to IN2. Together they are queued and multiplied to form the C_i sequence. The C_i's arriving at CONVO instruction are queued and added together to form the final answer SUM. The length of the summation, n, is specified by the CS.

Figure 12. CONVO Instruction

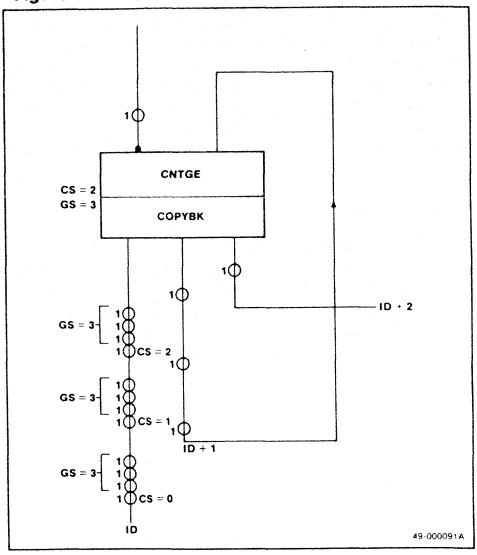


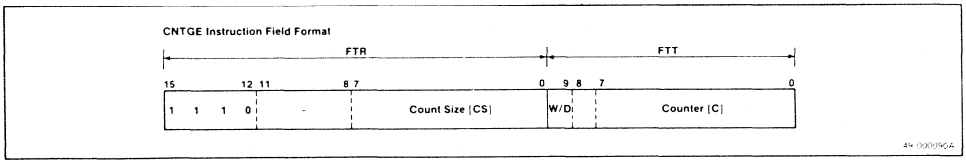


CNTGE [Count Generation]

CNTGE is normally used with COPYBK (Copy Block) to generate more than 16 copies of a single token (see figure 13). This instruction has both the dead (inactive) state and the wait (active) state. The instruction starts in the dead state. The FTRC bit = 0 tokens that arrive during the dead state of instruction are output to the ID + 2 token stream. It enters the wait state when a token with FTRC bit = 1 arrives and the token is output to ID token stream. Once the instruction is in the wait state, it counts the number of tokens arriving with FTRC bit = 0, outputting them to the ID token stream, until the number exceeds the number specified by CS. If Counter (C) reaches the number specified by Count Size (CS), the instruction automatically enters the dead state. Tokens with the FTRC bit = 1 arriving at CNTGE while the instruction is in the wait state are deleted by the instruction. Once the instruction enters the dead state, it can be reactivated by the arrival of a token with FTRC bit = 1.

Figure 13. CNTGE Instruction



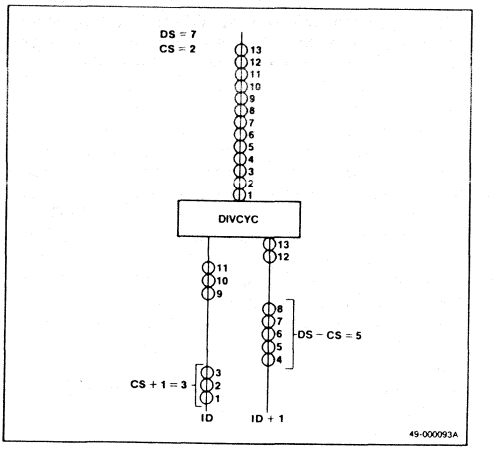


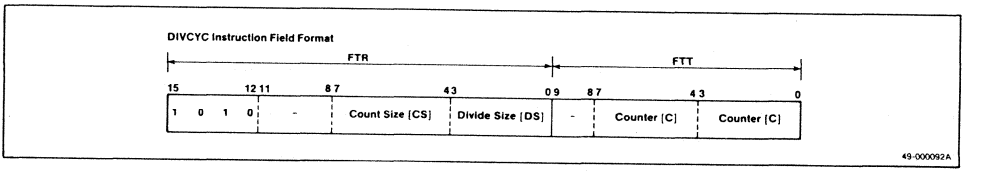
DIVCYC [Divide Cyclic]

DIVCYC divides an incoming stream of tokens into two streams of tokens: an ID token stream and an ID + 1 token stream. The pattern in which the incoming tokens are divided is specified by the Divide Size (DS) and Count Size (CS). The DS specifies cycle size whereas CS specifies the number of consecutive tokens to be in the ID stream. The first CS + 1 tokens are output to the ID token stream. The following consecutive (DS - CS) tokens are output to the ID + 1 token stream.

Figure 14 illustrates the DIVCYC instruction with DS = 7 and CS = 2. Note that an incoming stream of tokens is divided into a stream of ID tokens and a stream of ID + 1 tokens with a cycle of 8 tokens. Since CS = 2, the number of ID tokens in one cycle is 3, the number of ID + 1 tokens in a cycle is 5.

Figure 14. DIVCYC Instruction

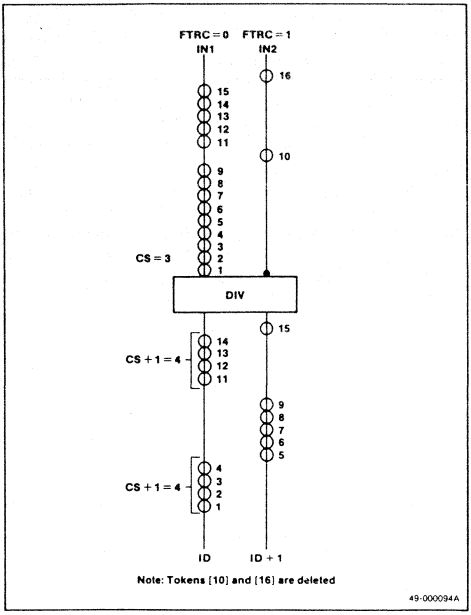


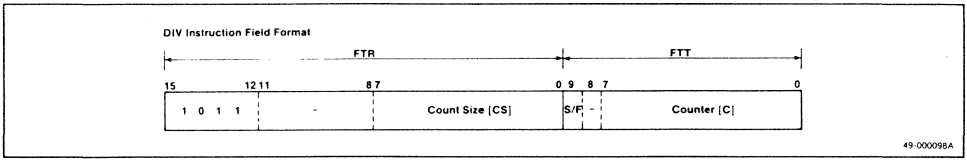


DIV [Divide]

DIV with CS = n divides an incoming stream of tokens with FTRC bit = 0 into two streams of tokens: ID tokens and ID + 1 tokens. The first (n + 1) incoming tokens with FTRC bit = 0 are output as the ID tokens, and the rest of the incoming tokens with FTRC bit = 0 are output as ID + 1 tokens. An incoming token with FTRC bit = 1 is used to reinitialize the DIV instruction. The stream of input tokens with FTRC bit = 0 after the reinitialization is again divided into a stream of (n + 1) ID tokens followed by ID + 1 tokens. A token with FTRC bit = 1 which reinitializes the DIV instruction is deleted from the output token stream. A DIV instruction with CS = 3 is illustrated in figure 15. The 10th and 16th input tokens have FTRC bit = 1, so they reinitialize the DIV instruction.

Figure 15. DIV Instruction

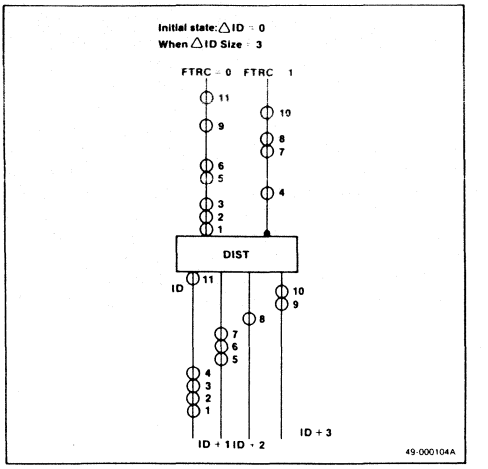


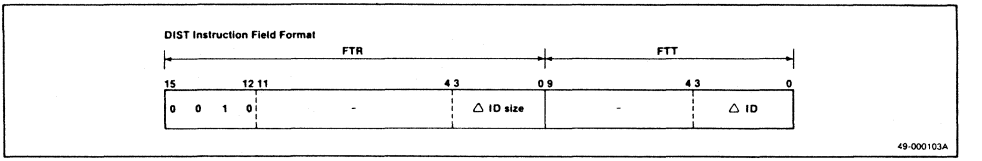


DIST [Distribute]

DIST is used to divide a stream of incoming tokens with the same ID into more than one stream of tokens with different IDs (see figure 16). The size of ID determines the maximum number of output token streams the instruction can have. ΔID is the value added to an incoming token's ID field to form the ID field of the output token. The ΔID field is initially set to zero, and it is incremented by one after a token with FTRC bit = 1 passes through the instruction. However, a token with FTRC bit = 0 has no effect on the value of ΔID field. If the value of ΔID before being incremented by a token with the FTRC bit = 1 is equal to the contents of the ΔID size field, the ΔID field will be reset to zero.

Figure 16. DIST Instruction



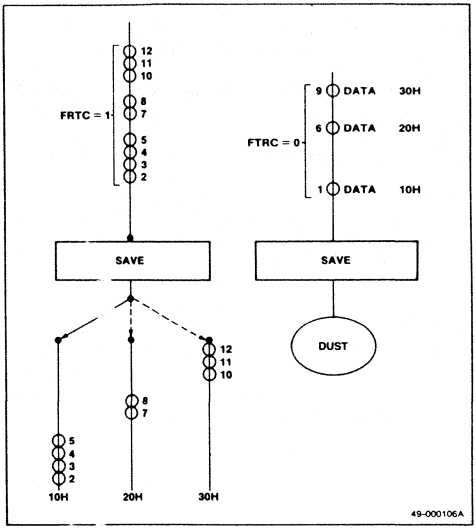


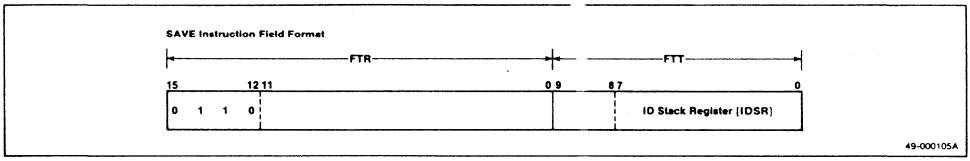
SAVE [Save ID]

SAVE is used to set the value of the ID field of a token. The instruction performs two different operations depending on whether the token's FTRC bit is 1 or 0. If the token's FTRC bit = 0, the instruction copies the lower eight bits of the data field into the Identifier Stack Register (IDSR) field. However, if the token's FTRC bit is 1, the instruction replaces the token's ID field with the contents of IDSR.

Figure 17 illustrates the use of the SAVE instruction. Token 1 assigns an ID field value of 10H to tokens 2, 3, 4 and 5, token 6 assigns an ID field value of 20H to tokens 7 and 8, and token 9 assigns an ID field value of 30H to tokens 10, 11 and 12. In this example, tokens 1, 6 and 9 are deleted after SAVE instruction.

Figure 17. SAVE Instruction

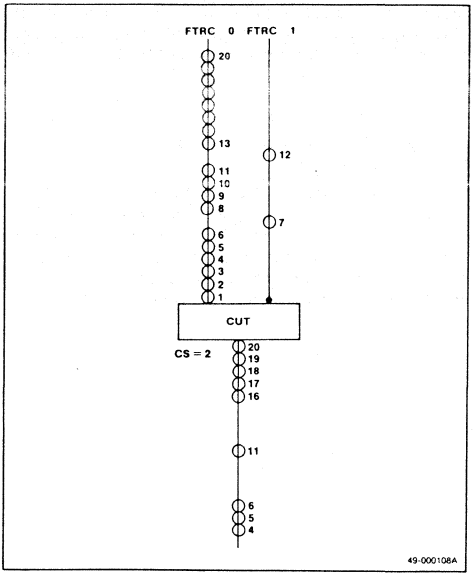




CUT [Cut Data Stream]

CUT is used to delete unnecessary tokens from a series of incoming tokens. The first n tokens arriving at the instruction are deleted, where n is the value contained in the CS field of the instruction. Initially the S/F bit and the Counter (C) are set to zero. When a token with its FTRC bit = 0 enters the instruction while S/F bit is zero, the token increments the Counter by one and the token itself is deleted. As the first (n + 1) tokens are deleted by the instruction, the Counter has the same value as n, the contents of CS field. This condition sets the S/F bit to 1. When the S/F bit is 1, a token with its FTRC bit = 0 can pass through the instruction without being deleted. However, if a token with its FTRC bit = 1 passes through the instruction, it resets the S/F bit to 0, thereby reinitializing the instruction. The token with its FTRC bit = 1 is also deleted after reinitializing the instruction. Figure 18 illustrates the use of CUT to delete tokens 7 and 12 and the three tokens following them.

Figure 18. CUT Instruction



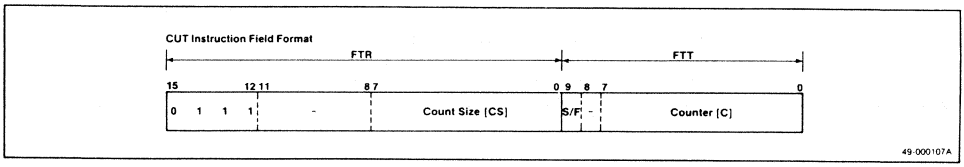
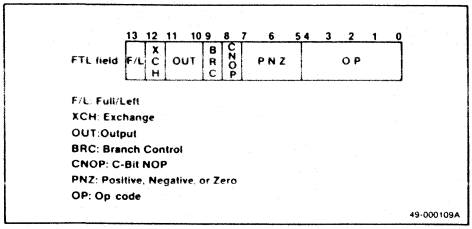


Table 10. AG and FC Instructions

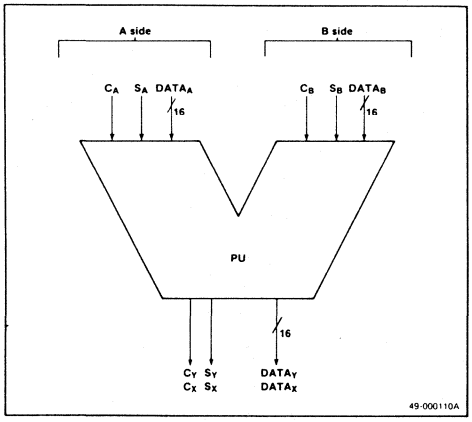
Mnemonic	FTR (16) 15 14 13 12	11 10 9 8 7 6 5 4 3 2 1 0	FTT (10) 9 8 7 6 5 4 3 2 1 0	FTRC (1)	Operation
QUEUE	0 0 1 1	DM Base (x 2^1) (8) / Queue Size (4)	A/B / W/R / Read Counter (4) / Write Counter (4)		Synchronize two tokens
RDCYCS	0 0 0 0	DM Base (x 2^1) (DMB) (8) / Buffer Size (BS) (4)	(6) / Read Counter (RC) (4)	0	DATA ← (DMB + RC), RC ← RC + 1
				1	DATA ← (DMB + RC), RC ← RC + 1, when BS = RC, copy with ID + 1
RDCYCL	1 0 0 0	DM Base (x 2^5) (4) / Buffer Size (8)	(2) / Read Counter (8)	0	DATA ← (DMB + RC), RC ← RC + 1
				1	DATA ← (DMB + RC), RC ← RC + 1, when BS = RC, copy with ID + 1
WRCYCS	0 0 0 1	Base (x 2^1) (8) / Buffer Size (4)	(6) / Write Counter (WC) (4)	0	(DMB + WC) ← DATA, WC ← WC + 1, delete token
				1	(DMB + WC) ← DATA, WC ← WC + 1, when BS = WC, token not deleted
WRCYCL	1 0 0 1	DM Base (x 2^5) (4) / Buffer Size (8)	(2) / Write Counter (8)	0	(DMB + WC) ← DATA, WC ← WC + 1, delete token
				1	(DMB + WC) ← DATA, WC ← WC + 1, when BS = WC, token not deleted
RDWR	0 1 0 0	DM Base (x 2^1) (8) / (4)	(2) / Address Register (AR) (8)	0	DATA ← (DMB + AR + DATA), AR ← AR + DATA
				1	(DMB + AR) ← DATA, AR ← 0
RDIDX	0 1 0 1	DM Base (x 2^1) (8) / (4)	(2) / Address Register (8)	0	DATA ← (DMB + AR + DATA), AR ← 0
				1	AR ← AR + DATA
PICKUP	1 1 0 0	(4) / Count Size (CS) (8)	(2) / Counter (C) (8)	0	When CS≠C, C←C+1; when CS=C, distribute, C←0
				1	C ← C + DATA, token deleted
COUNT	1 1 0 1	(4) / Count Size (8)	(2) / Counter (8)	0	When CS ≠ C, C ← C + 1; when CS = C, copy token, C ← 0
				1	C ← C + DATA, token deleted
CUT	0 1 1 1	(4) / Count Size (8)	S/F / (1) / Counter (8)	0	When S/F = 0 and C ≤ CS, C ← C + 1, delete token; when S/F = 0 and C > CS, or when S/F = 1, C ← C+1, token not deleted
				1	S/F ← 0, C ← 0, token deleted
DIVCYC	1 0 1 0	(4) / Count Size (4) / Divide Size (4)	(2) / Counter (4) / Counter (4)	0	When C ≤ CS, C ← C + 1; when C> CS, distribute, C ← C + 1; C←C. When C = DS, C ← 0
				1	C ← C + DATA, token deleted
DIV	1 0 1 1	(4) / Count Size (8)	S/F / (1) / Counter (8)	0	When S/F=0 and C ≤ CS, C ← C+1; when S/F = 0 and C > CS, or when S/F = 1, distribute, C ← C + 1;
				1	S/F ← 0, C ← 0, token deleted
DIST	0 0 1 0	(8) / Δ ID Size (4)	(6) / ΔID (4)	0	ID ← (ID + ΔID) modulo ΔID size
				1	When ΔID ≠ ΔID size, ID←(ID+ΔID) modulo ΔID size, ΔID ← ΔID + 1. When ΔID = ΔID size, ΔID ← 0
CONVO	1 1 1 1	(4) / Count Size (8)	(2) / Counter (7) / (1)		When CS ≠ C, ID ← ID + C (modulo 2), C ← C + 1; when CS = C, ID ← ID + 2, C ← 0
SAVE	0 1 1 0	(12)	(2) / ID Stack Register (8) (IDSR)	0	IDSR ← Lower 8-bit of DATA
				1	ID ← IDSR
CNTGE	1 1 1 0	(4) / Count Size (8)	W/D / (1) / Counter (8)	0	When dead, ID ← ID + 2; when wait, if C = CS, C ← 0, W/D = 0; when wait, if C ≠ CS, C ← C + 1
				1	When dead, initialization; when wait, delete token

PU Instructions



PU instructions (see table 20) are stored in the Function Table Left field of the Function Table memory. The bits 0 through 11 are used as control information for the Processing Unit. The bits 12 and 13 are deleted before the token arrives at the Processing Unit. Two operands from the A and B sides are operated on by the Processing Unit and the result is output to the X and Y sides (see figure 19).

Figure 19. The Processing Unit



Bit Assignments

F/L [Full/Left]: F/L bit = 0 indicates that the PU instruction is a one-operand instruction, and only the Function Table Left field is meaningful. F/L bit = 1 indicates that the PU instruction is a two-operand instruction, and both the Function Table Left field and the Function Table Right field are meaningful. Therefore, when F/L bit = 1, the PU instruction is used in conjunction with an AG/FC instruction.

XCH [Exchange]: This bit controls the exchange operation. Operands will be exchanged just before the two tokens enter the QUEUE when XCH = 1.

OUT [Output]: There are four different PU output token formats. The two OUT bits specify the output token format. See table 11.

Table 11. OUT Bits

OUT Bits	No. of Outputs	First Output ID	First Output DATA, C, S	Second Output ID	Second Output DATA, C, S
0 0	1	ID	X[1]		
0 1	1	ID	Y[2]		
1 0	2	ID	X	ID + 1	X
1 1	2	ID	X	ID + 1	Y

Notes: 1. This is the 18-bit result of the operation output to the X side. It includes the C_X and S_X bits.
2. This is the 18-bit result of the operation output to the Y side. It includes the C_Y and S_Y bits.

BRC [Branch Control]: The BRC bit controls the flow of the PU output data token. The output data token may be output to either the ID token stream or the ID + 1 token stream. When the BRC bit is set to 1 and the C bit of the PU output data token is also 1, the output data token is sent to the ID + 1 token stream. But when the BRC bit is set to 1 and the C bit of the output data token is 0, the token is sent to the ID token stream. Therefore, using the BRC bit implements a conditional branch on C.

CNOP Bit: This bit informs the Processing Unit whether or not the incoming token should be processed. If the CNOP bit is set, and the C_A bit is not equal to the C_B bit, then the token passes through the Processing Unit with no operation performed. See table 12.

Table 12. CNOP Bit

C_A	C_B	PU Operation
0	0	Processing specified by the OP code is performed.
0	1	Token passes through the Processing Unit as NOP.
1	0	Token passes through the Processing Unit as NOP.
1	1	Processing specified by the OP code is performed.

PNZ [Positive, Negative, Zero] Field: The PNZ field is used to test the resulting condition of the PU operation. If the resulting condition matches the condition set by the PNZ field, then the C bit of the output data token is set to 1. See table 13.

Table 13. PNZ Field

P	N	Z	Condition	C_X	C_Y	Assembler Description	
0	0	0	No condition set	C_A	C_B		
0	0	1	Result of operation = 0	1	1	EQ	True
			Result of operation ≠ 0	0	0		False
0	1	0	Result of operation < 0	1	1	LT	True
			Result of operation ≥ 0	0	0		False
0	1	1	Result of operation ≤ 0	1	1	LE	True
			Result of operation > 0	0	0		False
1	0	0	Result of operation > 0	1	1	GT	True
			Result of operation ≤ 0	0	0		False
1	0	1	Result of operation ≥ 0	1	1	GE	True
			Result of operation < 0	0	0		False
1	1	0	Result of operation ≠ 0	1	1	NE	True
			Result of operation = 0	0	0		False
1	1	1	Overflow generated	1	1	OVF	True
			No overflow generated	0	0		False

OP Code Field: This 5-bit OP code field specifies the PU operations to be performed. See table 14

Table 14. OP Code Field

Instruction	Mnemonic	Opcode
Logical	OR	00000
	AND	00001
	XOR	00010
	ANDNOT	00011
	NOT	01100
Arithmetic	ADD	11000
	ADDSC	11100
	SUB	11001
	SUBSC	11101
	MUL	11010
	MULSC	11110
	NOP	11011
	NOPSC	11111
	INC	01010
	DEC	01011
Shift	SHL	00100
	SHLBRV	00101
	SHR	00110
	SHRBRV	00111
Compare	CMPNOM	01000
	CMP	01001
	CMPXCH	10001
Bit manipulation	GET1	10101
	SET1	10110
	CLR1	10111
Bit check	ANDMSK	01101
	ORMSK	10000
Data conversion	CVT2AB	01110
	CVTAB2	01111
Double precision adjust	ADJL	10100
Accumulative addition	ACC	10010
C bit copy	COPYC	10011

Logical Instructions

These instructions perform 16-bit logical operations on $DATA_A$ and $DATA_B$. Usually there are no changes in C and S bits between the input token and the output token, however C bits can be affected by PNZ condition when specified.

OR, AND, XOR: These instructions perform 16-bit logical OR, AND, and XOR operations using input data tokens from the A and B sides of the Processing Unit. The 16 bit result is output to the X side.

ANDNOT: This instruction first complements $DATA_A$ and then performs logical AND operation with $DATA_B$. The 16-bit result is output to the X side.

NOT: This is a one-operand instruction which requires 16-bit data input from the A side only. The B side input is ignored. This instruction complements the 16-bit input data from the A side. The 16-bit result is output to the X side.

Arithmetic Instructions

These instructions perform 17-bit (including the sign bit) arithmetic operations on $DATA_A$ and $DATA_B$. When a PNZ condition is specified, the C bits of output data, C_X and C_Y, reflect the setting. However, if no PNZ condition is specified (i.e., PNZ = 000), then $C_X \leftarrow C_A$ and $C_Y \leftarrow C_B$.

ADD, SUB: These instructions perform addition or subtraction on $DATA_A$ and $DATA_B$ along with the sign bits, S_A and S_B. The result is output to the X side. $DATA_Y$ is normally 0000H. However, if an overflow occurs, then $DATA_Y$ is equal to +0001H ($S_Y = 0$). If an underflow occcurs, then the $DATA_Y$ is equal to −0001H ($S_Y = 1$).

MUL: This instruction multiplies $DATA_A$ and $DATA_B$. The correct sign bit for the product is determined from S_A and S_B. The 33-bit result including a sign bit is output as two 17-bit words, S_X and $DATA_X$, followed by S_Y and $DATA_Y$. $DATA_X$ is the upper 16-bit word and $DATA_Y$ is the lower 16-bit word. S_X holds the resulting sign bit, and S_Y is a mere duplicate of S_X.

NOP: This instruction performs no operation on the input token. The input data from A and B sides are output to the X and Y sides, respectively, without any change in their contents. If any control other than the OP code (such as PNZ control, BRC control, etc.) has been specified, the output complies with the control.

Shift Count Instructions

These four Shift Count (SC) instructions first perform the normal operations, then count the number of leading zeros in $DATA_X$ of the result, and finally output the number of zeros as $DATA_Y$ (see table 15). These instructions are provided for easy floating point processing.

ADDSC, SUBSC, NOPSC: These instructions perform addition, subtraction, or no operation. The number of preceding zeros in $DATA_X$ of the result is output as $DATA_Y$. If an overflow or an underflow occurs as a result of an operation, $DATA_Y$ contains + 0001H ($S_Y = 0$) or −0001H ($S_Y = 1$), respectively.

MULSC: This instruction performs a normal multiplication operation using the two 17-bit data. The upper order 16-bit data and its sign bit are output as $DATA_X$ and S_X, but the lower 16-bit data is not output as $DATA_Y$. Instead, the number of preceding zeros in $DATA_X$ are counted and output as $DATA_Y$. The S_Y bit is always zero.

Table 15. Shift Count Operation

$DATA_X$ After Operation																SC Output (Y)				
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	S_Y	Y	Data		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0 H
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	F H
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	x	0	0	0	0	E H
0	0	0	0	0	0	0	0	0	0	0	0	0	1	x	x	0	0	0	0	D H
0	0	0	0	0	0	0	0	0	0	0	0	1	x	x	x	0	0	0	0	C H
0	0	0	0	0	0	0	0	0	0	0	1	x	x	x	x	0	0	0	0	B H
0	0	0	0	0	0	0	0	0	0	1	x	x	x	x	x	0	0	0	0	A H
0	0	0	0	0	0	0	0	0	1	x	x	x	x	x	x	0	0	0	0	9 H
0	0	0	0	0	0	0	0	1	x	x	x	x	x	x	x	0	0	0	0	8 H
0	0	0	0	0	0	0	1	x	x	x	x	x	x	x	x	0	0	0	0	7 H
0	0	0	0	0	0	1	x	x	x	x	x	x	x	x	x	0	0	0	0	6 H
0	0	0	0	0	1	x	x	x	x	x	x	x	x	x	x	0	0	0	0	5 H
0	0	0	0	1	x	x	x	x	x	x	x	x	x	x	x	0	0	0	0	4 H
0	0	0	1	x	x	x	x	x	x	x	x	x	x	x	x	0	0	0	0	3 H
0	0	1	x	x	x	x	x	x	x	x	x	x	x	x	x	0	0	0	0	2 H
0	1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	0	0	0	0	1 H
1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	0	0	0	0	0 H*

Notes: * When an overflow or underflow has occurred
x don't care

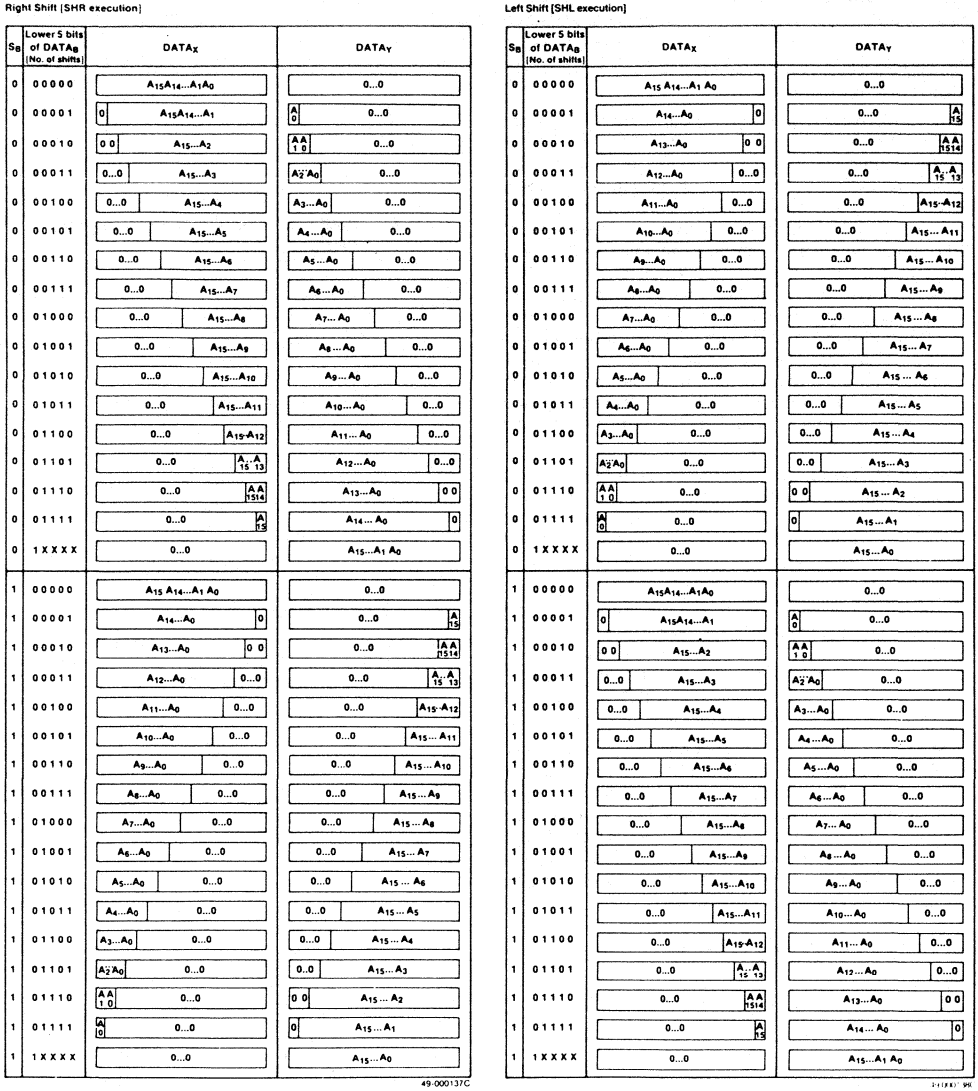
Increment and Decrement Instructions

INC, DEC: These instructions increment or decrement the 17-bit data from the A side (S_A and $DATA_A$), and outputs the result to X side as S_X and $DATA_X$. The S_Y and $DATA_Y$ are normally zero. However, if an overflow or an underflow occurs, then the Y side outputs + 0001H ($S_Y = 0$) or − 0001H ($S_Y = 1$), respectively. See figure 20 for detailed operation explanations.

Shift Instructions

SHR [Shift Right], SHL [Shift Left]: SHR or SHL instructions perform a barrel-shifting operation on the 16-bit data, $DATA_A$. The actual number of shifts and the direction is further specified by the lower five bits of $DATA_B$ and S_B, respectively. See figure 20 for detailed operation explanations.

Figure 20. SHR nd SHL



SHRBRV [Shift Right with Bit Reverse], SHLBRV [Shift Left with Bit Reverse]: SHRBRV or SHLBRV first reverses the order of the bits in $DATA_A$ and then performs a normal SHR or SHL operation, respectively. See figure 21.

Compare Instructions

The Compare instructions (see table 16) are different from other PU instructions in that PNZ conditions must be specified along with the instructions. When a compare instruction is used along with a specified PNZ field, the Processing Unit performs a subtract operation. This subtract operation produces a set of PNZ flags, which are compared against the PNZ field specified by the instruction. When these two PNZ fields coincide, the specified PNZ conditions are said to be true. When they do not coincide, the specified PNZ conditions are said to be false (see table 17). The output data from the Processing Unit differs significantly depending on the PNZ conditions. The following three instructions compare the 17-bit data (S_A and $DATA_A$) from the A side against the 17-bit data (S_B and $DATA_B$) from the B side.

CMPNOM [Compare and normalize]: If the specified PNZ conditions are false, then the control bits, sign bits and data for both the X and Y sides are set to zero. If the PNZ conditions are true, then C_X and C_Y are set to one, S_X and S_X are set to zero, $DATA_X$ is set to 0001H, and $DATA_Y$ is set to 0000H.

CMP [Compare]: This instruction outputs the 17-bit data words from the A and B sides to the X and Y sides without any change in their contents. It only alters the control bits. If the specified PNZ conditions are true, then C_X and C_Y are set to one. If the PNZ conditions are false, then C_X is set to one and C_Y is set to zero.

CMPXCH [Compare and exchange]: If the specified PNZ conditions are true, then both the input data from the A side and B side are unchanged and output to the X side and Y side, respectively, including their sign bits and the control bits. However, if the PNZ conditions are false, then the input data from the A side is exchanged with the input data from the B side, including the control and sign bits.

Figure 21. Bit Reversal Operations in SHRBRV and SHLBRV

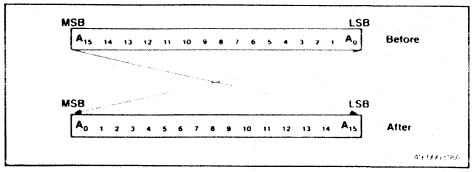


Table 17. PNZ Field Conditions for Compare Instructions

P	N	Z	Condition	True/ False	Function	Mnemonic
0	0	1	$S_A\ DATA_A = S_B\ DATA_B$	True	Equal	EQ
			$S_A\ DATA_A \neq S_B\ DATA_B$	False	Not equal	
0	1	0	$S_A\ DATA_A < S_B\ DATA_B$	True	Less than	LT
			$S_A\ DATA_A \geq S_B\ DATA_B$	False	Greater or equal	
0	1	1	$S_A\ DATA_A \leq S_B\ DATA_B$	True	Less or equal	LE
			$S_A\ DATA_A > S_B\ DATA_B$	False	Greater than	
1	0	0	$S_A\ DATA_A > S_B\ DATA_B$	True	Greater than	GT
			$S_A\ DATA_A \leq S_B\ DATA_B$	False	Less or equal	
1	0	1	$S_A\ DATA_A \geq S_B\ DATA_B$	True	Greater or equal	GE
			$S_A\ DATA_A < S_B\ DATA_B$	False	Less than	
1	1	0	$S_A\ DATA_A \neq S_B\ DATA_B$	True	Not equal	NE
			$S_A\ DATA_A = S_B\ DATA_B$	False	Equal	

Note: The significance of the PNZ bits when Compare instructions are executed differs from that of other instructions. Here, the use of PNZ = 111 or 000 is prohibited.

Table 16. Compare Instructions

Mnemonic	Input								Output				Notes
	C_A	S_A	$DATA_A$	C_B	S_B	$DATA_B$	C_X	S_X	$DATA_X$	C_Y	S_Y	$DATA_Y$	
CMPNOM	C_A	S_A	A	C_B	S_B	B	0	0	0000H	0	0	0000H	When PNZ is False
	C_A	S_A	A	C_B	S_B	B	1	0	0001H	1	0	0000H	When PNZ is true
CMP	C_A	S_A	A	C_B	S_B	B	0	S_A	A	0	S_B	B	When PNZ is false
	C_A	S_A	A	C_B	S_B	B	1	S_A	A	1	S_B	B	When PNZ is true
CMPXCH	C_A	S_A	A	C_B	S_B	B	C_A	S_A	A	C_B	S_B	B	When PNZ is true
	C_A	S_A	A	C_B	S_B	B	C_B	S_B	A	C_A	S_B	A	When PNZ is false

Bit Manipulation Instructions

GET1 [Get one bit]: This instruction is used to read a particular bit from $DATA_A$ (see table 18). A bit of $DATA_A$ specified by the lower 4 bits of $DATA_B$ is output as the least significant bit of $DATA_X$. All other bits of $DATA_X$ are set to zero. $DATA_Y$ is also set to zero. The control bits and the sign bits of $DATA_X$ and $DATA_Y$ are as follows: $C_X \leftarrow C_A$, $C_Y \leftarrow C_B$, $S_X \leftarrow S_A$, $S_Y \leftarrow 0$.

SET1 [Set one bit]: This instruction is used to set a particular bit of $DATA_A$. The bit of $DATA_A$ to be set is specified by the lower 4 bits of $DATA_B$. After the bit is set, the 16-bit result is output as $DATA_X$. $DATA_Y$ is always output as zero. The control bits and the sign bits of $DATA_X$ and $DATA_Y$ are as follows: $C_X \leftarrow C_A$, $C_Y \leftarrow C_B$, $S_X \leftarrow S_A$, $S_Y \leftarrow 0$.

CLR1 [Clear one bit]: This instruction is used to reset a particular bit of $DATA_A$. The bit of $DATA_A$ to be reset is specified by the lower 4 bits of $DATA_B$. After the bit is reset (cleared), the 16-bit result is output as $DATA_X$. $DATA_Y$ is always output as zero. The control bits and the sign bits of $DATA_X$ and $DATA_Y$ are as follows: $C_X \leftarrow C_A$, $C_Y \leftarrow C_B$, $S_X \leftarrow S_A$, $S_Y \leftarrow 0$.

Table 18. Bit Addressing

$DATA_B$ Bit				
3	2	1	0	$DATA_A$ Bit Position
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9
1	0	1	0	10
1	0	1	1	11
1	1	0	0	12
1	1	0	1	13
1	1	1	0	14
1	1	1	1	15

Bit Check Instructions

ANDMSK [Mask a word with logical AND]: This instruction tests certain bits in $DATA_A$. The bits in $DATA_A$ to be tested are first masked with a bit pattern in $DATA_B$. Only those bits in $DATA_A$ corresponding to the one bits of $DATA_B$ are considered. Then only those masked bits of $DATA_A$ are ANDed together to set or reset the control bits, C_X and C_Y. If the result of the AND operation is 1, then both the C_X and C_Y are set to 1. If the result of the operation is 0, then the both C_X and C_Y are set to 0. The rest of the output data fields are the following: $S_X \leftarrow S_A$, $S_Y \leftarrow S_B$, $DATA_X \leftarrow DATA_A$, $DATA_Y \leftarrow DATA_B$.

ORMSK [Mask a word with logical OR]: This instruction tests certain bits in $DATA_A$. The bits in $DATA_A$ to be tested are first masked with a bit pattern in $DATA_B$. Only those bits in $DATA_A$ corresponding to the one bits of $DATA_B$ are considered. Then only those masked bits of $DATA_A$ are ORed together to set or reset the control bits, C_X and C_Y. If the result of the OR operation is 1, then both C_X and C_Y are set to 1. If the result of the operation is 0, then the both C_X and C_Y are set to 0. The rest of the output data fields are the following: $S_X \leftarrow S_A$, $S_Y \leftarrow S_B$, $DATA_X \leftarrow DATA_A$, $DATA_Y \leftarrow DATA_B$.

Data Conversion Instructions

CVT2AB [Convert two's complement to sign-magnitude]: This instruction converts a 16-bit number in two's complement form to a 17-bit number in sign-magnitude form. The sign of the two's complement number is output as the S_X bit.

CVTAB2 [Convert sign-magnitude to two's complement]: This instruction converts a 17-bit number in sign-magnitude form to a 16-bit number in two's complement form. This operation has the potential danger of an overflow or an underflow. If an overflow or an underflow occurs, the C_X bit is set to 1.

Double Precision Adjustment Instruction

ADJL [Adjust long]: This instruction is used to adjust a double precision number, in which the sign bits of the upper and lower words are different. This situation may occur after a double precision arithmetic operation. The examples in table 19 illustrate the adjustments of double precision numbers.

Table 19. Double Precision Adjustment Examples

	Input/Output	Sign	Data
Input	High (A data)	0	1234H
	Low (B data)	0	5678H
Output	High (X data)	0	1234H
	Low (Y data)	0	5678H
Input	High (A data)	0	1234H
	Low (B data)	1	5678H
Output	High (X data)	0	1233H
	Low (Y data)	0	A988H
Input	High (A data)	1	1234H
	Low (B data)	0	5678H
Output	High (X data)	1	1233H
	Low (Y data)	1	A988H

Accumulative Addition Instruction

ACC [Accumulate]: This instruction (see figure 22) performs cumulative additions of incoming tokens' data fields. The incoming tokens are classified into type 1 and type 2 tokens. A type 1 token is deleted after the ACC operation, but a type 2 token is not. Moreover, a type 2 token reads the contents of the ACC register, which contains the accumulated sum of tokens. When a type 2 token reads the contents of the ACC register, the ID field of the token is unchanged. However, if an overflow has occurred prior to the arrival of a type 2 token, the ID field is incremented by one. Only the following three tokens qualify as type 2 tokens.

1. If the ACC instruction is used along with RDCYCS instruction, and the token's FTRC bit = 1, and the Buffer Size and Read Counter of RDCYCS instruction are equal.
2. If the ACC instruction is used along with RDCYCL instruction, and the token's FTRC bit = 1, and the Buffer size and Read Counter of RDCYCL instruction are equal.
3. If the ACC instruction is used along with COUNT instruction, and the token's FTRC bit = 0, and the Count Size and Counter of COUNT instruction are equal.

C Bit Copy Instruction

COPYC [Copy control bit]: This instruction copies the control bit of the A side and outputs it as C_Y.

$C_X \leftarrow C_A$, $S_X \leftarrow S_A$, $DATA_X \leftarrow DATA_A$, $C_Y \leftarrow C_A$, $S_Y \leftarrow S_B$, $DATA_Y \leftarrow DATA_B$.

Figure 22. ACC Instruction

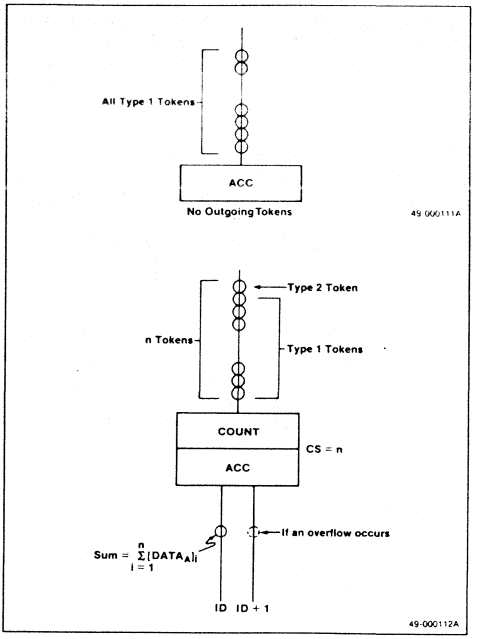


Table 20. PU Instruction

Mnemonic	OP Code	Input						Output						Notes
		C_A	S_A	$DATA_A$	C_B	S_B	$DATA_B$	C_X	S_X	$DATA_X$	C_Y	SY	$DATA_Y$	
Logical Operations														
OR	00000	C_A	S_A	A	C_B	S_B	B	C_X	S_A	A OR B	C_Y	0	0000H	
AND	00001	C_A	S_A	A	C_B	S_B	B	C_X	S_A	A AND B	C_Y	0	0000H	
XOR	00010	C_A	S_A	A	C_B	S_B	B	C_X	S_A	A XOR B	C_Y	0	0000H	
ANDNOT	00011	C_A	S_A	A	C_B	S_B	B	C_X	S_A	$\overline{A}$ AND B	C_Y	0	0000H	
NOT	01100	C_A	S_A	A				C_X	S_A	$\overline{A}$	C_Y	0	0000H	
Arithmetic Operations														
ADD	11000	C_A	0	A	C_B	0	B	C_X	0	A + B	C_Y	0	*	
		C_A	0	A	C_B	1	B	C_X	0	A − B	C_Y	0	0000H	When $A \geq B$, $S_X = 0$
								C_X	1	B − A	C_Y	1	0000H	When $A < B$, $S_X = 1$
		C_A	1	A	C_B	0	B	C_X	0	B − A	C_Y	0	0000H	When $A < B$, $S_X = 0$
								C_X	1	A − B	C_Y	1	0000H	When $A \geq B$, $S_X = 1$
		C_A	1	A	C_B	1	B	C_X	1	A + B	C_Y	1	*	
ADDSC	11100	C_A	0	A	C_B	0	B	C_X	0	A + B	C_Y	S_S	No. of shifts †	
		C_A	0	A	C_B	1	B	C_X	0	A − B	C_Y	S_S	*	When $A \geq B$, $S_X = 0$
								C_X	1	B − A	C_Y	S_S	No. of shifts †	When $A < B$, $S_X = 1$
		C_A	1	A	C_B	0	B	C_X	0	B − A	C_Y	S_S	*	When $A < B$, $S_X = 0$
								C_X	1	A − B	C_Y	S_S	No. of shifts †	When $A \geq B$, $S_X = 1$
		C_A	1	A	C_B	1	B	C_X	1	A + B	C_Y	S_S	No. of shifts†	
SUB	11001	C_A	0	A	C_B	0	B	C_X	0	A − B	C_Y	0	0000H	When $A > B$, $S_X = 0$
								C_X	1	B − A	C_Y	1	0000H	When $A < B$, $S_X = 1$
		C_A	0	A	C_B	1	B	C_X	0	A + B	C_Y	0	*	
		C_A	1	A	C_B	0	B	C_X	1	A + B	C_Y	1	*	
		C_A	1	A	C_B	1	B	C_X	0	B − A	C_Y	0	0000H	When $A < B$, $S_X = 0$
								C_X	1	A − B	C_Y	1	0000H	When $A \geq B$, $S_X = 1$
SUBSC	11101	C_A	0	A	C_B	0	B	C_X	0	A − B	C_Y	S_S	No. of shifts †	When $A \geq B$, $S_X = 0$
								C_X	1	B − A	C_Y	S_S	No. of shifts †	When $A < B$, $S_X = 1$
		C_A	0	A	C_B	1	B	C_X	0	A + B	C_Y	S_S	No. of shifts †	
		C_A	1	A	C_B	0	B	C_X	1	A + B	C_Y	S_S	No. of shifts †	
		C_A	1	A	C_B	1	B	C_X	0	B − A	C_Y	S_S	No. of shifts †	When $A < B$, $S_X = 0$
								C_X	1	A − B	C_Y	S_S	No of shifts †	When $A \geq B$, $S_X = 1$
MUL	11010	C_A	S_A	A	C_B	S_B	B	C_X	S_X	A x B High	C_Y	S_X	A x B Low	$S_X = S_A$ OR S_B (logical OR)
MULSC	11110	C_A	S_A	A	C_B	S_B	B	C_X	S_X	A x B High	C_Y	S_S	No. of shifts †	$S_X = S_A$ OR S_B (logical OR)

Table 20. PU Instruction (cont)

Mnemonic	OP code	Input						Output						Notes
		C_A	S_A	$DATA_A$	C_B	S_B	$DATA_B$	C_X	S_X	$DATA_X$	C_Y	SY	$DATA_Y$	
Arithmetic Operations														
NOP	11011	C_A	S_A	A	C_B	S_B	B	C_X	S_A	A	C_Y	S_B	B	
NOPSC	11111	C_A	S_A	A	C_B	S_B	B	C_X	S_A	A	C_Y	S_S	No. of shifts †	
INC	01010	C_A	0	A				C_X	0	A + 1	C_Y	0	*	
		C_A	1	A				C_X	0	1	C_Y	0	0000H	When A = 0, S_X = 0
								C_X	1	A − 1	C_Y	1	0000H	When A ≥ 1, S_X = 1
DEC	01011	C_A	0	A				C_X	0	A − 1	C_Y	0	0000H	When A ≥ 0, S_X = 0
								C_X	1	1	C_Y	1	0000H	When A = 0, S_X = 1
		C_A	1	A				C_X	1	A + 1	C_Y	1	*	
Shift														
SHL	00100	C_A	S_A	A	C_B	0	No. of shifts	C_X	S_A	Shift A left	C_Y	S_A	Shift A left	
		C_A	S_A	A	C_B	1	No. of shifts	C_X	S_A	Shift A right	C_Y	S_A	Shift A right	
SHLBRV	00101	C_A	S_A	A	C_B	0	No. of shifts	C_X	S_A	Invert A shift left	C_Y	S_A	Invert A shift left	
		C_A	S_A	A	C_B	1	No. of shifts	C_X	S_A	Invert A shift right	C_Y	S_A	Invert A shift right	
SHR	00110	C_A	S_A	A	C_B	0	No. of shifts	C_X	S_A	Shift A right	C_Y	S_A	Shift A right	
		C_A	S_A	A	C_B	1	No. of shifts	C_X	S_A	Shift A left	C_Y	S_A	Shift A left	
SHRBRV	00111	C_A	S_A	A	C_B	0	No. of shifts	C_X	S_A	Invert A shift right	C_Y	S_A	Invert A shift right	
		C_A	S_A	A	C_B	1	No. of shifts	C_X	S_A	Invert A shift left	C_Y	S_A	Invert A shift left	
Comparison														
CMPNOM	01000	C_A	S_A	A	C_B	S_B	B	0	0	0000H	0	0	0000H	When PNZ is false
		C_A	S_A	A	C_B	S_B	B	1	0	0001H	1	0	0000H	When PNZ is true
CMP	01001	C_A	S_A	A	C_B	S_B	B	0	S_A	A	0	S_B	B	When PNZ is false
		C_A	S_A	A	C_B	S_B	B	1	S_A	A	1	S_B	B	When PNZ is true
CMPXCH	10001	C_A	S_A	A	C_B	S_B	B	C_A	S_A	A	C_B	S_B	B	When PNZ is true
		C_A	S_A	A	C_B	S_B	B	C_B	S_B	B	C_A	S_A	A	When PNZ is false
Accumulative Addition														
ACC	10010	C_A	S_A	A	C_B	S_B	B	C_X	S_X	ΣA				Used as a pair with AG & FC instruction COUNT
C Bit Copy														
COPYC	10011	C_A	S_A	A	C_B	S_B	B	C_A	S_A	A	C_A	S_B	B	

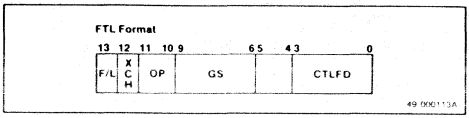
Table 20. PU Instruction (cont)

Mnemonic	OP code	Input							Output				Notes
		C_A	S_A	$DATA_A$	C_B	S_B	$DATA_B$	C_X	S_X	$DATA_X$	C_Y	SY	$DATA_Y$	
Bit Operations														
GET1	10101	C_A	S_A	A	C_B	S_B	Bit position	C_X	S_A	0000H	C_Y	0	0000H	When the bit specified by the lower 4 bits of $DATA_B$ is 0
		C_A	S_A	A	C_B	S_B	Bit position	C_X	S_A	0001H	C_Y	0	0000H	When the bit specified by the lower 4 bits of $DATA_B$ is 1
SET1	10110	C_A	S_A	A	C_B	S_B	Bit position	C_X	S_A	A bit in $DATA_A$ is set	C_Y	0	0000H	Bit specification by the lower 4 bits of $DATA_B$
CLR1	10111	C_A	S_A	A	C_B	S_B	Bit position	C_X	S_A	A bit in $DATA_A$ is cleared	C_Y	0	0000H	Bit specification by the lower 4 bits of $DATA_B$
Bit Check														
ANDMSK	01101	C_A	S_A	A	C_B	S_B	B	0	S_A	A	0	S_B	B	If ANDMSK = 0
		C_A	S_A	A	C_B	S_B	B	1	S_A	A	1	S_B	B	If ANDMSK = 1
ORMSK	10000	C_A	S_A	A	C_B	S_B	B	0	S_A	A	0	S_B	B	If ORMSK = 0
		C_A	S_A	A	C_B	S_B	B	1	S_A	A	1	S_B	B	If ORMSK = 1
Data Conversion														
CVT2AB	01110	C_A	S_A	A	C_B	S_B	B	C_X	S_X	Converted A data	C_Y	0	0000H	Absolute value ← twos complement
CVTAB2	01111	C_A	S_A	A	C_B	S_B	B	C_X	S_X	Converted A data	C_Y	0	0000H	Twos complement ← absolute value
Adjustment of Double Precision Numbers														
ADJL	10100	C_A	0	A	C_B	1	B	C_X	0	A − 1	C_Y	0	0000H-B	A ≠ 0 AND B ≠ 0
		C_A	1	A	C_B	0	B	C_X	1	A − 1	C_Y	1	0000H-B	A ≠ 0 AND B ≠ 0
		C_A	0	A	C_B	1	0000H	C_X	0	A	C_Y	0	0000H	
		C_A	0	0000H	C_B	1	B	C_X	1	0000H	C_Y	1	B	B ≠ 0
		C_A	1	A	C_B	0	0000H	C_X	1	A	C_Y	1	0000H	
		C_A	1	0000H	C_B	0	B	C_X	0	0000H	C_Y	0	B	B ≠ 0
		C_A	0	A	C_B	0	B	C_X	0	A	C_Y	0	B	
		C_A	1	A	C_B	1	B	C_X	1	A	C_Y	1	B	

Notes: * If an overflow occurs as the result of A + B, $DATA_Y$ = 0001H and if no overflow, $DATA_Y$ = 0000H.

† This indicates the number of consecutive zeros from the MS_B of $DATA_X$. This number is used to calculate the number of shifts to be performed by subsequent processing.

GE Instructions



Bit Assignments

F/L [Full/Left]: F/L bit = 0 indicates that the GE instruction is used alone, whereas F/L bit = 1 indicates that the GE instruction is used in conjunction with an AG/FC instruction.

XCH [Exchange]: XCH bit = 1 indicates that the data from A side and B side are to be exchanged before the two data tokens enter the Queue.

OP [OP code]: These two bits select an operation to be performed. See table 21.

Table 21. OP Bits

OP	Operation
00	COPYBK (Copy block)
01	COPYM (Copy multiple)
11	SETCTL (Set control field)

GS [Generation Size]: These four bits determine the number of copies of a token to be made. A minimum of 2 and a maximum of 17 copies can be made using a GE instruction.

CTLFD [Control Field]: This field is used with Set Control Field (SETCTL) instruction. The data in CTLFD field further specifies the types of operations to be performed by the SETCTL instruction.

COPYBK [Copy Block]

COPYBK is used to duplicate a block of tokens from a single token. These duplicated tokens have exactly the same ID as the original token except the token copied last which has the original token's ID plus one. The number of tokens to be generated is specified by the GS field, and the COPYBK instruction generates exactly GS + 2 tokens. The data fields of the tokens being duplicated can also be incremented or decremented in a systematic manner. The incremental (or decremental) step value is contained in $DATA_B$. The tokens generated are sent to the Link Table. The series of LT tokens output by the instruction is shown in figure 23.

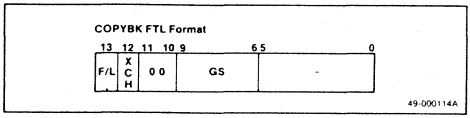
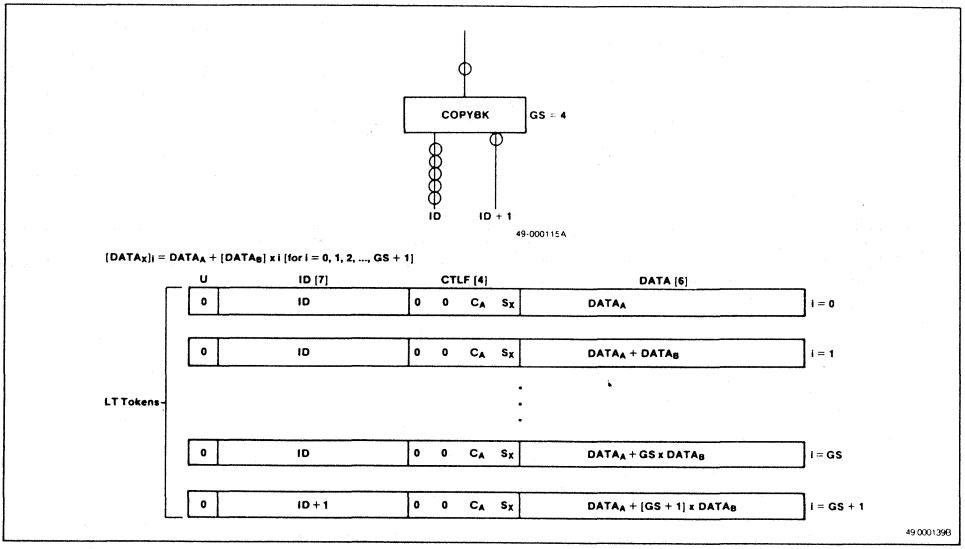


Figure 23. COPYBK Instruction Output



COPYM [Copy Multiple]

COPYM is used to generate multiple tokens from a single token. Each generated token has a different ID value. The number of tokens generated from the original token is GS + 2. The data field of the tokens being generated can also be incremented or decremented in a systematic manner. The incremental (or decremental) step value is contained in $DATA_B$. The generated tokens are sent to the Link Table as LT tokens. The series of LT tokens output by the COPYM instruction is shown in figure 24.

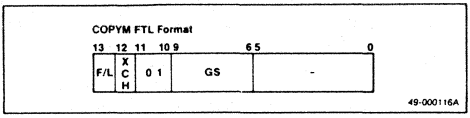
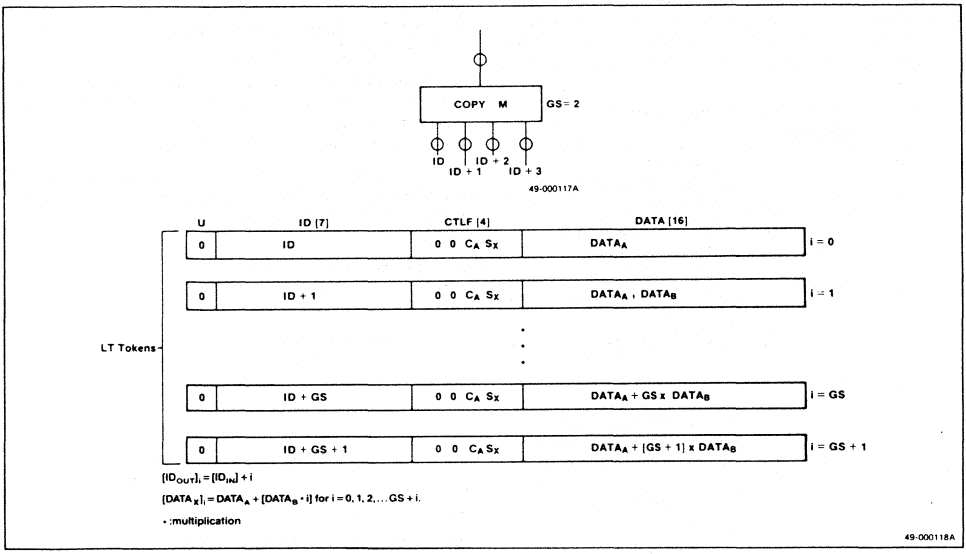
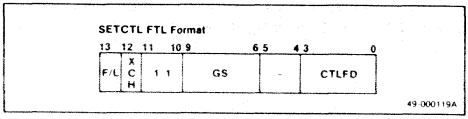


Figure 24. COPYM Instruction Output Tokens



SETCTL [Set Control Field]



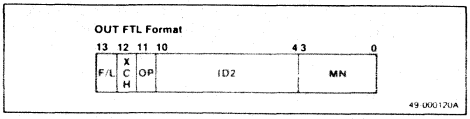
SETCTL is used to read and rewrite the contents of the Link Table and the Function Table. Since it can change the contents of the Link Table and the Function Table, this instruction can be used to write a self-modifying code. The type of operation to be performed is further specified by the contents of CTLFD field, as shown in table 22.

Table 22. SETCTL Instruction Control Field Operation

CTLFD				Operation
0	0	C	S	Normal data. Operation is exactly the same as COPYM.
1	1	0	0	The data field of this token is used to set a location in the Link Table memory (C and S bits are not included.) After the data is set, the token is deleted.
1	1	0	1	The data field of this token is used to set a location in the Function Table Right field. After the data is set, the token is deleted.
1	1	1	0	The lower 14 bits of the data field of this token are used to set a location in the Function Table Left field (higher bits are ignored.) After the data is set, the token is deleted.
1	1	1	1	The lower 10 bits of the data field of this token are used to set a location in the Function Table Temporary field (higher bits are ignored.) After the data is set, the token is deleted.
1	0	0	0	This token reads the LT address indicated by the ID field and outputs the contents.
1	0	0	1	This token reads the Function Table Right field address indicated by the ID field and outputs the contents.
1	0	1	0	This token reads the Function Table Left field address indicated by the ID field and outputs the contents.
1	0	1	1	This token reads the Function Table Temporary field address indicated by the ID field and outputs the contents.
0	1	0	0	These tokens should not be generated by the Processing
0	1	0	1	Unit. They are operating-mode-related tokens.
0	1	1	0	
0	1	1	1	

Note: The set or write operation is performed at the address indicated by the ID field of the token.

OUT Instructions



Bit Assignments

F/L [Full/Left]: F/L bit = 0 indicates that the OUT instruction is to be used alone. F/L bit = 1 indicates that the OUT instruction is to be used in conjunction with an AG/FC instruction.

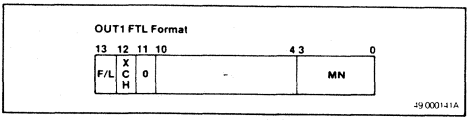
XCH [Exchange]: If XCH bit = 1, the output data tokens from the A side are exchanged with those from the B side before they go to the Output Queue. If XCH bit = 0, no exchange operation is performed.

OP [OP Code]: This bit is used to further specify the OUT instruction. If OP = 0, then OUT1 instruction is performed, whereas if OP = 1, OUT2 instruction is performed.

ID2 [Second ID]: This field is used only by the OUT2 instruction. ID2 is the ID of the second output data token.

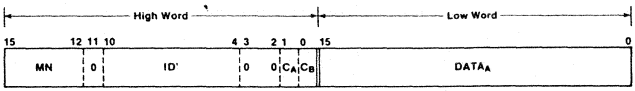
MN [Module Number]: This field indicates the destination module of the output data token.

OUT1



This instruction outputs a 32-bit data token via the Output Data Bus (ODB). Since the size of the ODB is 16 bits, a 32-bit output data token is divided into two 16-bit words and output one 16-bit word at a time. The format of an output data token is shown in figure 24.

Figure 25. OUT1 Output Token Format

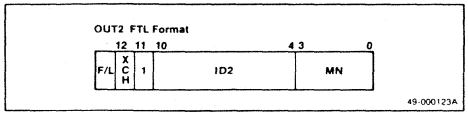


MN: Determined by the lower 4 bits of FTL contents
ID': 7-bit ID comes from the contents of LT referenced by the OUT1 instruction
C_A, S_A: Control bit and sign bit of $DATA_A$
$DATA_A$: 16-bit output data

49-000121A

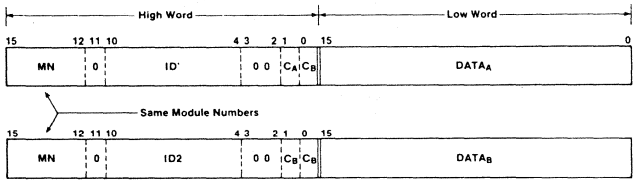
OUT2

This instruction outputs two 32-bit data tokens via ODB. Since the ODB is 16 bits wide, each 32-bit token is divided into two 16-bit words and output one 16-bit word at a time. This instruction is useful when a double precision number is to be output. The formats of two output data tokens are shown in figure 25.



49-000123A

Figure 26. OUT2 Output Tokens Format



Note: First and second tokens must have the same module numbers

MN:	Determined by the lower four bits of the FTL contents.
ID':	7-bit ID coming from the contents of the Link Table referenced by the OUT2 instruction.
ID2:	7-bit ID comes from the FTL field of the OUT2 instruction.
C_A, S_A:	Control bit and sign bit of $DATA_A$.
$DATA_A$:	First 16-bit output data.
C_B, S_B:	Control bit and sign bit of $DATA_B$.
$DATA_B$:	Second 16-bit output data.

49-000122A

Figure 27. Data-Flow Graph Explanation

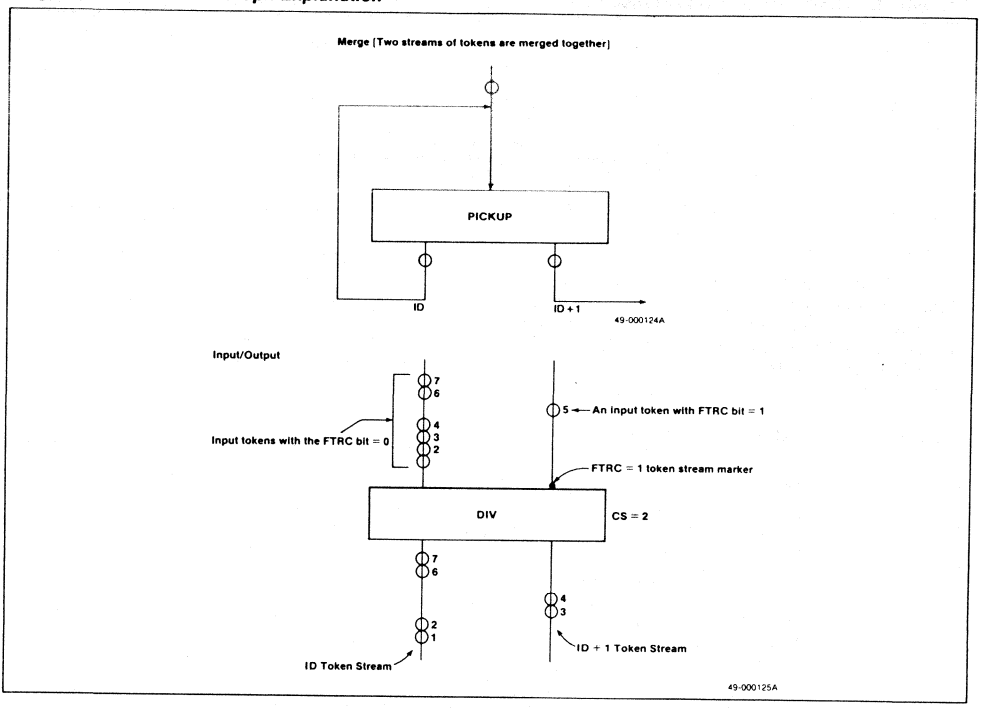
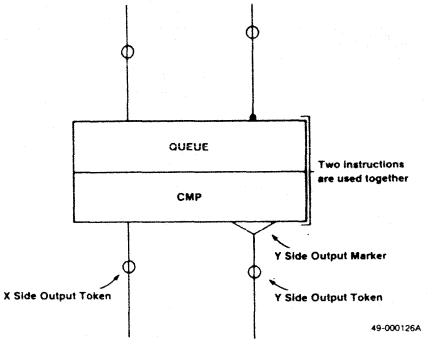
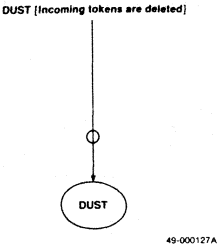
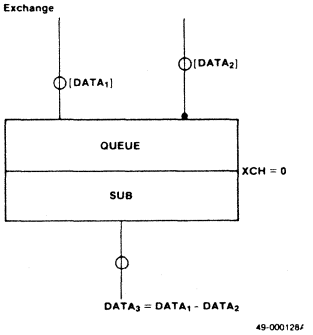
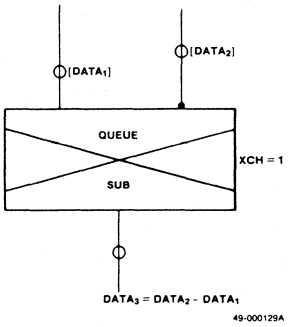


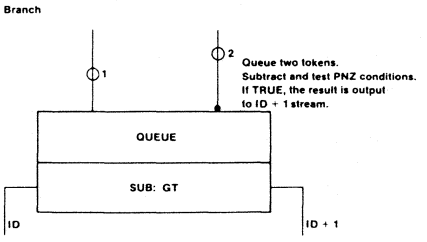
Figure 27. Data-Flow Graph Explanation (cont)

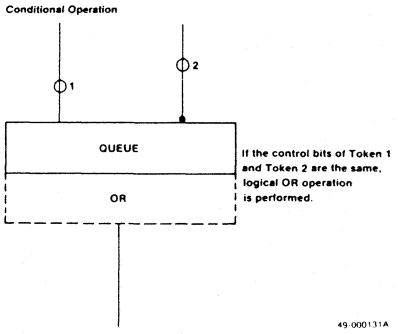












PRELIMINARY ELECTRICAL SPECIFICATIONS μPD7281D

Absolute Maximum Ratings ($T_a = 25°C$)

Parameter	Symbol	Test Conditions	Ratings	Units
Supply Volatge	V_{CC}		−0.3 to +7.0	V
Input Voltage	V_I		−0.3 to +7.0	V
Output Voltage	V_O		−0.3 to +7.0	V
Operating Temperature	T_{opt}		−10 to +70	°C
Storage Temperature	T_{stg}		−65 to +150	°C

CAPACITANCE ($T_a = 25°C$, $V_{CC} = 0V$)

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Units
CLK, SCK Capacitance	$C_Ø$				20	pF
Input Capacitance	C_{IN}	Fc = 1 MHz			10	pF
Output Capacitance	C_{OUT}				20	pF

DC Characteristics ($T_a = +25°C$, $V_{CC} = +5 \pm 10\%$)

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Input Low Volatge 1 (RESET/IDB15-0)	V_{IL1}		−0.5		0.8	V
Input High Volatge 1 (RESET/IDB15-0)	V_{IH1}		2.0		V_{CC} +0.5	V
Input Low Voltage 2 REQ/, OACK/	V_{IL2}		−0.5		0.45	V
INput High Voltage 2 IREQ/, OACK/	V_{IH2}		3.5		V_{CC} +0.5	V
Output Low Voltage	V_{OL}	I_{OL} = 2.0 mA			0.45	V
Output High Voltage	V_{OH}	I_{OH} = 400 μA	2.4			V
Input Leakage (Input Low)	I_{LIL}	$V_{IN} = 0V$			−10	μA
Input Leakage (Input High)	I_{LIH}	$V_{IN} = V_{CC}$			10	μA
Input Leakage (Output Low)	I_{LOL}	V_{OUT} = 0.47V			−10	μA
Input Leakage (Output High)	I_{LOH}	$V_{OUT} = V_{CC}$			−10	μA
Supply Current (V_{CC})	I_{CC}			300	500	mA

"SIGNAL/" Means Active Low Signal

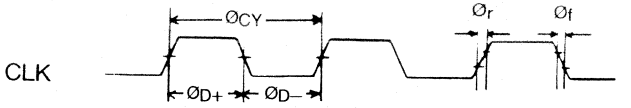
PRELIMINARY ELECTRICAL SPECIFICATIONS μPD7281D

AC Characteristics ($T_a = 25°C$, $V_{CC} = 5V \pm 10\%$)

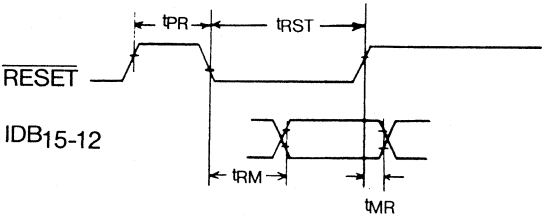
Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Units
CLK Cycle Time	ØCY	Measured Between 1V&3V	100		200	ns
CLK Pulse width high	ØD+		48			ns
CLK Pulse width low	ØD–		48			ns
CLK Rise time	Ør				10	ns
CLK Fall time	Øf				10	ns
IACK/Delay time –1 (from IREQ/down)	tWA –1				40	ns
IACK/Delay time –2 (from IREQ/up)	tWA –2				40	ns
IACK/Delay Time –3 (from IREQ/down)	tWA –3				60	ns
IACK/Delay time –4 (From IREQ/up)	tWA –4				60	ns
Min Time between transitions on IREQ/and IACK/	tAW		45			ns
IREQ/rise time	tr				10	ns
IREQ/fall time	tf				10	ns
Data set up time (before IREQ/up)	tDW		50			
Data Hold time (after IREQ/up)	tWD		0			
OREQ/Delay time –1 (from OACK/down)	tAR –1				40	
OREQ/Delay time –2 (from OACK/up)	tAR –2				45	
OREQ/Delay time –3 (from OACK/down	tAR –3				40	
OREQ/Delay time –4 (from OACK/up)	tAR –4				45	
Min time between transitions on OREQ/and OACK/	tRA		45			
OACK/rise time	tr				10	
OACK/fall time Data Access Time (after OREQ/down)	tf tRD				10 20	
Data Float Time (after OREQ/up)	tDF		10		100	
Pre-RESET/high time	tPR		2			OCY
RESER/low time	tRST		4			OCY
Module number data setup time (after RESET/down)	tRM				2	OCY
Module number data hold time (after RESET/up)	tMR		0			ns

"Up" Means On Rise Edge, "Down" Means On Falling Edge, "SIGNAL/" Means Active Low Signal

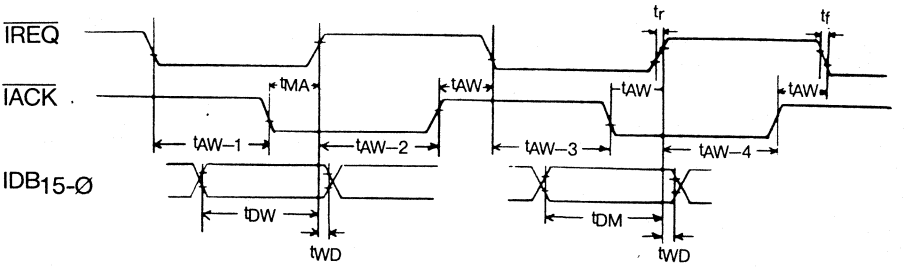
μPD7281 Preliminary Electrical Specification



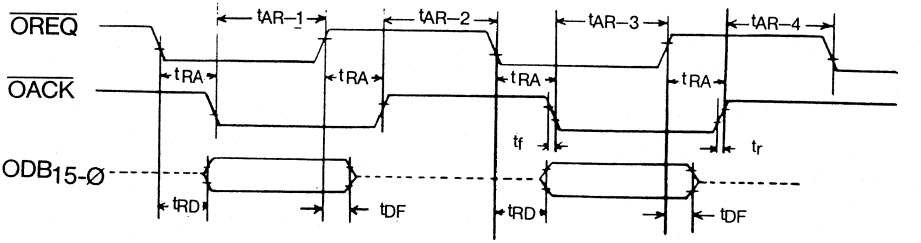
MODULE NUMBER SETTING:



INPUT HANDSHAKE TIMING



OUTPUT HANDSHAKE TIMING



MEMORY ACCESS AND GENERAL BUS INTERFACE FOR THE μPD7281

Description

The NEC μPD9305 memory access and general bus interface chip (MAGIC) is a peripheral LSI support device for the μPD7281 image pipelined processor (ImPP). The μPD7281 is a data flow architecture processor that supports high speed image and signal processing applications. The μPD9305 chip can support from one to eight μPD7281s and also interfaces to both 8-bit and 16-bit host processors.

The μPD9305's powerful interface capabilities allow it to support basic interface operations, object program load, read/write/modify operations on image memory, and multiple μPD7281 image memory accesses.

Since the μPD7281 ImPP does not use direct addressing, the memories in a μPD7281 processor system can be seen as processing modules with unique module numbers. These separate modules must output memory access tokens containing their own unique address, data, and control signals. The modules must perform the necessary processing, and then output the result of the access as another memory access token. To do this, the multiple μPD7281 modules require external circuitry to process the memory access tokens that they output. In addition, this same circuitry is required to organize the data output from the memory into token format.

Circuitry is also needed between the host processor and the μPD7281s to organize the data from the host into token format and to return the data output from the μPD7281s into the form required by the host processor. Finally, tokens may have to be returned to other μPD7281s in token form for further processing.

The μPD9305 simplifies the above operations by keeping the data in the most convenient form. The μPD9305 replaces approximately 80 medium/small scale integrated devices with a single integrated circuit.

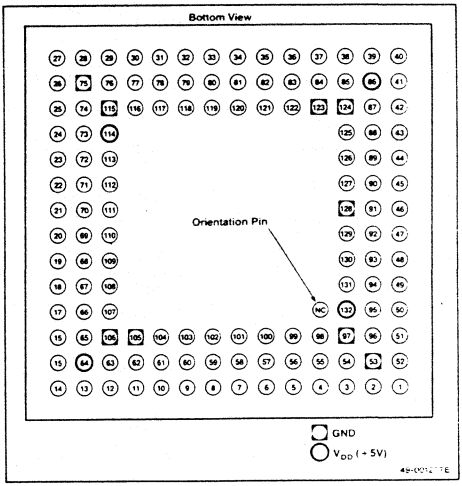
Features

- ☐ High performance image memory interface
- ☐ Reduces external circuits required for ImPP system
- ☐ Simplifies host interface
- ☐ Up to 24-bit image memory addressing
- ☐ Up to 18-bit image memory data
- ☐ Register file for memory access
- ☐ Refresh control of image memory
- ☐ Functions with separate DMA controller
- ☐ Single +5 V power supply
- ☐ CMOS technology for lower power consumption

Ordering Information

Part Number	Package Type
μPD9305R	132-pin ceramic grid array

Pin Configuration



Pin Identification

No.	Symbol	Function
1	CLK	Clock input
2-4	D_{10},D_{12}, D_{15}	Bidirectional data bus bits
5	$\overline{OACK}$	Output acknowledge input
6	$\overline{OREQ}$	Output request output
7	IDB_{14}	Input data bus bit
8	ODB_{14}	Output data bus bit
9	IDB_{11}	Input data bus bit
10, 11	ODB_{11}, ODB_8	Output data bus bits
12	IDB_9	Input data bus bit
13	ODB_5	Output data bus bit
14	IDB_8	Input data bus bit
15	ODB_4	Output data bus bit
16	IDB_7	Input data bus bit
17	ODB_2	Output data bus bit

Pin Identification (Cont)

No.	Symbol	Function
18	IDB_6	Input data bus bit
19	MN_2	Module number output
20	IDB_4	Input data bus bit
21	IMA_{22}	Image memory address output bit
22	IDB_2	Input data bus bit
23, 24	IMA_{18}, IMA_{15}	Image memory address output bits
25	IDB_0	Input data bus bit
26-28	IMA_{12}-IMA_{10}	Image memory address output bits
29	SOLBSY	Self object load busy output
30	CPURQ	CPU request output
31	DMAAEN	DMA address enable input
32-34	IMA_5,IMA_2, IMA_0	Image memory address output bits
35	$\overline{DMAAK1}$	DMA / 1 acknowledge input
36	$\overline{DMARQ1}$	DMA / 1 request output
37	IMD_{13}	Bidirectional image memory data bus bit
38	$\overline{IMAK}$	Image memory acknowledge input
39-42	IMD_{10}-IMD_7	Bidirectional image memory data bus bits
43	A_0	Address select input
44,45	IMD_3,IMD_1	Bidirectional image memory data bus bits
46	IMWR	Image memory write output
47	$\overline{WR}$	Write input
48,49	D_2,D_5	Bidirectional data bus bits
50	$\overline{CS}$	Chip select input
51,52	D_8,D_9	Bidirectional data bus bits
53	GND	Ground
54,55	D_{11},D_{14}	Bidirectional data bus bits
56	$\overline{IREQ}$	Input request input
57	$\overline{IACK}$	Input acknowledge output
58	IDB_{13}	Input data bus bit
59	ODB_{13}	Output data bus bit
60	IDB_{10}	Input data bus bit
61-63	ODB_{10},ODB_7, ODB_6	Output data bus bits
64	V_{DD}	+5 V power supply
65,66	ODB_3,ODB_1	Output data bus bits
67	IDB_5	Input data bus bit
68	MN_1	Module number output bit

Pin Indentification (Cont)

No.	Symbol	Function
69,70	IMA_{23},IMA_{21}	Image memory address output bits
71	IDB_1	Input data bus bit
72-74	IMA_{17},IMA_{14}, IMA_{13}	Image memory address output bits
75	GND	Ground
76,77	IMA_9,IMA_8	Image memory address output bits
78	INBUSY	Input to ImPP busy output
79, 80	IMA_4,IMA_1	Image memory address output bits
81	IMD_{17}	Bidirectional image memory data bus bit
82	$\overline{DMAAK2}$	DMA / 2 acknowledge input
83	$\overline{DMARQ2}$	DMA / 2 request output
84, 85	IMD_{12},IMD_{11}	Bidirectional image memory data bus bits
86	V_{DD}	+5 V power supply
87,88	IMD_6,IMD_5	Bidirectional image memory data bus bits
89	A_1	Address select input
90	IMD_0	Bidirectional image memory data bus bit
91	IMRF	Image memory refresh output
92	D_0	Bidirectional data bus bit
93	$\overline{RD}$	Read input
94-96	D_4,D_6,D_7	Bidirectional data bus bits
97	GND	Ground
98	D_{13}	Bidirectional data bus bit
99	$\overline{IPPRST}$	Image pipelined processor reset output
100	IDB_{15}	Input data bus bit
101	ODB_{15}	Output data bus bit
102	IDB_{12}	Input data bus bit
103,104	ODB_{12},ODB_9	Output data bus bits
105,106	GND	Ground
107	ODB_0	Output data bus bit
108,109	MN_3,MN_0	Module number output bits
110	IDB_3	Input data bus bit
111-113	IMA_{20},IMA_{19}, IMA_{16}	Image memory address outputs
114	V_{DD}	+5 V power supply
115	GND	Ground
116-118	IMA_7,IMA_6, IMA_3	Image memory address outputs

Pin Identification (Cont)

No.	Symbol	Function
119	$\overline{RESET}$	Reset input
120-122	IMD_{16}-IMD_{14}	Bidirectional image memory data bus bits
123,124	GND	Ground
125,126	IMD_4,IMD_2	Bidirectional image memory data bus bits
127	IMRD	Image memory read output
128	GND	Ground
129	ERR	Error output
130,131	D_1,D_3	Bidirectional data bus bits
132	V_{DD}	+5 V power supply

Pin Functions

Table 1 shows the μPD9305 pins in their particular functional groups. The paragraphs that follow table 1 describe the operation of the pins in each group.

All unused input or output pins should be pulled up to V_{DD} or down to GND through a 2K-3K ohm resistor.

Table 1. μPD9305 Pins by Function

I/O	Signal	No.
I	CLK	1
	$\overline{RESET}$	119
	Status	
O	ERR	129
	$\overline{SOLBSY}$	29
	$\overline{CPURQ}$	30
	$\overline{INBUSY}$	78
	Host Interface	
I	$\overline{WR}$	47
	$\overline{RD}$	93
	$\overline{CS}$	50
	A_0	43
	A_1	89
I/O	D_0	92
	D_1	130
	D_2	48
	D_3	131
	D_4	94
	D_5	49
	D_6	95
	D_7	96
	D_8	51
	D_9	52
	D_{10}	2
	D_{11}	54
	D_{12}	3
	D_{13}	98
	D_{14}	55
	D_{15}	4
	DMA	
O	$\overline{DMARQ1}$	36
	$\overline{DMARQ2}$	83
I	$\overline{DMAAK1}$	35
	$\overline{DMAAK2}$	82
	DMAAEN	31

Table 1. μPD9305 Pins by Function (Cont)

I/O	Signal	No.
	μPD7281 Interface	
O	MN_0	109
	MN_1	68
	MN_2	19
	MN_3	108
O	$\overline{OREQ}$	6
I	$\overline{OACK}$	5
	$\overline{IREQ}$	56
O	$\overline{IACK}$	57
	$\overline{IPPRST}$	99
O	ODB_0	107
	ODB_1	66
	ODB_2	17
	ODB_3	65
	ODB_4	15
	ODB_5	13
	ODB_6	63
	ODB_7	62
	ODB_8	11
	ODB_9	104
	ODB_{10}	61
	ODB_{11}	10
	ODB_{12}	103
	ODB_{13}	59
	ODB_{14}	8
	ODB_{15}	101
I	IDB_0	25
	IDB_1	71
	IDB_2	22
	IDB_3	110
	IDB_4	20
	IDB_5	67
	IDB_6	18
	IDB_7	16
	IDB_8	11
	IDB_9	12
	IDB_{10}	60
	IDB_{11}	9
	IDB_{12}	102
	IDB_{14}	7
	IDB_{15}	100

Table 1. μPD9305 Pins by Function (Cont)

I/O	Signal	No.
	Image Memory Interface	
I	$\overline{IMAK}$	38
O	$\overline{IMRD}$	127
	$\overline{IMWR}$	46
	$\overline{IMRF}$	91
I/O	IMD_0	90
	IMD_1	45
	IMD_2	126
	IMD_3	44
	IMD_4	125
	IMD_5	88
	IMD_6	87
	IMD_7	42
	IMD_8	41
	IMD_9	40
	IMD_{10}	39
	IMD_{11}	85
	IMD_{12}	84
	IMD_{13}	37
	IMD_{14}	122
	IMD_{15}	121
	IMD_{16}	120
	IMD_{17}	81

Table 1. μPD9305 Pins by Function (Cont)

I/O	Signal	No.
	Image Memory Interface	
	IMA_0	34
	IMA_1	80
	IMA_2	33
	IMA_3	118
	IMA_4	79
	IMA_5	32
	IMA_6	117
	IMA_7	116
	IMA_8	77
	IMA_9	76
	IMA_{10}	28
0	IMA_{11}	27
	IMA_{12}	26
	IMA_{13}	74
	IMA_{14}	73
	IMA_{15}	24
	IMA_{16}	113
	IMA_{17}	72
	IMA_{18}	23
	IMA_{19}	112
	IMA_{20}	111
	IMA_{21}	70
	IMA_{22}	21
	IMA_{23}	69

CLK (Clock)

CLK is the single phase master clock input. The μPD9305 clock frequency can be independent of ImPP clock frequency.

$\overline{\text{RESET}}$ (Reset)

$\overline{\text{RESET}}$ initializes the μPD9305. A reset places $\overline{\text{OREQ}}$, $\overline{\text{IACK}}$, the token I/O flip-flop, and IM access request signals at an inactive level. $\overline{\text{RESET}}$ resets the refresh address counter, refresh timer counter, and mode register to 0. $\overline{\text{RESET}}$ must be held low for a minimum of four μPD9305 or μPD7281 clock cycles, whichever is slower.

V_{DD} (Power)

V_{DD} is the single +5 volt power supply.

GND (Ground)

GND is the ground signal.

Status Signal Pin Functions

CPURQ (CPU Request)

CPURQ indicates to the host processor that the μPD9305 is ready to transfer a token to the host.

INBUSY (Input Busy)

INBUSY indicates that tokens are being input to the first ImPP from the μPD9305.

SOLBSY (Self Object Load Busy)

SOLBSY indicates that a self object load is being executed.

ERR (Error)

ERROR indicates that an error was output from the ImPPs, the host has read an invalid output token, or that the host has input a token while INBUSY was active.

Host Interface Signal Pin Functions

$\overline{\text{RD}}$ (Read)

RD reads the contents of the internal registers specified by A_1 and A_0.

$\overline{\text{WR}}$ (Write)

$\overline{\text{WR}}$ writes an input from the data bus to the internal register specified by A_1 and A_0.

$\overline{\text{CS}}$ (Chip Select)

$\overline{\text{CS}}$ enables the $\overline{\text{RD}}$ or $\overline{\text{WR}}$ control signals.

A_0, A_1 (Address)

A_0 and A_1 select the internal register for a read or write operation.

D_0-D_{15} (Data Bus)

The contents of the internal registers are read from or written to via data bus bits D_0-D_{15}.

DMA Signal Pin Functions

DMAAEN (Direct Memory Access Address Enable)

DMAAEN is used to indicate to the μPD9305 that an external DMA controller is putting DMA addresses on the address bus. During a DMA operation, DMA addresses (system memory addresses) are input to A_0 and A_1. However, these addresses have no meaning for the μPD9305 and might alter register contents. For this reason, the μPD9305 operates as if A_0 and A_1 are both reset to 0 when DMAAEN is active (high).

$\overline{\text{DMARQ1}}$ (Direct Memory Access Request 1)

$\overline{\text{DMARQ1}}$ issues a request to an external DMA controller to transfer data from the host system memory to the μPD9305.

$\overline{\text{DMARQ2}}$ (Direct Memory Access Request 2)

DMARQ2 issues a request to an external DMA controller to transfer data from the μPD9305 to the host system memory.

$\overline{\text{DMAAK1}}$ (Direct Memory Access Acknowledge 1)

$\overline{\text{DMAAK1}}$ is issued by the external DMA controller to indicate to the μPD9305 that $\overline{\text{DMARQ1}}$ has been received.

$\overline{\text{DMAAK2}}$ (Direct Memory Access Acknowledge 2)

$\overline{\text{DMAAK2}}$ is issued by the external DMA controller to indicate to the μPD9305 that $\overline{\text{DMARQ2}}$ has been received.

μPD7281 Interface Signal Pin Functions

MN_0-MN_3 (Module Number)

MN_0-MN_3 specify the module number of one ImPP. During a reset, one module number is output via MN_0-MN_3, the other via IDB_{12}-IDB_{15}. MN_0-MN_3 are three-state pins.

$\overline{\text{OREQ}}$ (Output Request)

$\overline{\text{OREQ}}$ signals to the first ImPP that the μPD9305 is ready to transfer half a token.

$\overline{\text{OACK}}$ (Output Acknowledge)

$\overline{\text{OACK}}$ signals to the μPD9305 that a half token has been accepted by the first ImPP.

$\overline{\text{IREQ}}$ (Input Request)

$\overline{\text{IREQ}}$ signals from the last ImPP that a half token is ready to be transferred from the ImPP to the μPD9305.

$\overline{\text{IACK}}$ (Input Acknowledge)

$\overline{\text{IACK}}$ indicates to the last ImPP that the μPD9305 has accepted the half token.

$\overline{\text{IPPRST}}$ (Image Pipelined Processor Reset)

IPPRST resets the ImPPs during RESET or a command reset.

ODB_0-ODB_{15} (Output Data Bus)

ODB_0-ODB_{15} transfer tokens from the μPD9305 to the first ImPP.

IDB_0-IDB_{15} (Input Data Bus)

IDB_0-IDB_{15} transfer tokens between the output of the last ImPP and the μPD9305.

Image Memory Interface Signal Pin Functions

IMRD (Image Memory Read)

IMRD requests a read of the contents of the image memory addressed by IMA_0-IMA_{23}.

IMWR (Image Memory Write)

IMWR requests a write to the image memory location addressed by IMA_0-IMA_{23}.

IMRF (Image Memory Refresh)

IMRF indicates an image memory refresh cycle.

$\overline{\text{IMAK}}$ (Image Memory Acknowledge)

$\overline{\text{IMAK}}$ indicates to the μPD9305 that an image memory read, write or refresh has been completed.

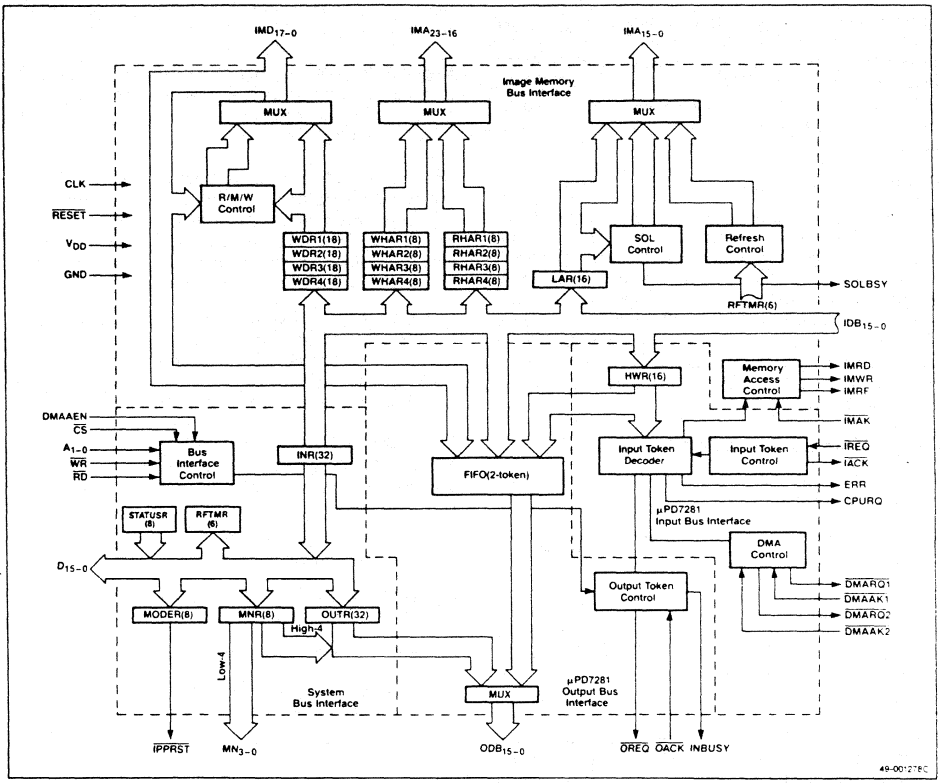
IMA_0-IMA_{23} (Image Memory Address)

IMA_0-IMA_{23} supplies the image memory address for a read or write operation or for DRAM refresh (IMA_0-IMA_9 only).

IMD_0-IMD_{17} (Image Memory Data)

IMD_0-IMD_{17} is the bidirectional data bus for transferring data to and from the image memory.

μPD9305 Block Diagram



Functional Description

The μPD9305 has the following functional units:

- μPD7281 input bus interface
- μPD7281 output bus interface
- System bus interface
- Image memory bus interface
  - —Register file
  - —R/M/W control
  - —Self object load control
  - —Image memory refresh control

μPD7281 Input Bus Interface

After the last ImPP outputs a token, the input bus interface determines whether the token should be an output token to the host CPU, to the image memory, or to the output bus interface block. The high order 16 bits of the token output from the last ImPP are latched into in the high word register (HWR) and then decoded by the input token decoder to determine the token type.

μPD7281 Output Bus Interface

The output bus interface logic transmits tokens through the multiplexer (MUX) to the first ImPP. The transmitted tokens come from the system bus interface, the μPD7281 input bus interface, or the image memory bus interface. The output bus interface uses a priority control mechanism to prevent collisions between the tokens coming from the different blocks.

System Bus Interface

The system bus interface receives a token from the host CPU for the ImPPs, sends it to the output register (OUTR), and signals the output bus interface. Conversely, it sends a token, which is output from the last ImPP, through the input register (INR) to the host CPU according to instructions from the host CPU. The host CPU can set input or output modes (MODER register), read the status register (STATUSR), set image memory refresh timing (RFTMR register), and set module numbers (MNR) for two μPD7281s.

Image Memory Bus Interface

The image memory bus interface accepts the following five types of tokens:

Token	Description
WHA	Write high address
WLA	Write low address
WD	Write data
RHA	Read high address
RLA	Read low address

Tokens have a 16-bit data value, so the address is transferred in two tokens to form the 24-bit image memory address. The lower 16-bits of the image memory address are latched in the lower address register.

The image memory bus interface also performs read/modify/write functions with the R/M/W control logic and provides a register file.

Register File. The register file is used for storing write high addresses (WHAR/four 8-bit registers), write data (WDR/four 18-bit registers), and read high addresses (RHAR/four 8-bit registers).

Read/Modify/Write (R/M/W) Control. The R/M/W control reads a word from the image memory, performs a logical operation (AND, OR, or XOR) between it and the contents of a write data register (WDR), and then writes it back to a location referenced by the WHAR (the same lower 16-bit address, but a different upper eight bits).

Self Object Load (SOL). The self object load control loads ImPP object programs stored in image memory into the ImPPs. When the SOL is given a starting address, the SOL control automatically generates the appropriate addresses to read the image memory.

Image Memory Refresh Control. The μPD9305 generates a 10-bit address and the timing for refreshing dynamic image memories. The timing is set by the RFTMR register.

Figure 1 shows the input/output token format and table 2 shows how the image memory access tokens function.

Figure 1. Input/output Token Format

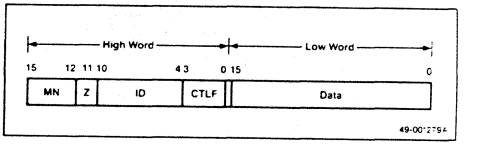


Table 2. Image Memory Access Tokens(1)

MN	Z	ID		CTLF	Data	Function	Operation
0001	–	MN′	ID′	----	Image memory read low address	Image memory read (RHAR1 reference)	R
		111	----	----	----- Image memory read high address	Read high address register (RHAR1) set (Note 2)	S
0010	–	MN′	ID′	----	Image memory read low address	Image memory read (RHAR2 reference)	R
		111	----	----	----- Image memory read high address	Read high address register (RHAR2) set (Note 2)	S
0011	–	MN′	ID′	----	Image memory read low address	Image memory read (RHAR3 reference)	R
		111	----	----	----- Image memory read high address	Read high address register (RHAR3) set (Note 2)	S
0100	–	MN′	ID′	----	Image memory read low address	Image memory read (RHAR4 reference)	R
		111	----	----	----- Image memory read high address	Read high address register (RHAR4) set (Note 2)	S
		00000	DIR	----	Image memory write low address	Image memory write (referencing WHAR and WDR selected by DIR)	W
		001--	DIR	----	----- Image memory write high address	Set write high address register (WHAR) selected by DIR	S
0101	–	010--	DIR	--C,S	Image memory write data register	Set write data register (WDR) selected by DIR	S
		011--	DIR	----	----- Image memory read high address	Set read high address register (RHAR) selected by DIR	S
		100 MASK	DIR	----	Read/write low address	Read/modify/write	RW
		101--	DIR	----	Read/write low address	Read / modify / write (write CS bits selects mask)	RW
		00---	DIR	----	Load starting low address	Self object load	R
0110	–	01---	DIR	----	Load starting low address	Self object load MN of output token is SOLMN)	R
		1----	--	----	---------- SOLMN	Set SOLMN for self object load	S

Notes:

(1) The following definitions refer to the above table:
- MN: Module number
- Z: Always 0
- ID: Identifier
- CTLF: Control field
- ID′: ID used for next circulation
- MN′: MN used for next circulation (MN ≠ 111)
- DIR: Specifies registers for memory image access
- MASK: Specifies the modify mode
- –: Do not care
- S: Set
- R: Read
- W: Write

(2) When RHASEL of the mode register is 1, the tokens become image memory read (request) tokens

Table 3 shows module number (MN) values and the five token types (refer to figure 12).

The five token types are:
(1) Output request data to the host
(2) Image memory access data
(3) DMA request data
(4) Pass data
(5) Delete data

Table 3. MN Values and Token Types

Token Type	MN	ID	Function	Abbreviation
(1)	0 0 0 0	x x x x x x x x	μPD7281 output data to host	CPU
(2)	0 0 0 1	MN′ ID′ x x x x x x x x	Image memory read1 (RHAR1 select)	IMR
		1 1 1 x x x x	RHAR1 set (Note 2)	
	0 0 1 0	MN′ ID′ x x x x x x x x	Image memory read2 (RHAR2 select)	
		1 1 1 x x x x	RHAR2 set (Note 2)	
	0 0 1 1	MN′ ID′ – –	Image memory read3 (RHAR3 select)	
		1 1 1 x x x x	RHAR3 set (Note 2)	
	0 1 0 0	MN′ ID′ – –	Image memory read4 (RHAR4 select)	
		1 1 1 x x x x	RHAR4 set (Note 2)	
	0 1 0 1	0 0 0 0 0 DIR –	Image memory write	IMW
		0 0 1 x x DIR –	High address set for write (selected register file is DIR +1)	IMWHA
		0 1 0 x x DIR –	Write data set (selected register file is DIR +1)	IMWD
		0 1 1 x x DIR –	High address set for read (selected register file is DIR +1)	IMREA
		1 0 0 Mask DIR – –	Read/modify/write1	RMW1
		1 0 1 x x DIR –	Read / modify / write2 (mask selected by CS bits of image memory write data)	RMW2
(3)	0 1 0 1	1 1 0 x x x x	DMA1 (host → μPD7281)	DMA1
		1 1 1 x x x x	DMA2 (μPD7281 → host)	DMA2
(2)	0 1 1 0	0 0 x x x DIR –	Self object load1	SOL1
		0 1 x x x DIR –	Self object load2 (rewrite MN)	SOL2
		1 x x x x x x	MN set for self object load	SOLMN
(4)	0 1 1 1		μPD7281 module number (when RHASEL=1)	PASS
	1 0 0 0 1 0 0 1 1 0 1 0 1 1 0 0 1 1 0 1 1 1 1 0		μPD7281 module numbers	
(5)	1 1 1 1		Deleted	VANISH

Notes:

(1) The following definitions refer to the above table:
MN: Module number
ID: Identifier
MN′: MN used for next circulation (MN ≠ 111)
ID′: ID used for next circulation

(2) When RHASEL of the mode register is 1, the tokens become image memory read tokens.

μPD9305 Operation

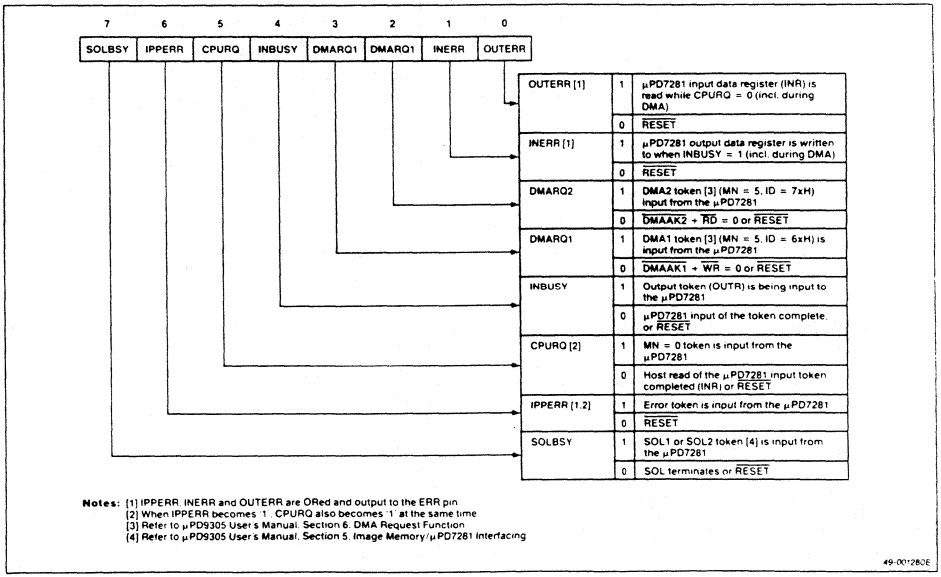
Table 4 shows how the μPD9305 uses signals $\overline{CS}$, $\overline{RD}$, $\overline{WR}$, and A_1, A_0 to read or write to I/O ports.

Table 4. I/O Ports

$\overline{CS}$	$\overline{RD}$	$\overline{WR}$	A_1	A_0	Internal I/O Ports
0	0	1	0	0	Read ImPP input data register (from ImPP)
0	0	1	0	1	Read status register
0	0	1	1	0	Command $\overline{RESET}$, data read has no meaning
0	0	1	1	1	Not used
0	1	0	0	0	Write ImPP output data register (to ImPP)
0	1	0	0	1	Write mode register
0	1	0	1	0	Write module number register
0	1	0	1	1	Write refresh timing register

Figure 2 shows the status register format.

Figure 2. Status Register Format

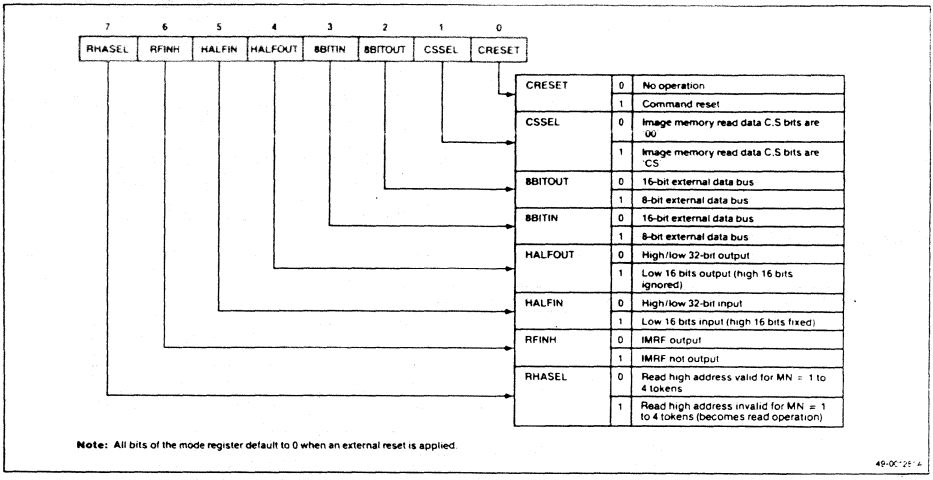


Notes: [1] IPPERR, INERR and OUTERR are ORed and output to the ERR pin.
[2] When IPPERR becomes '1', CPURQ also becomes '1' at the same time.
[3] Refer to μPD9305 User's Manual, Section 6, DMA Request Function.
[4] Refer to μPD9305 User's Manual, Section 5, Image Memory/μPD7281 Interfacing.

49-001280E

Figure 3 shows the mode register format.

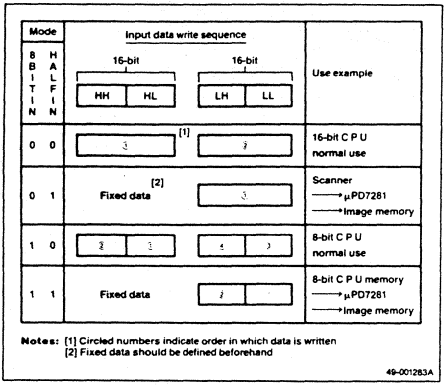
Figure 3. Mode Register Format



Note: All bits of the mode register default to 0 when an external reset is applied.

Figures 4-20 graphically show μPD9305 operation. For a detailed description of μPD9305 operation, refer to the *μPD9305 User's Manual*.

Figure 4. Setting Write Method for Input Data



Notes: [1] Circled numbers indicate order in which data is written
[2] Fixed data should be defined beforehand

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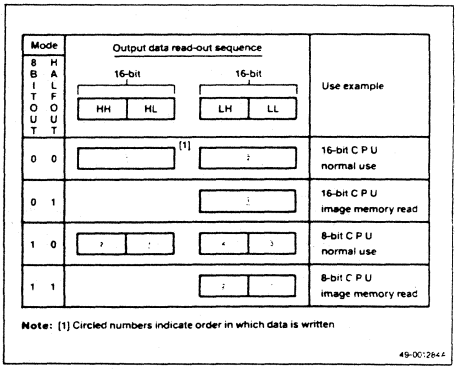
Figure 5. Setting Read Method for Output Data



Note: [1] Circled numbers indicate order in which data is written

49-001284A

Figure 6. Setting Fixed (16-Bit) Data

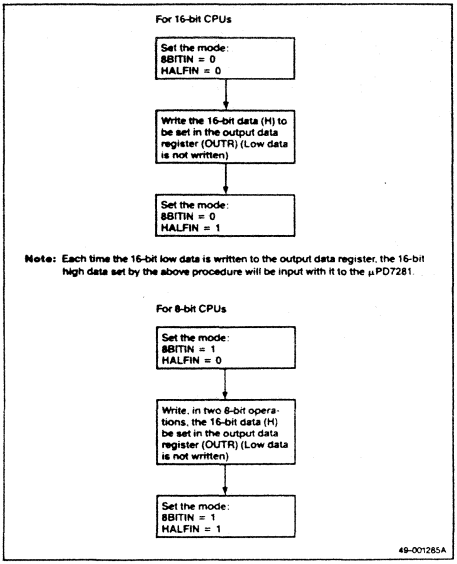


Figure 7. MN Register

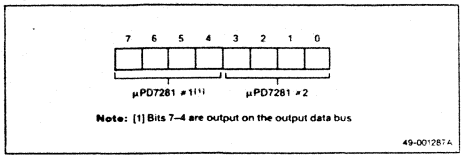


Figure 8. Refresh Timing Register

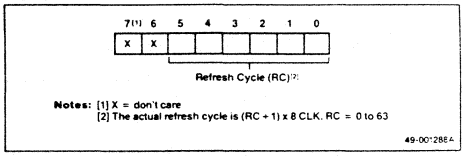


Figure 9. Input Timing (Host to μPD9305 to μPD7281)

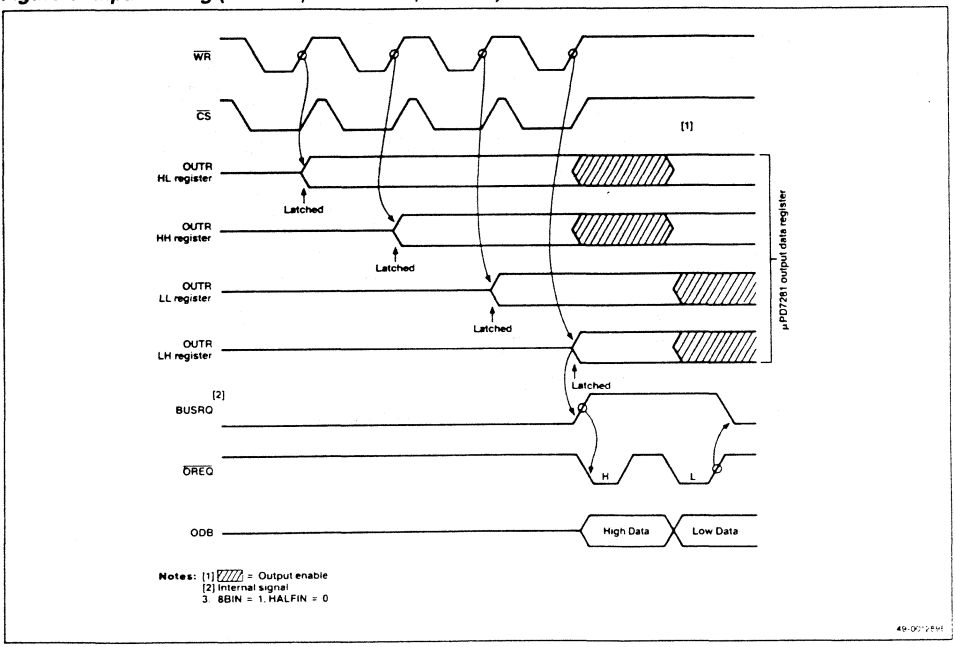


Figure 10. Output Timing (μPD7281 to μPD9305 to Host)

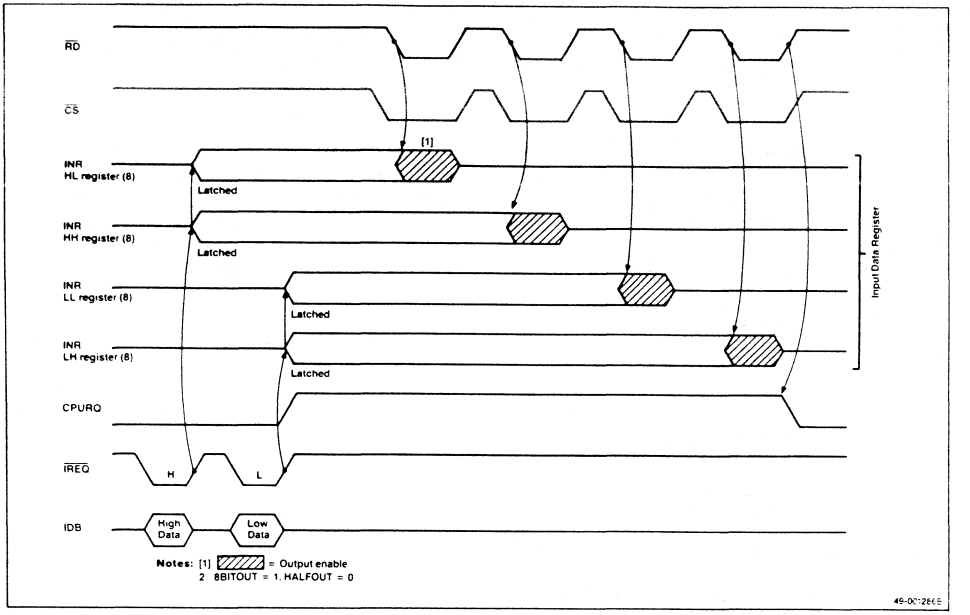


Figure 11. Output to μPD7281, Control Data Paths

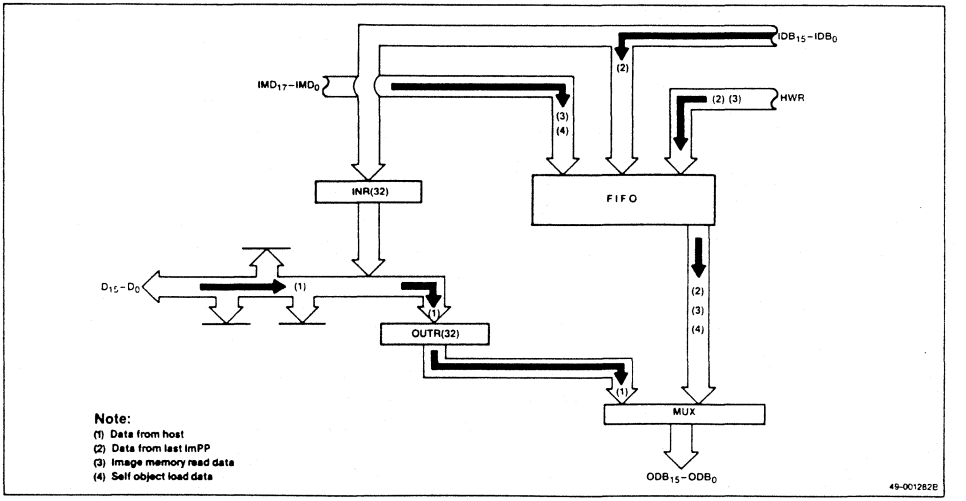


Figure 12. μPD7281, Input Control Data Flow

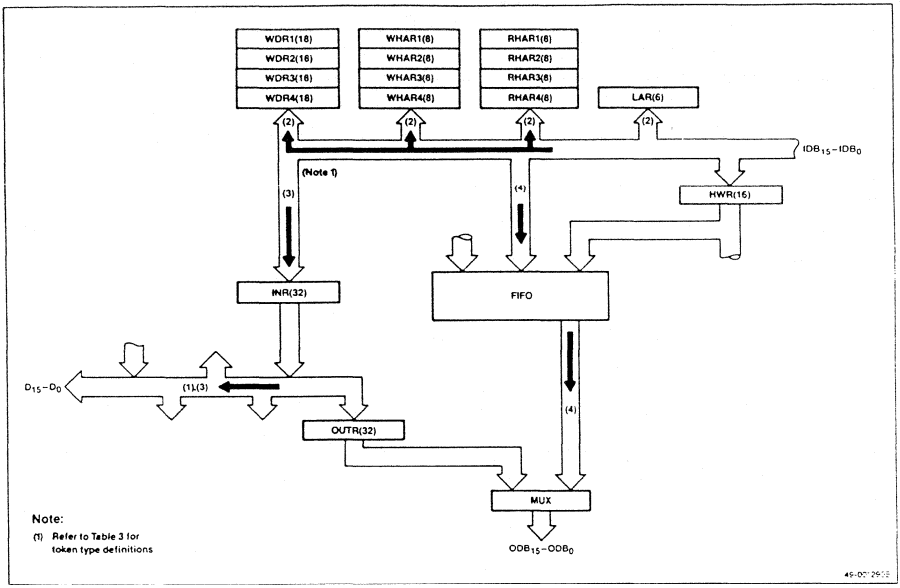


Figure 13. Image Memory Read Timing (Without Refresh Request)

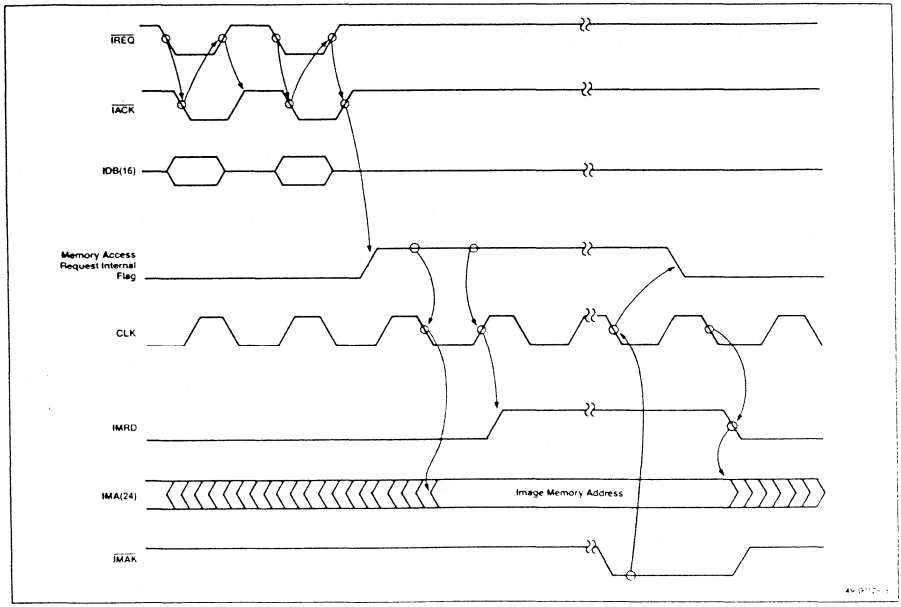


Figure 14. Image Memory Write Timing (Without Refresh Request)

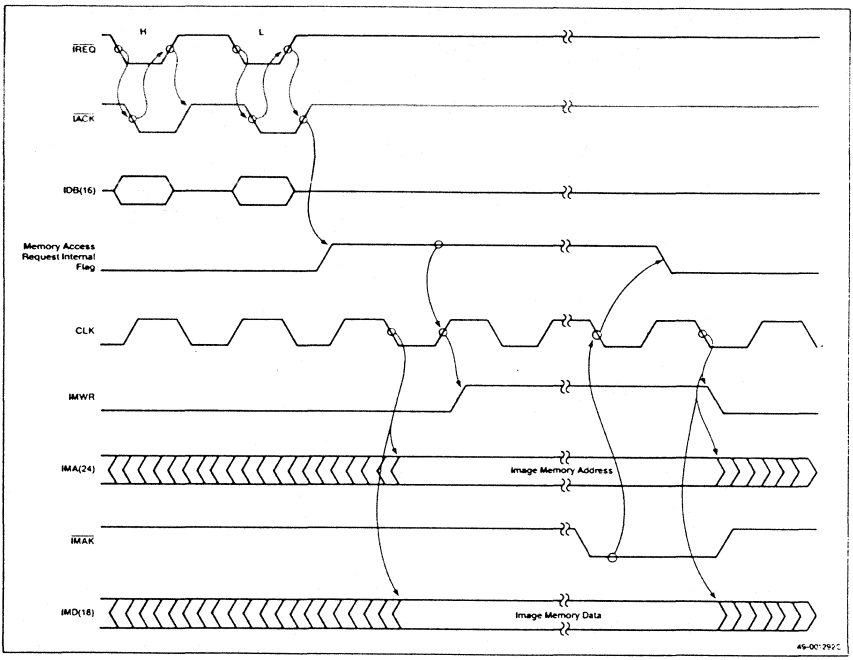


Figure 15. Image Memory Access Request Priority Control

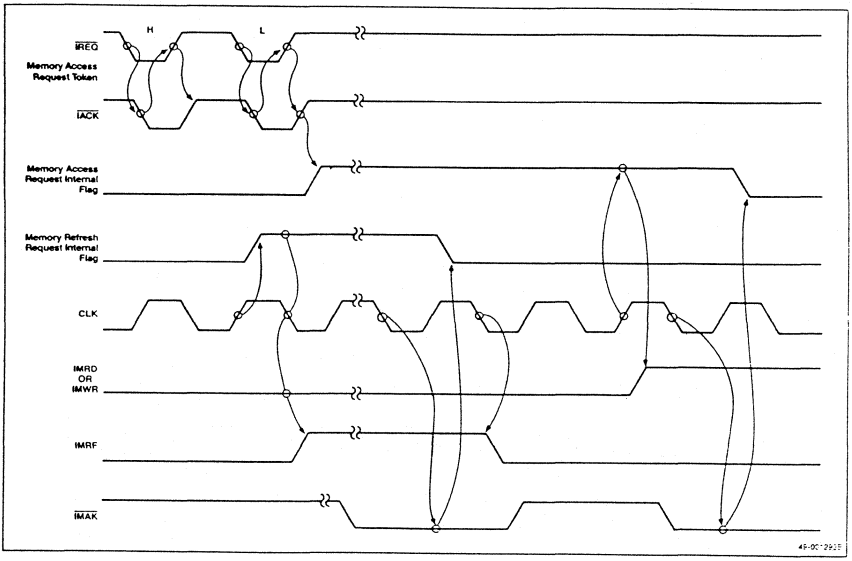


Figure 16. Read Data — μPD7281 Output Timing (Single Output)

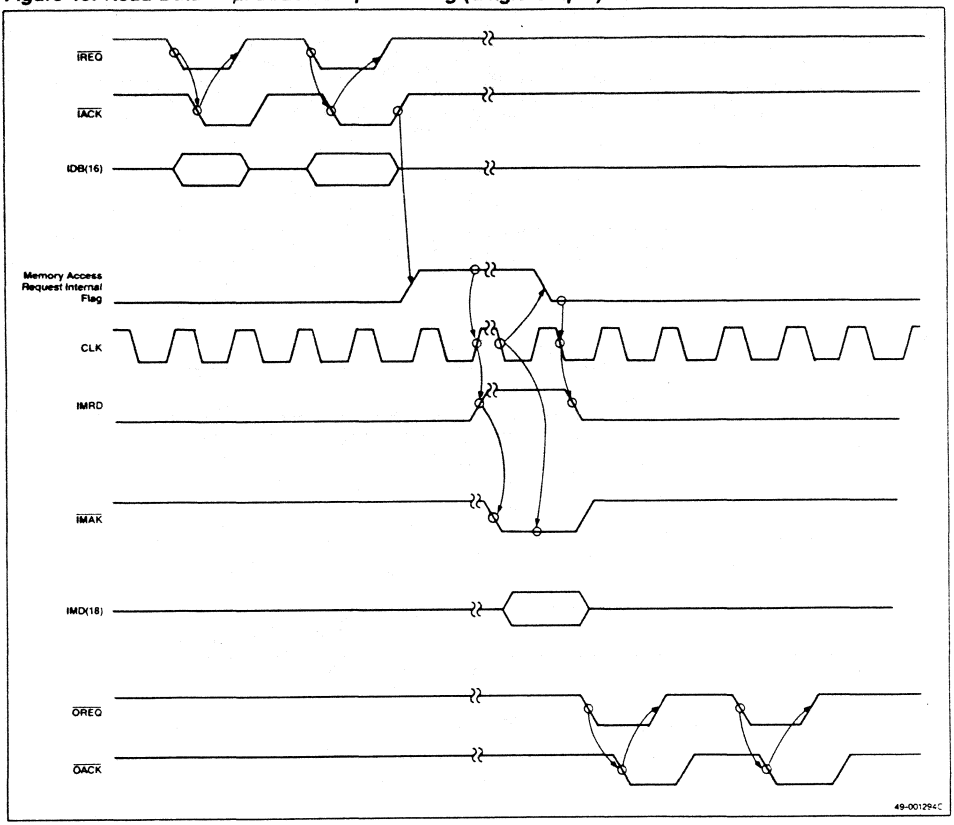


Figure 17. Read Data – μPD7281 Output Timing (Continuous Output)

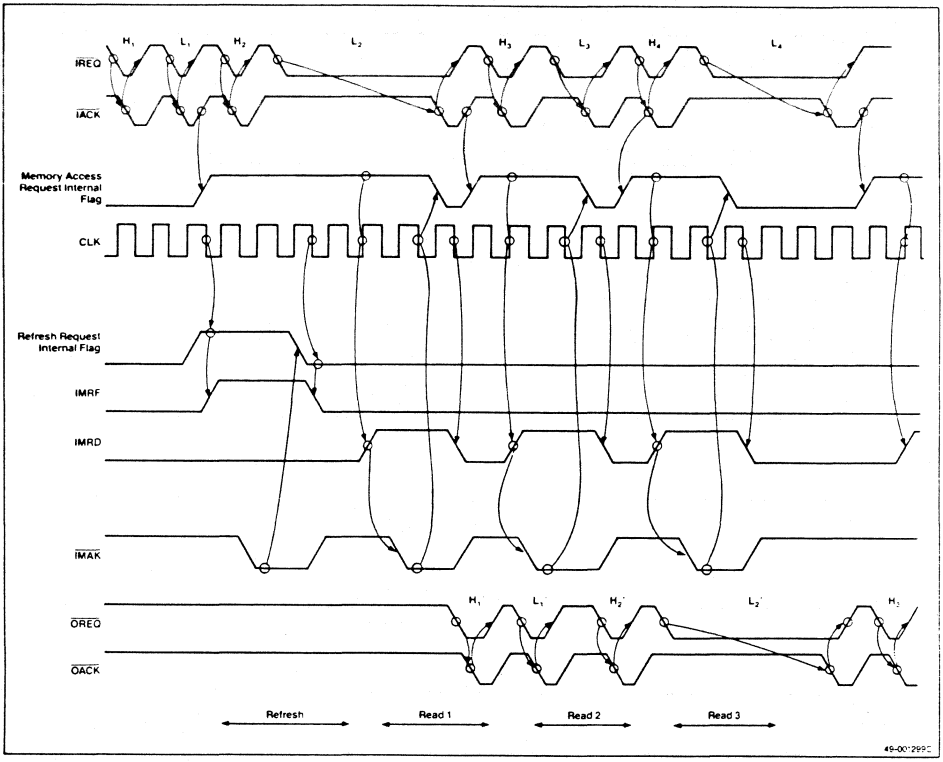


Figure 18. Self Object Load Timing

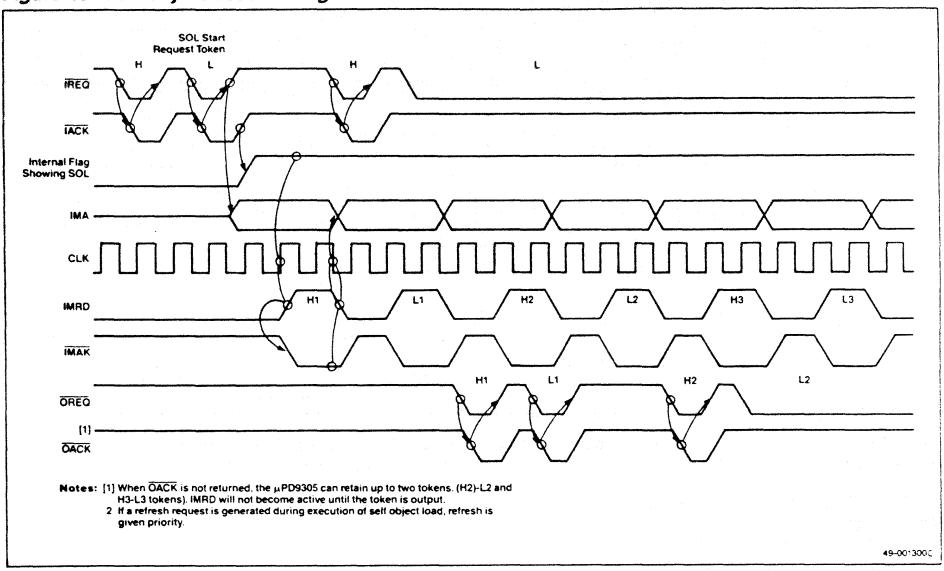


Figure 19. Refresh Timing

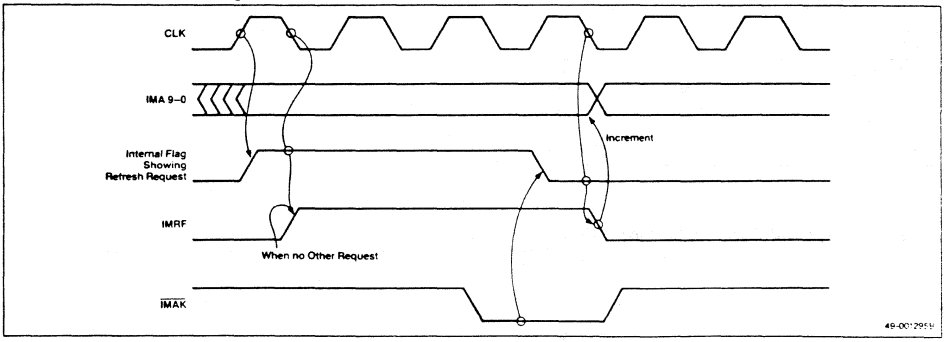


Figure 20. Read/Modify/Write Timing

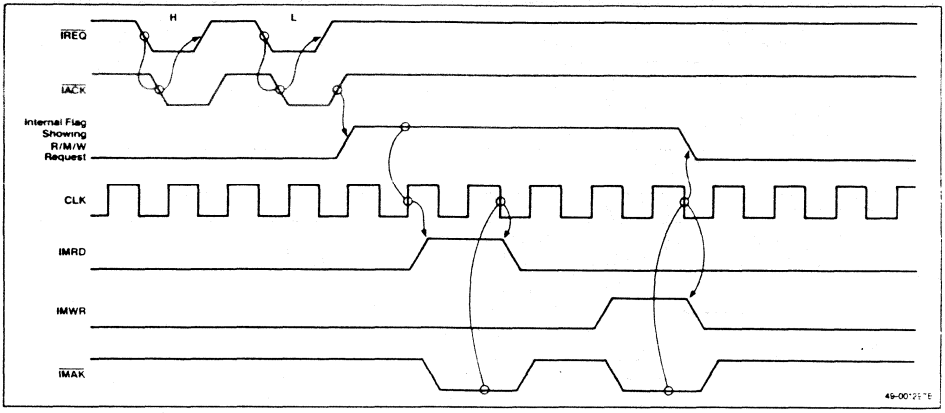


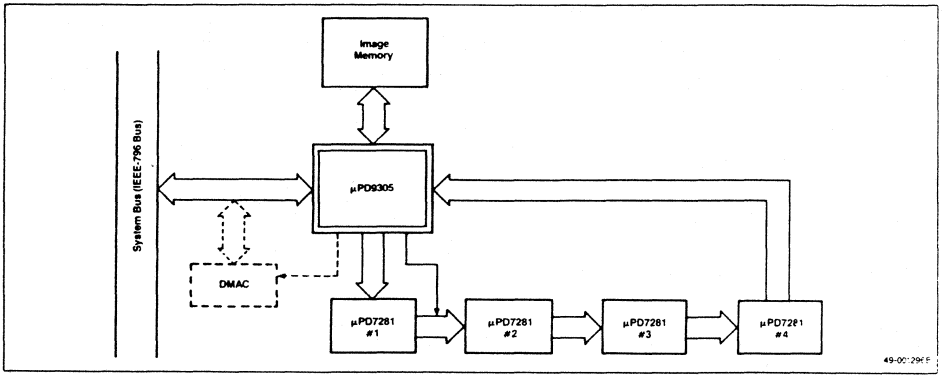
Table 5 shows the differences between command and external resets.

Figure 21 shows a typical system configuration using the μPD9305 with several ImPPs.

Table 5. Command and External Reset Differences

Item	RESET	Command Reset
I/O data counter Tokens in the μPD9305 Image memory access requests (except refresh) OREQ, IACK DMA request	Cleared	Cleared
Refresh timer Refresh request Refresh address Mode register	Default values	No change
IPPRST pin	0 (active)	0 (active)

Figure 21. Typical System Configuration



μPD9305 PRELIMINARY ELECTRICAL SPECIFICATION

ABSOLUTE MAXIMUM RATINGS (T_a = 25°C)

Parameter	Symbol	Test Conditions	Ratings	Units
Supply Voltage	V_{DD}		−0.5 to 7.0	V
Input Voltage	V_I		−0.5 to 7.0	V
Output Current	I_O		10	mA
Operating Temperature	T_{opt}		0 to 70	°C
Storage Temperature	T_{stg}		−65 to 150	°C

DC Characteristics (T_a = 0 to + 70°C, V_{DD} = 5V ± 10%)

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Input Low Voltage	V_{IL}		−0.5		0.8	V
Input High Voltage	V_{IH}		2.0		V_{DD}+0.5	V
Output Low Voltage	V_{OL}	I_{OL} = 2mA			0.4	V
Output High Volatge	V_{OH}	I_{OL} = −400 μA	V_{DD}−0.4			V
Input Leakage Current	I_{LI}	$0 \leqq V_I \leqq V_{DD}$			± 10	μA
Output Leakage Current	I_{LO}	$0 \leqq V_I \leqq V_{DD}$			± 10	μA
Supply Current	I_{DD}	10 MHz		10	100	mA

Capacitance (T_a = 25°C)

Paramater	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Input Capacitance	C_I	fc = 1 MHz			10	p F
Output Capacitance	C_O	Unmeasured Pins			15	p F
I/O Capacitance	C_{IO}	return to ØV			15	p F

AC Characteristics (T_a = 0 to + 70°C, V_{DD} = 5V ± 10%)

Clock Timing

Paramater	Symbol	Test Conditions	Min.	Max.	Units
CLK Cycle Time	t_{CYK}		80		ns
Clock Pulse width high	t_{WKH}		30		ns
Clock Pulse width low	t_{WKL}		30		ns
Clock Rise Time	t_{KR}			10	ns
Clock Fall Time	t_{KF}			10	ns

Input Timing

Parameter	Symbol	Test Conditions	Min.	Max.	Units
Input Rise Time	t_{IR}		0	10	μs
Input Fall Time	t_{IF}		0	10	μs

RESET Timing

Parameter	Symbol	Test Conditions	Min.	Max.	Units
RESET/Pulse Width	t_{RST}	μPD9305 (only)	t_{CYK}		ns
RESET/Setup time to IPPRST/	t_{DRSPRL}			40	ns
IPPRST/Hold Time after RESET/up	t_{DRSPRH}			50	ns
IPPRST/Setup to MN0-3	t_{DMN}			60	ns
MN0-3 Float time after IPPRST/up	t_{FMN}			50	ns
IPPRST/Low Till ODB15-12 Active	t_{DPROD}			60	ns
ODB15-12 Float time after IPPRST/up	t_{FPROD}			50	ns

Host «---» μPD9305 Read/Write (Timing)

Parameter	Symbol	Test Conditions	Min.	Max.	Units
Address Setup to WR/down, RD/down	t_{SARW}		20		ns
Addres hold time after WR/ up, RD/up	t_{HRWA}		20		ns
CS/setup to WR/down, RD/down	t_{SCRW}		0		ns
CS/Hold time after WR/up, RD/up	t_{HRWC}		0		ns
WR/, RD/Pulse Width	t_{WRWL}		100		ns
RD/Setup to Data	t_{DRD}			80	ns
Data Float time after RD/up	t_{FRD}			30	ns
Data setup to WR/	t_{SDW}		20		ns
Data Hold after WR/up	t_{HWD}		20		ns

I/O Request/Acknowledge Timing

Parameter	Symbol	Test Conditions	Min.	Max.	Units
IREQ/ setup time to IACK/	t_{DIQIAL}		15	60	ns
1st IACK/setup time to IREQ/up	t_{DIAIQH}		10		ns
1st IREQ/up setup time to IACK/up	t_{DIQIAH}		20	70	ns
1st IACK/up setup to IREQ/low	t_{DIAIQL}		10		ns
ID Bus setup time to IREQ/up	t_{SIDIQ}		20		ns
ID Bus Hold time from IREQ/up	t_{HIQID}		10		ns
OREQ/setup time to OACK/	t_{DOQOAL}		10		ns
OACK/setup time to OREQ/up	t_{DOAOQH}		20	70	ns
OREQ/up setup time to OACK/up	t_{DOQOAH}		10		ns
OACK/up setup time to OREQ/low	t_{DOAOQL}		15	60	ns
OREQ/setup time to ODB Valid	t_{DOQOD}			10	ns
ODB Float time after OREQ/up	t_{FOQOD}		10		ns

DMA Transfer Timing

Parameter	Symbol	Test Conditions	Min.	Max.	Units
DMARQ/low setup time to DMAAK/low	t_{DDQDA}		20		ns
DMARQ/Hold time from DMAAK/low	t_{DDADQ}			50	ns
DMARQ/Recovery Time DMAAK/high	t_{RVDQ}		50		ns
DMAAEN up setup time to (RD/, WR/) low	t_{SDERW}		30		ns
DMAAEN low Hold time after (RD/, WR/) high	t_{HRWDE}		30		ns
DMAAK/low setup time to (RD/, WR/) low	t_{SDARW}		0		ns
DMAAK hold time after (RD/, WR/) high	t_{HRWDA}		0		ns
DMAAK/pulse width (low to high)	t_{WDAL}		t_{CYK}		ns

DMARQ/ = DMARQ1/, DMARQ2/
DMAAK/ = DMAAK1/, DMAAK2/

Image Memory Read, Write, Refresh Timing

Parameter	Symbol	Test Conditions	Min.	Max.	Units
IMA Active time CLK	t_{DKMARF}	IM Refresh		100	ns
IMA Active time CLK	t_{DKMAMC}	IM Read/IM Write		60	ns
IMA Float time from IMWR/IMRD low	t_{FMCMA}		10		ns
IMWR/IMRD Recovery time	t_{RVMC}		1.5 t_{CYK}		ns
IMWR/IMRD/IMWR high delay time from CLK high	t_{DKMCH}			35	ns
IMWR/IMRD/IMWR low delay time from CLK low	t_{DKMCL}			40	ns
IMAK/setup time to CLK down	t_{SMKK}		10		ns
IMD setup time to CLK high	t_{SMDK}	Image Memory Read Timing	20		ns
IMD hold time from IMRD low	t_{HMRMD}	Image Memory Read Timing	0		ns
IMD delay time from CLK low	t_{DKMD}	Image Memory Write Timing		30	ns
IMD Float time from IMWR low	t_{FMWMD}	Image Memory Write Timing	20		ns
IMAK/Recovery time	t_{RVMK}		1.5 t_{CYK}		ns
IMAK/hold time from IMRD/IMWR low	t_{HMCMK}		0		ns

SOLBSY Timing

Parameter	Symbol	Test Conditions	Min.	Max.	Units
SOLBSY Delay time from IACK/up	t_{DIASB}			30	ns
SOLBSY delay time from CLK low	t_{DKSB}			60	ns

CPURQ Timing

Parameter	Symbol	Test Conditions	Min.	Max.	Units
CPURQ delay time from IACK/high	t_{DIAPQ}			30	ns
CPURQ delay time from RD/high	t_{DPRQ}			60	ns

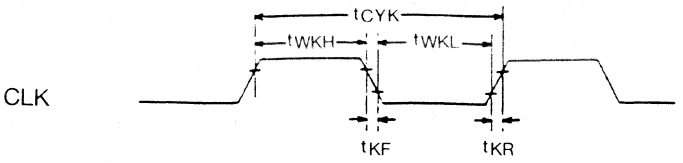
INBUSY Timing

Parameter	Symbol	Test Conditions	Min.	Max.	Units
INBUSY delay time from WR/high	t_{DWIB}			70	ns
INBUSY delay time from OREQ/high	t_{DOQIB}			40	ns

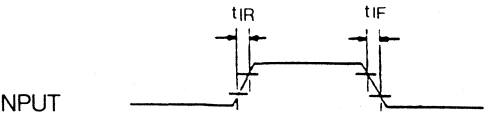
ERR Timing

Parameter	Symbol	Test Conditions	Min.	Max.	Units
ERR delay time from IACK/high	t_{DIAE}			30	ns
ERR delay time from WR/low	t_{DWE}	INBUSY = 1		60	ns
ERR delay time RD/low	t_{DRE}	CPURQ = 0		60	ns
INBUSY hold time from WR/low	t_{HWIB}			10	ns
CPURQ setup time to RD/low	t_{SPQR}			10	ns

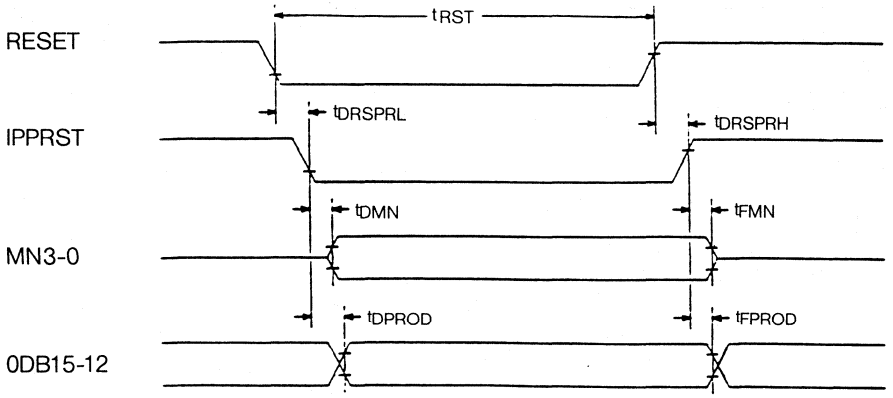
CLOCK TIMING



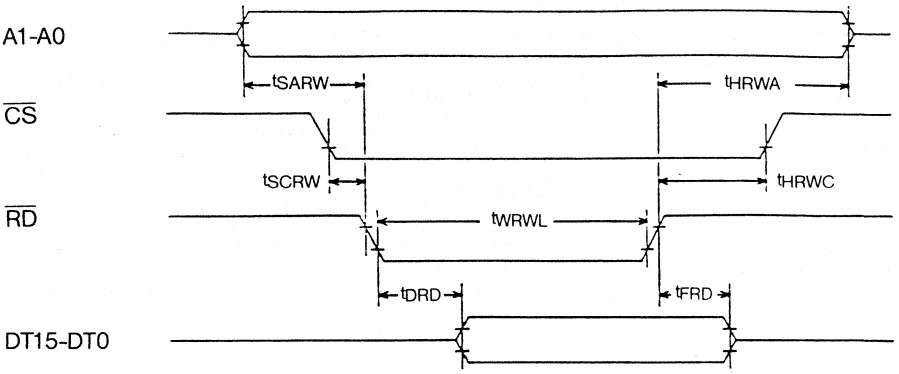
INPUT TIMING



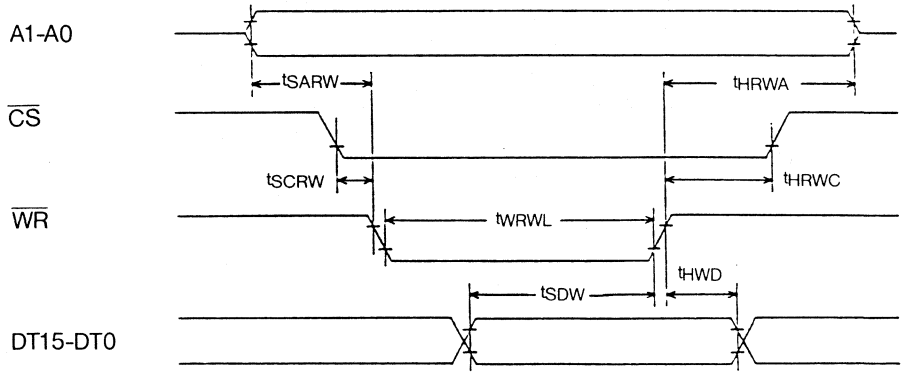
RESET TIMING



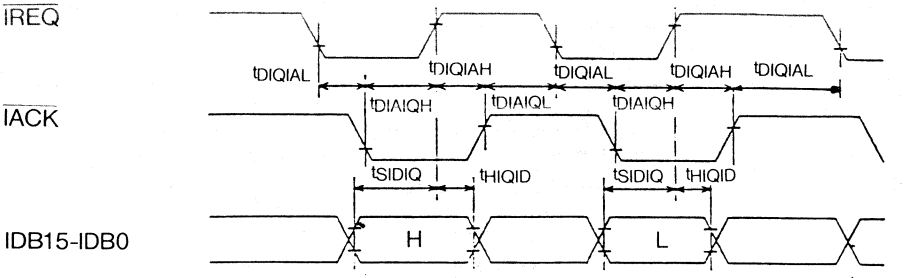
HOST CPU μPD9305 READ TIMING

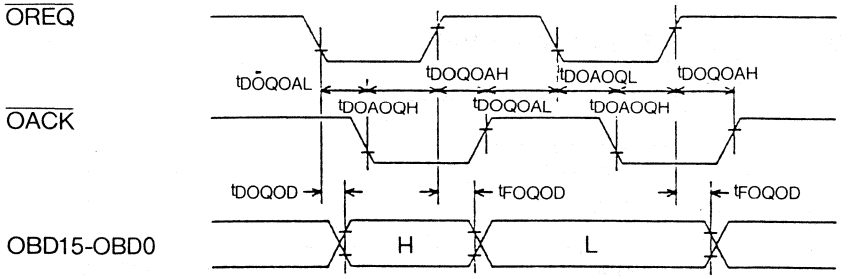


HOST CPU μPD9305 WRITE TIMING

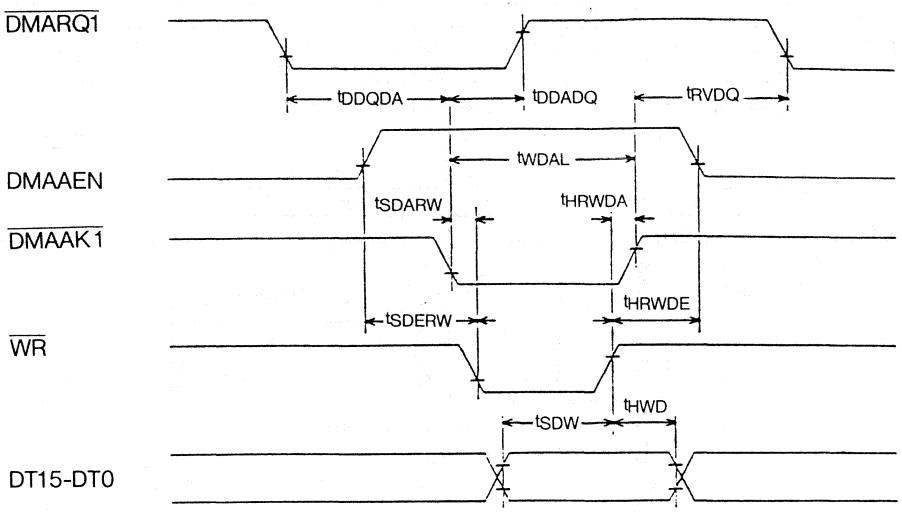


I/O DATA BUS HANDSHAKE TIMING





DMA1 TIMING



DMA2 TIMING

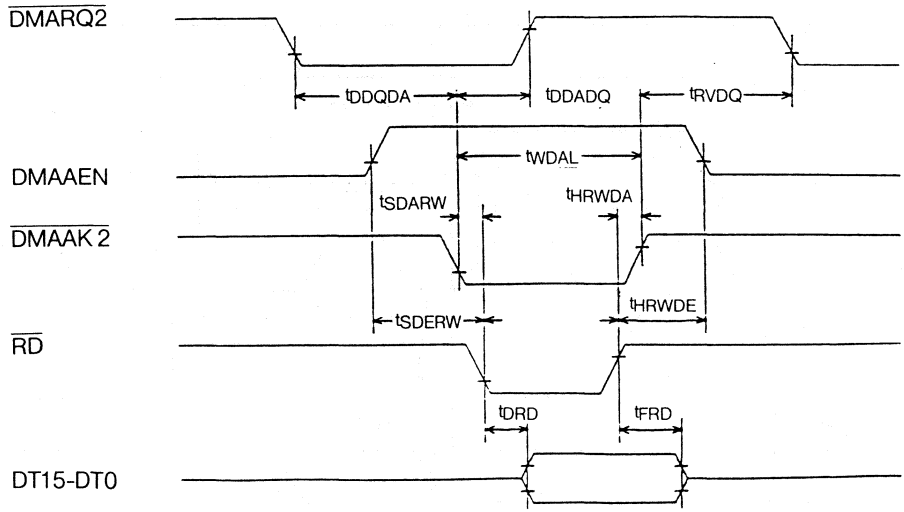


IMAGE MEMORY READ TIMING

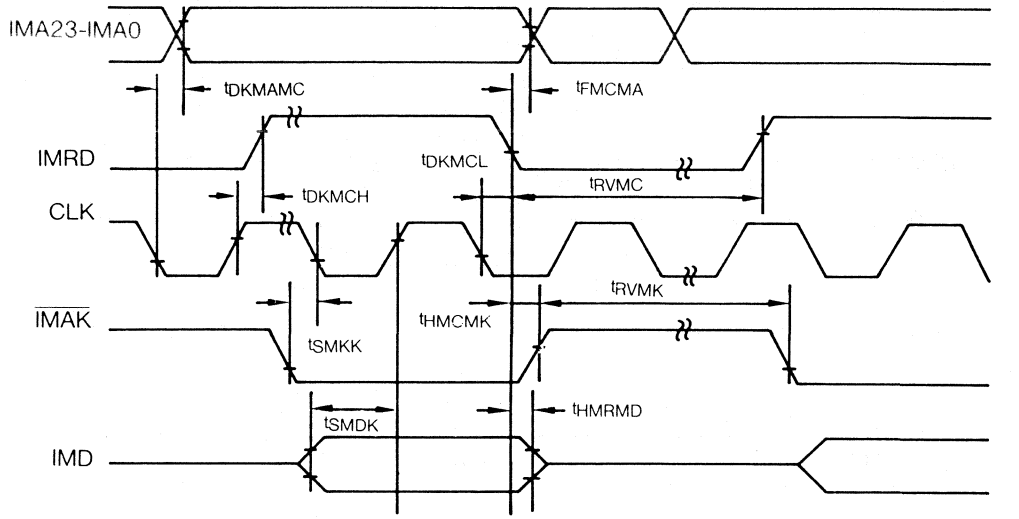


IMAGE MEMORY WRITE TIMING

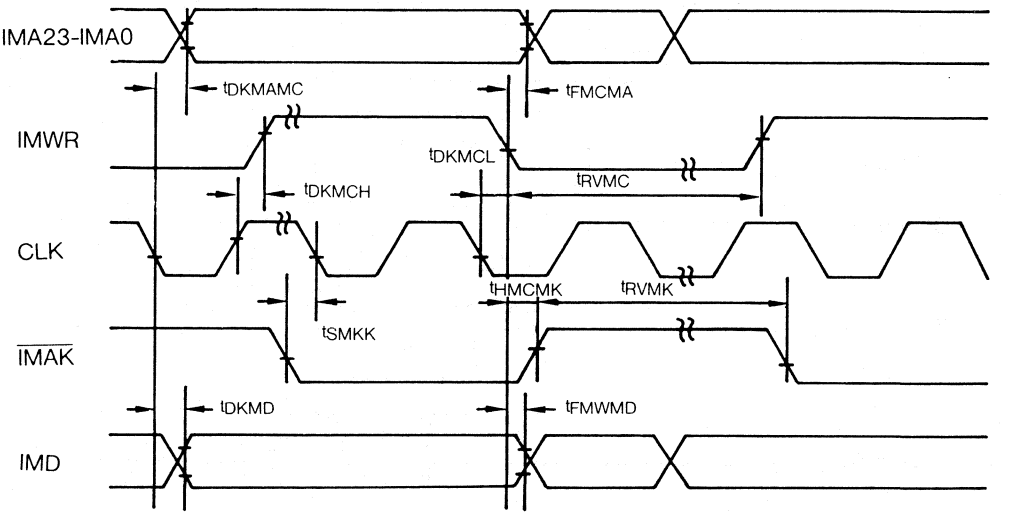
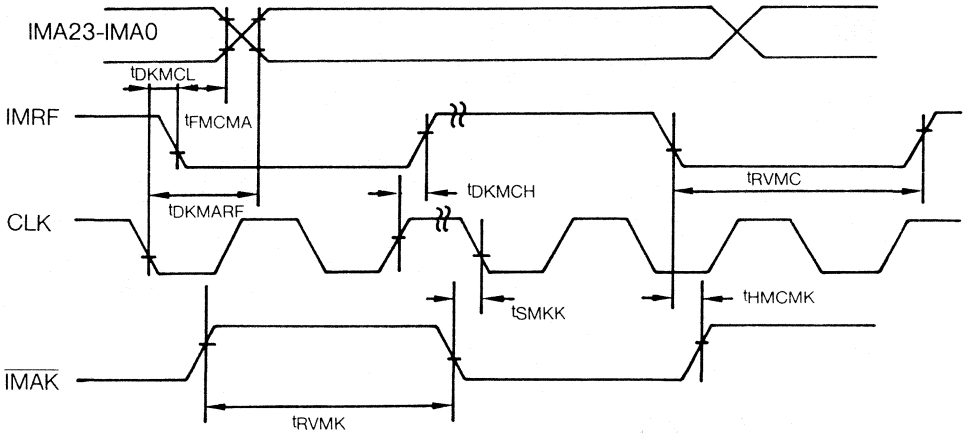
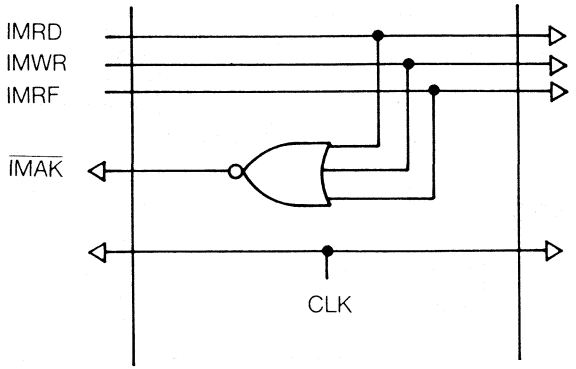


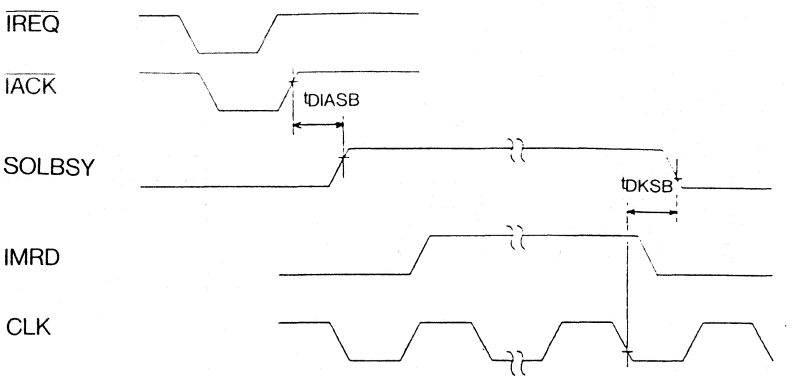
IMAGE MEMORY REFRESH TIMING



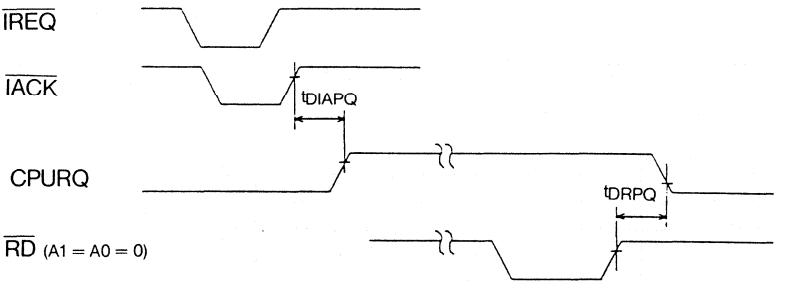
IMAK GENERATION EXAMPLE (CYCLETIME = 3 X CLOCK)



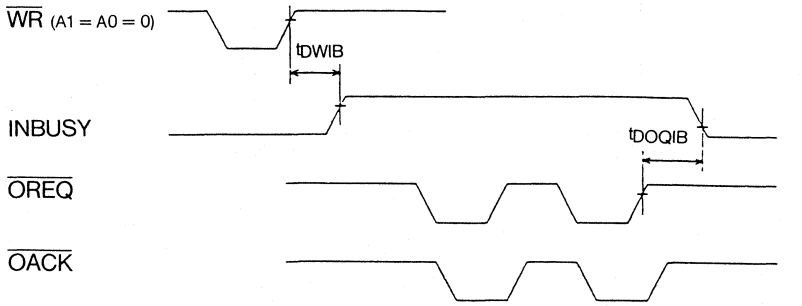
SOLBSY TIMING



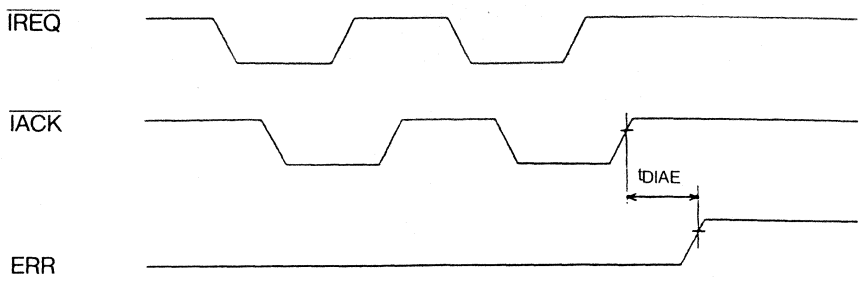
CPURQ TIMING



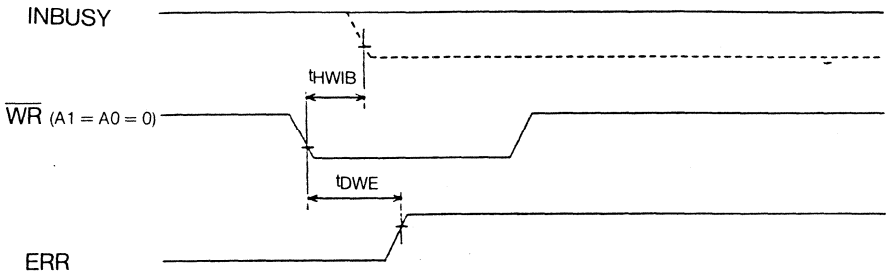
INBUSY TIMING



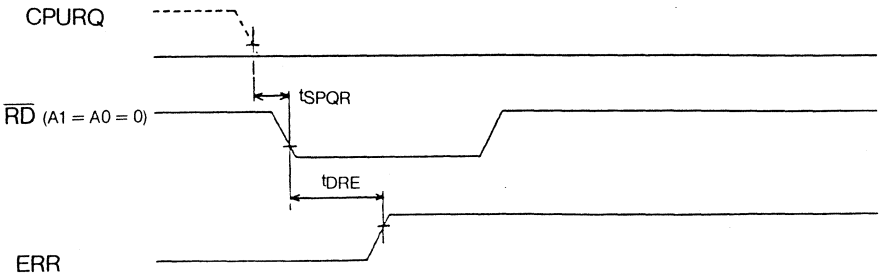
ERR TIMING (1)



ERR TIMING (2)



ERR TIMING (3)



NEC

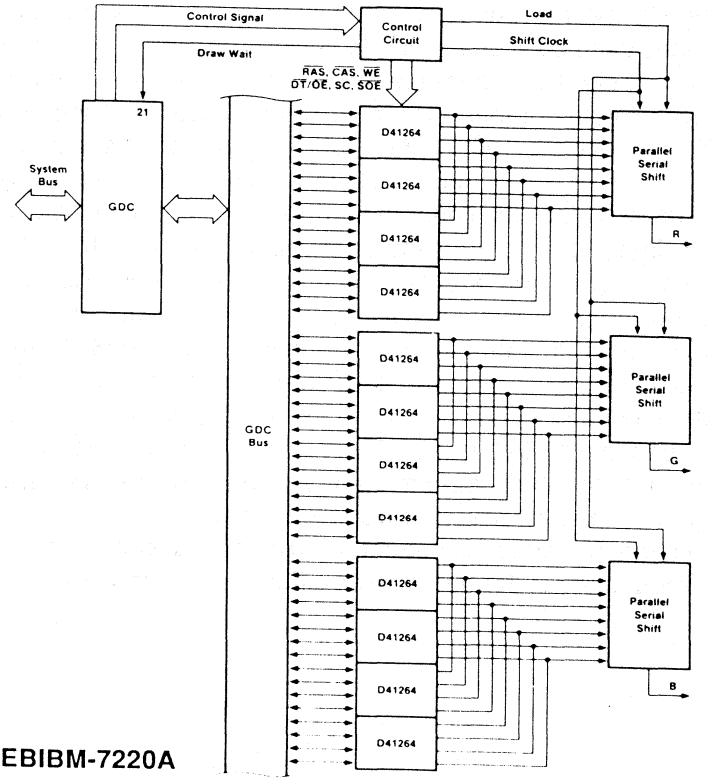
EBIBM-7220A

IBM-Board for μPD7220A and μPD41264 Dual Port VRAM

The board is dedicated for the demonstration of the extreme high drawing speed of the GDC μPD7220A together with the μPD41264 Video RAMs It cannot be used to replace existing IBM color boards because it is not 100% IBM compatible (E.g. The μPD7220A draws a vector by simply specifying the startaddress, direction and length whereas the original IBM color board needs each pixel of a vector to be calculated by the microprocessor).
Nevertheless it is possible to use this board as an IBM color board after modifying the graphic drawing driver procedures of graphics programs.
Note: There are 100% compatible IBM color boards available on the market which make use of the μPD7220A. These boards are nearly standard color cards with the additional feature that the on board GDC can also access the image memory for faster drawings. The EBIBM-7220A board design differs from these boards. (e.g. no 6845 CRT controller has been used; no direct image memory access by the microprocessor is available)
The board is useful to become familiar with the GDC and to test certain features. For this purpose there is a menu driven evaluation/ demonstration software which comes along with the board. It has been written in PASCAL (Turbo Pascal = Trade Mark of Borland Inc.) to enable the user to modify the program very easyly. This evaluation software runs on all IBM color or monochrome displays.
On the provided diskette this program is stored in source code and executable file format for two different color monitor resolutions.

Hardware Description

The GDC-VRAM provides a resolution of 1024 dots per line by 1024 lines for each of three color planes. These three color planes can therefore store each pixel in one of 8 colors. (E.g. a yellow pixel is stored by setting its position in the red and green plane and resetting it in the blue plane).
Because of the 16 bit data bus of the μPD7220A and the 64 K x 4 bit organisation of the μPD41264 Video RAM four devices have been used for each plane to simplify the design. Therefore the GDC controls 12 Video RAMs which make a 384K bytes image memory or 3.072 million different pixels.
The selection of the color planes is done by the GDC address bits A16 and A17 which can be selected by the CURS (= Cursor Set) command of the μPD7220A.



Block Diagram EBIBM-7220A

Software Description

The supplied evaluation/demo programs (GDC 14 and GDC 21) on the diskette can be used in two different operation modes. One time it is the education mode where it is used to test certain features and commands of the Graphics Display Controller μPD7220A. This mode is also quite useful to become familiar with the controller.
The other operation is the demonstration mode. Here the GDC will perform a lot of small graphics drawing procedures. This is useful to demonstrate the high speed drawing available with the GDC and Video RAMS and the special drawing features of the GDC. This demonstration will be done in an endless loop which can be left when pressing ESCAPE and waiting a short time.
The evaluation/demonstration program can be started by simply pressing GDC 14 or GDC 21 and carriage return. Then the following menu will occur on the screen.

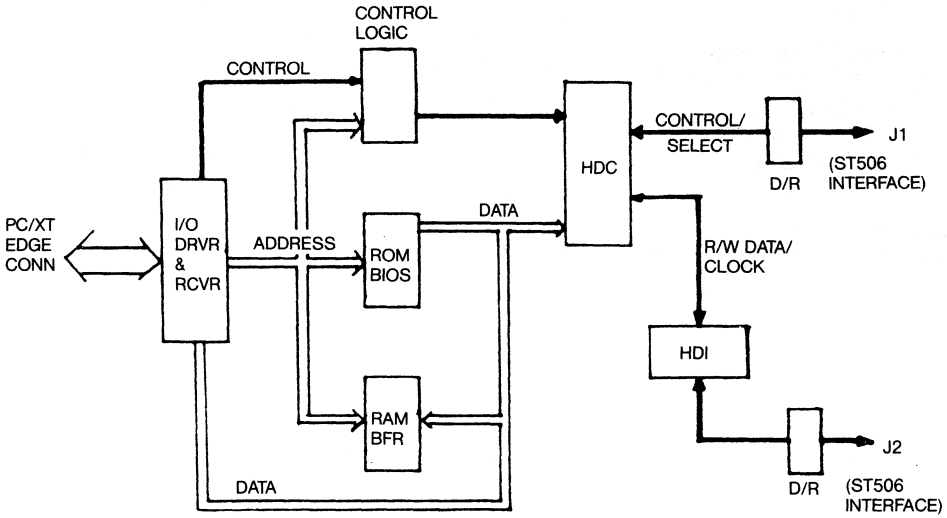
HARD DISK CONTROLLER BOARD EBIBM-7261A

Description

Originally designed as an application tool, the Hard Disk Controller Board (HDCB) provides a simple interface for an ST506-type winchester in a typical PC environment: specifically the IBM-PC or -PC/XT and look-alikes. This single board controller achieves all the functions as called out in IBM's PC/XT specification for its Fixed Disk Drive Adapter using NEC's μPD7261A HDC chip and the μPD9306, the Hard Disk Interface chip along with necessary drivers and logic for drive selection.

Necessary control firmware is provided in the on-board ROM to utilize the system DMA for data transfers between the disk and memory, to handle interrupts and to provide device level control for the hard disk controller so that the hardware differences are completely transparent to the system CPU and to the user.

The HDCB attaches to the winchester via standard ST506 interface cables and to the PC system board through its I/O channel interface.



HARD DISK CONTROL BOARD BLOCK DIAGRAM

The μPD7261A is an intelligent microprocessor which acts as command processor, format controller and microprocessor interface for the HDCB. Some of the functions it performs are:

To decode command received from the host over the 8-bit data bus;
To execute seek and recalibrate commands;
To interface to the drive and to read the drive status lines;
Serial-to-parallel and parallel-to-serial data conversion;
CRC and ECC generation and checking;
MFM data decoding and encoding;
Generation of Write Precompensation signals;
Address mark detection and generation;
ID field search;
DMA data transfer control during read/write operations.

The μPD9306 performs data separation using a digital phase-locked loop, and contains the necessary logic for write precompensation and clock generation for the μPD7261A.

The ROM BIOS that is provided on the board contains routines which handle interrupts from the μPD7261A, translate the

IBM codes for the μPD7261A, set-up the system DMAC as specified by IBM, and sets up the μPD7261A for the following soft-sector format:

4 heads
17 sectors/track
512 bytes/sector
615 cylinders

Specifications

PHYSICAL CHARACTERISTICS

Gold-plated edge fingers mount into standard IBM-PC or -PC/XT system board I/O interface slot.
Height – 4.375 in.
Width – 6.625 in.
Depth – 0.5 in.

ELECTRICAL CHARACTERISTICS

DC Power Requirements – 5V 0.7A typ.

REFERENCE LITERATURE

IBM PC/XT Technical Reference
μPD7261A Data Sheet
μPD9306 Data Sheet
μPD7261A User's Manual

Ordering Information:

EBIBM-7261A Hard Disk Controller Board for PC-XT

Image Pipelined Processor μPD7281 Tools

Description

The support the Image Pipelined Processor μPD7281 IMPP NEC has developed a complete support tool package consisting of both Software and Hardware.

Software

A software package containing a functional assembler, a simulator and an object converter is provided for NEC's development system as well as for many other personal computers and minis.

Features

- Complete software development system for μPD7281
- Assembler for generating μPD7281 tokens
- Software simulator provides
  - Program debugging capabilities
  - System simulation and evaluation
- Runs on a variety of operating systems
  - CP/M-86*)
  - MS-DOS*)
  - VAX/VMS*) and VAX/UNIX*)

AS7281 Assembler

AS7281 translates symbolic source programs for the μPD7281 into object modules which serve as input to either the software simulator or the object code conversion programs.
Features are as follows:

- Automatic generation of all required tokens
- Extensive error reporting
- Command line controls
- User-selectable and directable output files

Note:

CP/M-86	is a registered trademark of Digital Research Corporation
MS-DOS	is a registered trademark of Microsoft Corporation
VAX and VMS	are registered trademarks of Digital Equipment Corporation
UNIX	is a trademark of AT&T

OH7281 Object Code Converter

OH7281 converts object modules produced by the assembler into hexadecimal format object module files for input to a HEX-loader or into ASCII data format object module files for use as data within a source module. A symbol table file may be produced for use with the software simulator.

SM7281 Software Simulator

SM7281 accepts object code modules produced by the assembler and simulates the user program under specified system parameters. The simulator can fully simulate and entire processing subsystem, providing the user the tools to fully debug his program and to evaluate system performance without having to actually build the hardware. Features are as follows:

- Support simulation of three system models
  - One or more cascaded μPD7281s, μPD9305 and image memory
  - One or more cascaded μPD7281s and image memory
  - One or more cascaded μPD7281s only
- Continous/single-step execution
- Set/display input data timing
- Display/modify contents of memory, latch or registers
- Sophisticated breakpoint capabilities
- Sophisticated trace capabilities
  - Define/display items to be traced
  - Define/display trace start/stop conditions
- Supports full symbolic debug
  - Define/delete/modify symbols
  - Display symbols
- On-line assembler and disassembler
- Macro command file capability
- Save/load simulator setup to/from disk
- Save console input commands and execution results on disk
- Display LT, PU, IM operating ratios for program evaluation

Ordering Information:

FAMSD-05DD-7281	MS-DOS, 5 1/4" double-density floppy diskette
FACPM-05DD-7281	CP/M-86, 5 1/4" double-density floppy diskette
FAMPM-08SS-7281	CP/M-86, 8" single-density floppy diskette
FAVMS-OT16-7281	VAX/VMS, 9-track 1600 BPI magnetic tape
FAUNI-OT16-7281	VAX/UNIX, 9-track 1600 BPI magnetic tape

Hardware

The method of program debugging for the μPD7281 largely differs from debugging method for typical microcomputers. This is because the μPD7281 employs a data flow-type microprocessor.

In debugging typical microcomputers, the focus is put mainly on data transfers between the microcomputer and its I/O devices, especially the memory. That is, when a desired data is given to the microcomputer, the operation of the microcomputer is temporarily interrupted to check its status. Modification is then made if necessary. Then, execution is again assumed. This method is very effective for typical microcomputers, because the number of instructions being executed when operation is interrupted is only one. Therefore, even if operation is interrupted, the execution can be easily resumed from the same status after checking the internal status.

This means that the basic unit of the debugging cycle is instruction execution.

However, the μPD7281 employs the data flow method. Therefore the concept of the instruction unit (fetch -- decode -- execution) cannot be used for the μPD7281. The number of instructions being executed may not be only one at a point. Usually, two or more instructions are being executed.

Additionally, it is know wheter or not the instruction sent to the pipeline first is being executed. Therefore, if execution is interrupted once and the internal status is sent outside, the internal status changes completely and the original status cannot be resumed. Therefore, because the μPD7281 employs data flow method, its debugging method differs significantly from other development tools commonly used (such as EVAKIT or IE). In debugging with the SX-7281-S, the main focus is put on efficient control of the tokens of the μPD7281.

SX-7281-S hardware units allow real time testing of user's programs for binary image processing. SX-7281-M is a two multibus board system containing on one board 4 times μPD7281, the support chip μPD9305 MAGIC and a Graphic display controller μPD7220. On the second board the image memory of 256K x 18 bits for 16 bit of data plus sign and control bits. For image information the memory can beconfigured up to 1024 x 1024 dots in 4 planes. Access is provided by the IEEE796 Bus (Multibus).

By adding a third Multibus board containing a 8086 processor and a serial interface RS232 into a 3 slot Multibus frame the system called SX-7281-S becomes a stand-alone unit for connection to any host computer. Commands and functions are the same for both Multibus and stand-alone system.

Commands are available for system control, debugging, macros and demonstrations. For grey scale appliations a different tool is available using the IBM-PC as a host. The EBIBM-7281GS contains the complete grey scal image processing hardware including camera interface, video A/D converter, image memory, image processor (4 x 7281), colour palette and video D/A converter. This tool is not only for debugging but can be used also as an application hardware example. Utility software and demonstration programs are included.

Ordering Information:

SX-7281-M	Hardware system for binary image processing, Multibus unit
SX-7281-S	Hardware system for binary image processing, stand-alone unit
EBIBM-7281GS	PC board for grey scale image processing

NEC

CMOS SYSTEM SUPPORT PRODUCTS 6

Section 6 – CMOS System Support Products

Description

The μPD71011 is a clock pulse generator/driver for microprocessors and their peripherals using NEC's high-speed CMOS technology.

Features

- ☐ CMOS technology
- ☐ Clock pulse generator/driver for μPD70108/70116 or other CMOS or NMOS CPUs and their peripherals
- ☐ 50% duty cycle
- ☐ Frequency source can be crystal or external clock input
- ☐ Reset signal with Schmitt-trigger circuit for CPU or peripherals
- ☐ Bus ready signal with two-bus system synchronization
- ☐ Clock synchronization with other μPD71011s
- ☐ Single +5 V ±10% power supply
- ☐ Industrial temperature range: −40 to +85 °C

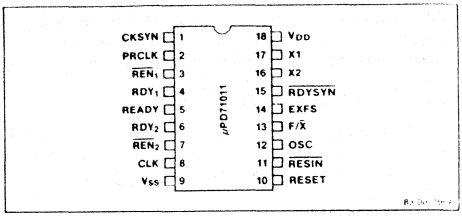
Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD71011C	18-pin plastic DIP	20 MHz
μPD71011G	20-pin plastic SO	20 MHz

Pin Identification

No.	Symbol	Function
1	CKSYN	Clock synchronization input
2	PRCLK	Peripheral clock output
3	$\overline{REN_1}$	Bus ready enable input 1
4	RDY_1	Bus ready input 1
5	READY	Ready output
6	RDY_2	Bus ready input 2
7	$\overline{REN_2}$	Bus ready enable input 2
8	CLK	Processor clock output
9	V_{SS}	Ground potential
10	RESET	Reset output
11	$\overline{RESIN}$	Reset input
12	OSC	Oscillator output
13	F/X	External frequency source/crystal select input
14	EXFS	External frequency source input
15	$\overline{RDYSYN}$	Ready synchronization select input
16	X2	Crystal input
17	X1	Crystal input
18	V_{DD}	+5 V Power supply

Pin Configuration



Pin Functions

X1, X2 [Crystal]

When F/$\overline{X}$ is low, a crystal connected to X1 and X2 will be the frequency source for a CPU and its peripherals. The crystal frequency should be two times the frequency of CLK.

EXFS [External Frequency Source]

EXFS input is the external frequency input in the external TTL-frequency source mode (F/$\overline{X}$ high). A square TTL-level clock signal two times the frequency of CLK's output should be used for the source.

F/$\overline{X}$ [Frequency/Crystal Select]

F/$\overline{X}$ input selects whether an external TTL-type input or an external crystal input is the frequency source of the CLK output. When F/$\overline{X}$ is low, CLK is generated from the crystal connected to X1 and X2. When F/$\overline{X}$ is high, CLK is generated from an external TTL-level frequency input on the EXFS pin. At the same time, the internal oscillator circuit will go into stop mode and the OSC output will be high.

CLK [Processor Clock]

The CLK output supplies the CPU and its local bus peripherals' clocks. CLK is a 50% duty cycle clock of one-half the frequency of the external frequency source. The CLK output is +0.4 V higher than the other outputs.

PRCLK [Peripheral Clock]

The PRCLK output supplies a 50% duty cycle clock at one-half the frequency of CLK to drive peripheral devices.

OSC [Oscillator]

OSC outputs a signal at the same frequency as the crystal input. When EXFS is selected, the OSC output is powered down, and its output will be high.

CKSYN [Clock Synchronization]

CKSYN synchronizes one μPD71011 to other μPD71011s. A high level at CKSYN resets the internal counter, and a low level enables it to count.

$\overline{\text{RESIN}}$ [Reset]

This Schmitt-trigger input generates the RESET output. It is used as a power-on reset.

RESET [Reset]

This output is a reset signal for the CPU. Reset timing is provided by the $\overline{\text{RESIN}}$ input to a Schmitt-trigger input gate and a flip-flop which will synchronize the reset timing to the falling edge of CLK. Power-on reset can be provided by a simple RC circuit on the $\overline{\text{RESIN}}$ input.

RDY_1, RDY_2 [Bus Ready]

A peripheral device sends RDY_1 or RDY_2 to signal that the data on the system bus has been received or is ready to be sent. $\overline{\text{REN}}_1$ and $\overline{\text{REN}}_2$ enable the RDY_1 or RDY_2 signals.

$\overline{\text{REN}}_1$, $\overline{\text{REN}}_2$ [Bus Ready Enable]

$\overline{\text{REN}}_1$ and $\overline{\text{REN}}_2$ qualify their respective RDY inputs.

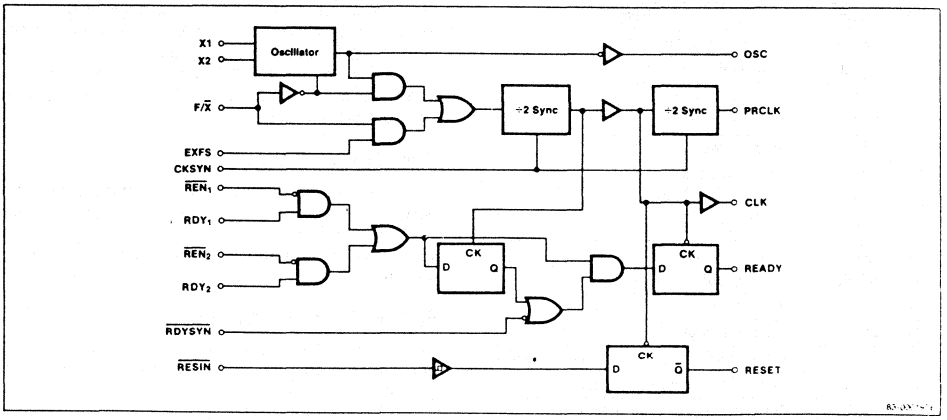
$\overline{\text{RDYSYN}}$ [Ready Sychronization Select]

$\overline{\text{RDYSYN}}$ selects the mode of READY signal synchronization. A low-level signal makes the synchronization a two-step process. This is used when RDY_1 and RDY_2 inputs are not synchronized to CLK. A high-level signal makes synchronization a one-step process. This is used when RDY_1 and RDY_2 are synchronized to CLK. See Block Diagram.

READY [Ready]

The READY signal to the processor is synchronized by the RDY inputs to the processor CLK. READY is cleared after the RDY signal goes low and the guaranteed hold time of the processor has been met.

Block Diagram



Crystal

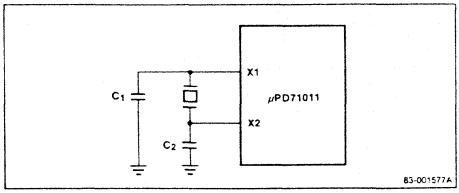
The oscillator circuit of the μPD71011 works with a parallel-resonant, fundamental mode, "AT cut" crystal connected to pins X1 and X2.

Figure 1 shows the recommended circuit configuration. Capacitors C1 and C2 are required for frequency stability. The values of C1 and C2 (C1 = C2) can be calculated from the load capacitance (C_L) specified by the crystal manufacturer.

$$C_L = \frac{C1 \times C2}{C1 + C2} + C_S$$

Where CS is any stray capacitance in parallel with the crystal, such as the μPD71011 input capacitance C_{in}.

Figure 1. Crystal Configuration Circuit



Absolute Maximum Ratings

(T_A = 25°C, V_{SS} = 0 V)

Power supply voltage, V_{DD}	−0.5 to +7.0 V
Input voltage, V_I	−1.0 V to V_{DD} + 1.0 V
Output voltage, V_O	−0.5 V to V_{DD} + 0.5 V
Power dissipation, P_{DMAX}	500 mW
Operating temperature, T_{opt}	−40°C to +85°C
Storage temperature, T_{stg}	−65°C to +150°C

Comment: Exposing the device to stresses above those listed in the absolute maximum ratings could cause permament damage. Exposure to absolute maximum ratings for extended periods may affect device reliability.

DC Characteristics

(T_A = −40 to +85°C, V_{DD} = 5 V ± 10%)

Parameter	Symbol	Limit Min	Limit Max	Units	Test Conditions
Input voltage high	V_{IH}	2.2		V	
Input voltage high	V_{IH}	2.6		V	$\overline{RESIN}$ only
Input voltage low	V_{IL}		0.8	V	
Output voltage high	V_{OH}	V_{DD} − 0.8		V	
Output voltage high	V_{OH}	V_{DD} − 0.4		V	CLK I_{OH} = −4 mA
Output voltage low	V_{OL}		0.45	V	I_{OL} = 4 mA
Input current leakage	I_{IL}	−1.0	1.0	μA	
$\overline{RDYSYN}$ input current	I_I	−400	1.0	μA	
$\overline{RESIN}$ input hysteresis	V_H	0.25		V	
Power supply current (dynamic)	I_{DDdyn}		30	mA	F_{in} = 20 MHz
Power supply current (static)	I_{DD}		200	μA	

Capacitance

(T_A = 25°C, V_{DD} = +5 V)

Parameter	Symbol	Limit Min	Limit Max	Units	Test Conditions
Input capacitance	C_{in}		12	pF	F = 1 MHz

AC Characteristics

(@ f_{OSC} = 10 MHz, V_{DD} = 5 V ± 10%, T_A = −40 to +85°C)
(@ f_{OSC} = 16 MHz, V_{DD} = 5 V ± 5%, T_A = −10 to +70°C)

Parameter	Symbol	Limit Min	Limit Max	Units	Test Conditions
EXFS cycle time	t_{CYFS}	50		ns	
EXFS high	t_{FSH}	20		ns	From 90% to 90% V_{in}
EXFS low	t_{FSL}	20		ns	From 10% to 10% of V_{in}
OSC frequency	f_{OSC}	8	20	MHz	
CKSYN width	t_{PWCT}	$2t_{CYFS}$		ns	
CKSYN hold for EXFS (active)	t_{HFSCT}	20		ns	
CKSYN setup (inactive)	t_{SCTFS}	20		ns	
CLK cycle time	t_{CYCK}	125		ns	
CLK high	t_{PWCKH}	50		ns	Test point 3.0 V, f_{OSC} = 16 MHz
		80		ns	Test point 3.0 V, f_{OSC} = 10 MHz
CLK low	t_{PWCKL}	60		ns	Test point 1.5 V, f_{OSC} = 16 MHz
		90		ns	Test point 1.5 V, f_{OSC} = 10 MHz
CLK rise time	t_{LHCK}		8	ns	Test point 1.5 V to 3.0 V, f_{OSC} = 16 MHz
			10	ns	Test point 1.5 V to 3.0 V, f_{OSC} = 10 MHz
CLK fall time	t_{HLCK}		7	ns	Test point 3.0 V to 1.5 V, f_{OSC} = 16 MHz
			10	ns	Test point 3.0 V to 1.5 V, f_{OSC} = 10 MHz
OSC to CLK ↑ delay	t_{DCK}	2	30	ns	

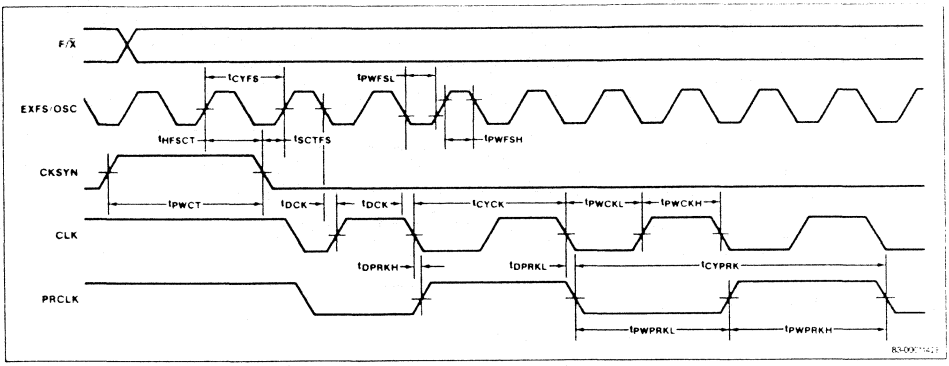
AC Characteristics (cont)

(@ f_{OSC} = 10 MHz, V_{DD} = 5 V ± 10%, T_A = −40 to +85°C)
(@ f_{OSC} = 16 MHz, V_{DD} = 5 V ± 5%, T_A = −10 to +70°C)

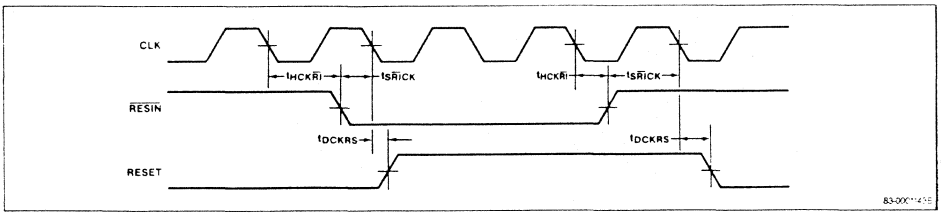
Parameter	Symbol	Limit Min	Limit Max	Units	Test Conditions
OSC to CLK ↓ delay	t_{DCK}	−6	28	ns	
PRCLK cycle time	t_{CYPRK}	250		ns	
PRCLK high	t_{PWPRKH}	t_{CYCK}−20		ns	
PRCLK low	t_{PWPRKL}	t_{CYCK}−20		ns	
CLK ↓ to PRCLK ↑ delay	t_{DPRKH}		22	ns	
CLK ↓ to PRCLK ↓ delay	t_{DPRKL}		22	ns	
$\overline{RESIN}$ to CLK ↓ setup	$t_{S\overline{RI}CK}$	65		ns	
CLK ↓ to $\overline{RESIN}$ hold	$t_{HCK\overline{RI}}$	20		ns	
CLK ↓ to RESET delay	t_{DCKRS}		40	ns	
$\overline{REN}_{1,2}$ to $RDY_{1,2}$ setup	$t_{S\overline{RE}RY}$	15		ns	
CLK ↓ to $\overline{REN}_{1,2}$ hold	t_{HCKRE}	0		ns	
$RDY_{1,2}$ to CLK ↓ setup	t_{SRYCK}	35		ns	$\overline{RDYSYN}$ high
$RDY_{1,2}$ to CLK ↑ setup	t_{SRYCK}	35		ns	$\overline{RDYSYN}$ low
CLK ↓ to $RDY_{1,2}$ hold	t_{HCKRY}	0		ns	
$\overline{RDYSYN}$ ↑ to CLK ↓ setup	$t_{S\overline{RYS}CK}$	50		ns	
CLK ↑ to $\overline{RDYSYN}$ ↓ hold	$t_{HCK\overline{RYS}}$	0		ns	
CLK ↓ to READY ↑ output delay	t_{DCKRDY}		8	ns	
CLK ↓ to READY ↓ output delay	t_{DCKRDY}		8	ns	
Rise time	t_{LH}		20	ns	0.8 V to 2.0 V
Fall time	t_{HL}		12	ns	2.0 V to 0.8 V

Timing Waveforms

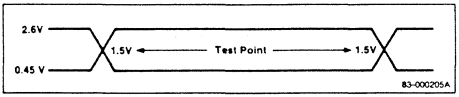
Clock Output



RESET Output

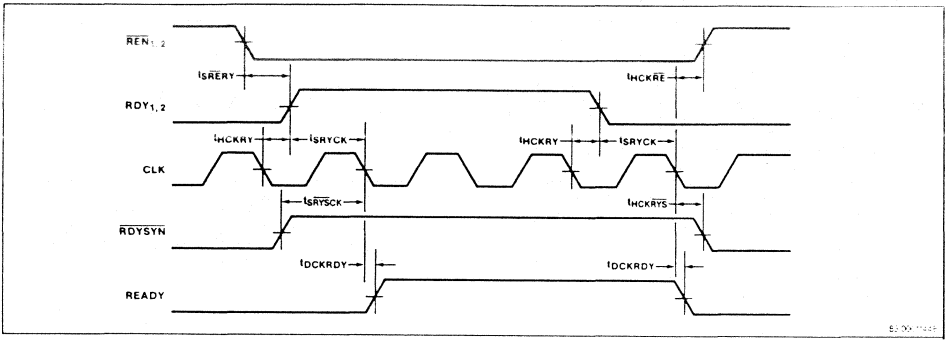


Input/Output Waveform for AC Test

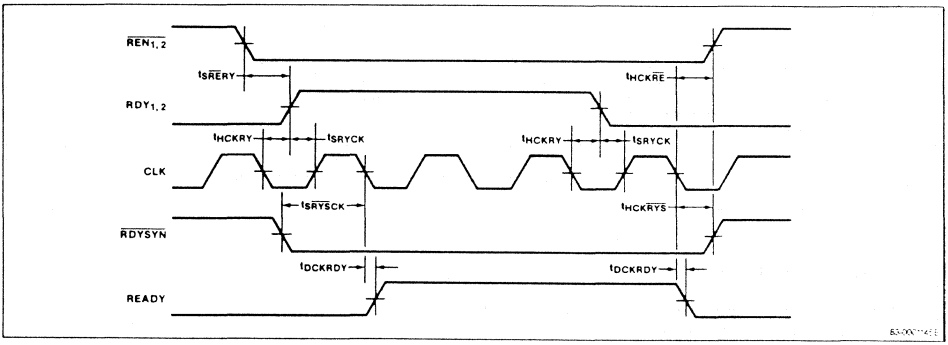


Timing Waveforms (cont)

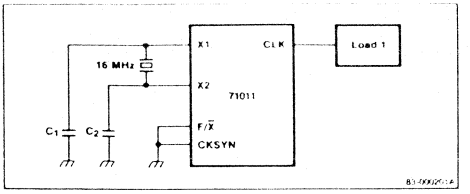
READY Output (RDYSYN High)



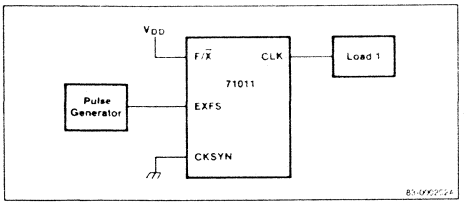
READY Output (RDYSYN Low)



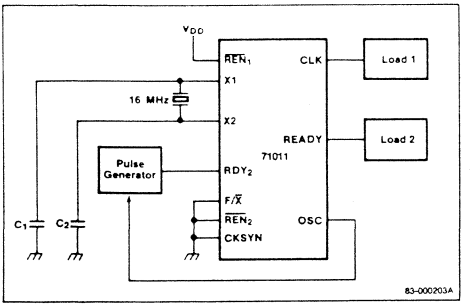
Test Circuit for CLK High or Low Time (In Crystal Oscillation Mode)



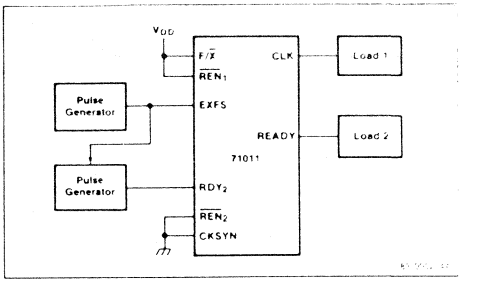
Test Circuit for CLK High or Low Time (In EXFS Oscillation Mode)



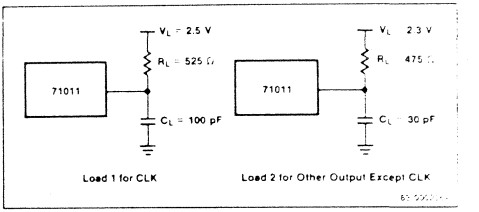
Test Circuit for CLK to READY (in Crystal Oscillation Mode)



Test Circuit for CLK to READY (in EXFS Oscillation Mode)



Loading Circuits



Description

The μPD71051 serial control unit is a CMOS USART designed to provide serial data communications in microcomputer systems. The CPU uses it as a peripheral I/O device and programs it to communicate in synchronous or asynchronous serial data transmission protocols, including IBM bisync.

The USART receives serial data streams and converts them into parallel data characters for the CPU. While receiving serial data, the USART can also accept parallel data from the CPU, convert it to serial, and transmit the data. The USART signals the CPU when it has received or transmitted a character and requires service. The CPU may read complete USART status data at any time.

Features

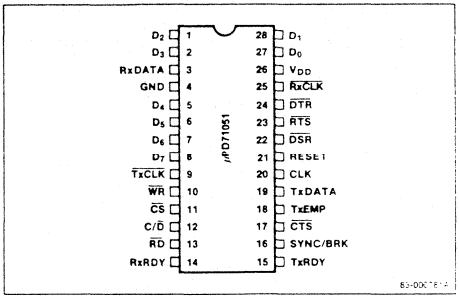
- ☐ Synchronous operation
  - One or two SYNC characters
  - Internal/external synchronization
  - Automatic SYNC character insertion
- ☐ Asynchronous operation
  - Clock rate: (baud rate)
  - x1, x16, or x64
  - Send stop bits: 1, 1.5, or 2 bits
  - Break transmission
  - Automatic break detection
  - Valid start bit detection
- ☐ Baud rate: DC - 240 kbit/s at x1 clock
- ☐ Full duplex, double-buffered transmitter/receiver
- ☐ Error detection: parity, overrun, and framing
- ☐ Five- to eight-bit characters
- ☐ Low-power standby mode
- ☐ Compatible with standard microcomputers
- ☐ Functionally equivalent to (except standby mode) and can replace the μPD8251AF
- ☐ CMOS technology
- ☐ Single +5 V ± 10% power supply
- ☐ Industrial temperature range −40 to +85 °C
- ☐ 28-pin plastic DIP or 44-pin plastic miniflat

Ordering Information

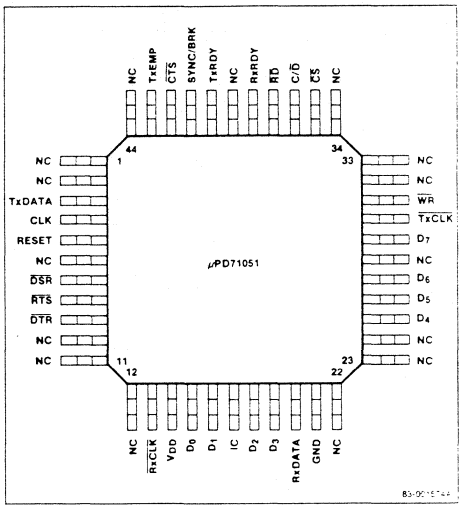
Part Number	Package Type	Max. Frequency of Operation
μPD71051C	28-pin plastic DIP	8 MHz
μPD71051G	44-pin plastic miniflat	8 MHz
μPD71051L	28-pin PLCC (available 1Q87)	8 MHz

Pin Configurations

28-Pin Plastic DIP



44-Pin Plastic Miniflat



Pin Identification

Plastic DIP

No	Symbol	Function
1, 2	D_2, D_3	Data bus, bits 2 and 3
3	RxDATA	Receive data input
4	GND	Ground
5-8	D_4-D_7	Data bus, bits 4-7
9	$\overline{TxCLK}$	Transmitter clock input
10	$\overline{WR}$	Write strobe input
11	$\overline{CS}$	Chip select input
12	C/$\overline{D}$	Control or data input
13	$\overline{RD}$	Read strobe input
14	RxRDY	Receiver ready output
15	TxRDY	Transmitter ready output
16	SYNC/BRK	Synchronization/Break input/output
17	$\overline{CTS}$	Clear to send input
18	TxEMP	Transmitter empty output
19	TxDATA	Transmit data output
20	CLK	Clock input
21	RESET	Reset input
22	$\overline{DSR}$	Data set ready input
23	$\overline{RTS}$	Request to send output
24	$\overline{DTR}$	Data terminal ready output
25	$\overline{RxCLK}$	Receiver clock input
26	V_{DD}	+5 V power supply
27, 28	D_0, D_1	Data bus, bits 0 and 1

Plastic Flatpack

No	Symbol	Function
1, 2	NC	Not connected
3	TxDATA	Transmit data output
4	CLK	Clock input
5	RESET	Reset input
7	$\overline{DSR}$	Data set ready input
8	$\overline{RTS}$	Request to send output
9	$\overline{DTR}$	Data terminal ready output
10-12	NC	Not connected
13	$\overline{RxCLK}$	Receiver clock input
14	V_{DD}	+5 V power supply
15, 16	D_0, D_1	Data bus, bits 0 and 1
17	IC	Internally connected (Do not connect any signal to pin 17)
18, 19	D_2, D_3	Data bus, bits 2 and 3
20	RxDATA	Receive data input
21	GND	Ground
22-24	NC	Not connected
25-27	D_4-D_6	Data bus, bits 4-6
28	NC	Not connected
29	D_7	Data bus, bit 7
30	$\overline{TxCLK}$	Transmitter clock input
31	$\overline{WR}$	Write strobe input
32-34	NC	Not connected
35	$\overline{CS}$	Chip select input
36	C/$\overline{D}$	Control or data input
37	$\overline{RD}$	Read strobe input
38	RxRDY	Receiver ready output
39	NC	Not connected
40	TxRDY	Transmitter ready output
41	SYNC/BRK	Synchronization/Break input/output
42	$\overline{CTS}$	Clear to send input
43	TxEMP	Transmitter empty output
44	NC	Not connected

Pin Functions

D_7-D_0 [Data Bus]

D_7-D_0 are an 8-bit, 3-state, bidirectional data bus. The bus transfers data by connecting to the CPU data bus.

RESET [Reset]

A high level to the RESET input resets the μPD71051 and puts it in an idle state. It performs no operations in the idle state. The μPD71051 enters standby mode when this signal falls from a high level to a low level. Standby mode is released when the CPU writes a mode byte to the μPD71051. The reset pulse width must be at least 6 t_{CYK} cycles and the clock must be enabled.

CLK [Clock]

This clock input produces internal timing for the μPD71051. The clock frequency should be at least 30 times the transmitter or receiver clock input frequency ($\overline{TxCLK}$, $\overline{RxCLK}$) in sync or async mode with the X1 clock. This assures stable operation. The clock frequency must be more than 4.5 times the $\overline{TxCLK}$ or $\overline{RxCLK}$ in async mode using x16 or x64 clock mode.

$\overline{CS}$ [Chip Select]

The $\overline{CS}$ input selects the μPD71051. The μPD71051 is selected by setting $\overline{CS} = 0$. When $\overline{CS} = 1$, the μPD71051 is not selected, the data bus (D_7-D_0) is in the high impedance state, and the $\overline{RD}$ and $\overline{WR}$ signals are ignored.

$\overline{RD}$ [Read Strobe]

The $\overline{RD}$ input is low when reading data or status information from the μPD71051.

$\overline{WR}$ [Write Strobe]

The $\overline{WR}$ input is low when writing data or a control byte to the μPD71051.

C/$\overline{D}$ [Control or Data]

The C/$\overline{D}$ input determines the data type when accessing the μPD71051. When C/$\overline{D}$ = 1, the data is a control byte (table 1) or status. When C/$\overline{D}$ = 0, the data is character data. This pin is normally connected to the least significant bit (A_0) of the CPU address bus.

$\overline{DSR}$ [Data Set Ready]

$\overline{DSR}$ is a general-purpose input pin that can be used for modem control. The status of this pin can be determined by reading bit 7 of the status byte.

$\overline{DTR}$ [Data Terminal Ready]

$\overline{DTR}$ is a general-purpose output pin that can be used for modem control. The state of this pin can be controlled by writing bit 1 of the command byte. If bit 1 = 0, then $\overline{DTR} = 1$. If bit 1 = 1, then $\overline{DTR} = 0$.

$\overline{RTS}$ [Request to Send]

$\overline{RTS}$ is a general-purpose output pin that can be used for modem control. The status of this pin can be controlled by writing bit 5 of the command byte. If bit 5 = 1, then $\overline{RTS} = 0$. If bit 5 = 0, then $\overline{RTS} = 1$.

$\overline{CTS}$ [Clear to Send]

The $\overline{CTS}$ input controls data transmission. The μPD71051 is able to transmit serial data when $\overline{CTS} = 0$ and the command byte sets TxEN = 1. If $\overline{CTS}$ is set equal to 1 during transmission, the sending operation stops after sending all currently written data and the TxDATA pin goes high.

TxDATA [Transmit Data]

The μPD71051 sends serial data over the TxDATA output.

TxRDY [Transmitter Ready]

The TxRDY output tells the CPU that the transmit data buffer in the μPD71051 is empty; that is, that new transmit data can be written. This signal is masked by the TxEN bit of the command byte and by the $\overline{CTS}$ input. It can be used as an interrupt signal to request data from the CPU.

The status of TxRDY can be determined by reading bit 0 of the status byte. This allows the μPD71051 to be polled. Note that TxRDY of the status byte is not masked by $\overline{CTS}$ or TxEN.

TxRDY is cleared to 0 by the falling edge of $\overline{WR}$ when the CPU writes transmit data to the μPD71051. Data in the transmit data buffer that has not been sent is destroyed if transmit data is written while TxRDY = 0.

TxEMP [Transmitter Empty]

The μPD71051 reduces CPU overhead by using a double buffer; the transmit data buffer (second buffer) and the transmit buffer (first buffer) in the transmitter. When the CPU writes transmit data to the transmit data buffer (second buffer), the μPD71051 sends data by transferring the contents of the second buffer to the first buffer, after transmitting the contents of the first buffer.

This empties the second buffer and TxRDY is set to 1. The TxEMP output becomes 1 when the contents of the first buffer are sent and the second buffer is empty. Thus, TxEMP = 1 shows that both buffers are empty. In half-duplex operation, you can determine when to change from sending to receiving by testing TxEMP = 1.

When TxEMP = 1 occurs in async mode, the TxDATA pin goes high. When the CPU writes transmit data, TxEMP is set to 0 and data transmission resumes.

When TxEMP = 1 occurs in sync mode, the μPD71051 loads SYNC characters from the SYNC character register and sends them through the TxDATA pin. TxEMP is set to 0 and resumes sending data after sending (one or two) SYNC characters and the CPU writes new transmit data to the μPD71051.

$\overline{\text{TxCLK}}$ [Transmitter Clock]

The $\overline{\text{TxCLK}}$ input is the reference clock input that determines the transmission rate. Data is transmitted at the same rate as $\overline{\text{TxCLK}}$ in sync mode. In async mode, set $\overline{\text{TxCLK}}$ to 1, 16, or 64 times the transmission rate. Serial data from TxDATA is sent at the falling edge of $\overline{\text{TxCLK}}$.

For example, a rate of 19200 baud in sync mode means that $\overline{\text{TxCLK}}$ is 19.2 kHz. A rate of 2400 baud in async mode can represent a $\overline{\text{TxCLK}}$ of:

x1 clock = 2.4 kHz
x16 clock = 38.4 kHz
x64 clock = 153.6 kHz

RxDATA [Receive Data]

The μPD71051 receives serial data through the RxDATA input.

RxRDY [Receiver Ready]

The RxRDY output becomes 1 when the μPD71051 receives one character of data and transfers that data to the receive data buffer; that is, when the receive data can be read. This signal can be used as an interrupt signal for a data read request to the CPU. You can determine the status of RxRDY by reading bit 1 of the status byte and use the μPD71051 in a polling application. RxRDY becomes 0 when the CPU reads the receive data.

Unless the CPU reads the receive data (after RxRDY = 1 is set) before the next single character is received and transferred to the receive buffer, an overrun error occurs, and the OVE status bit is set. The unread data in the receive data buffer is overwritten by newly transferred data and lost.

RxRDY is set to 0 in the receive disable state. This state is set by changing the RxEN bit to 0 through the command byte. After RxEN is set to 1 (making receiving possible), RxRDY becomes 1 whenever new characters are received and transferred to the receive data buffer.

SYNC/BRK [Synchronization/Break]

The SYNC pin detects synchronization characters in sync mode. The SYNC mode byte selects internal or external SYNC detection. The SYNC pin becomes an output when internal synchronization is set, and an input when external synchronization is set.

The SYNC output goes high when the μPD71051 detects a SYNC character in internal synchronization. When two SYNC characters are used, SYNC goes high when the last bit of the two consecutive SYNC characters is detected. You can read the status of the SYNC signal in bit 6 of the status byte. Both the SYNC pin and status are set to 0 by a read status operation.

In external synchronization, in order for the external circuit to detect synchronization, a high level of at least one period of $\overline{\text{RxCLK}}$ must be input to the SYNC pin. When the μPD71051 detects the high level, it begins to receive data, starting at the rising edge of the next $\overline{\text{RxCLK}}$. The high level input may be removed when synchronization is released.

The BRK output is used only in async mode and shows the detection of a break state. BRK goes high when a low level signal is input to the RxDATA pin for two character bit lengths (including the start, stop, and parity bits). As with SYNC, you can read the status of BRK in bit 6 of the status byte. BRK is not cleared by the read operation.

The set BRK signal is cleared when the RxDATA pin returns to high level, or when the μPD71051 is reset by hardware or software. The SYNC/BRK pin goes low on reset, regardless of previous mode. Figure 1 shows the break state and BRK signal.

$\overline{\text{RxCLK}}$ [Receiver Clock]

$\overline{\text{RxCLK}}$ is a reference clock input that controls the receive data rate. In sync mode, the receiving rate is the same as $\overline{\text{RxCLK}}$. In async mode, $\overline{\text{RxCLK}}$ can be 1, 16, or 64 times the receive rate. Serial data from RxDATA is input by the rising edge of $\overline{\text{RxCLK}}$.

V_{DD} [Power]

+5 V power supply.

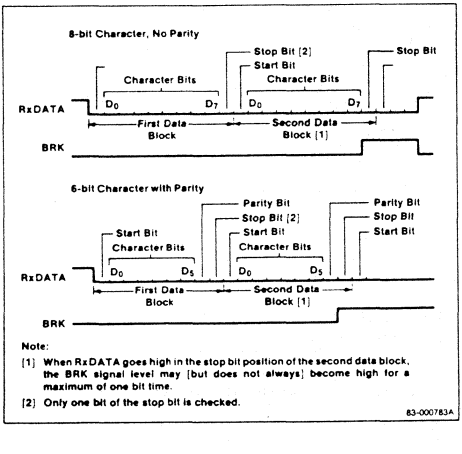
GND [Ground]

Ground.

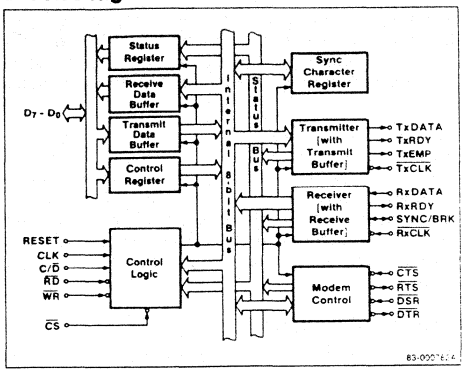
Table 1. Control Signals and Operations

$\overline{CS}$	$\overline{RD}$	$\overline{WR}$	C/$\overline{D}$	μPD71051	CPU Operation
0	0	1	0	Receive data buffer ⇨ Data bus	Read receive data
0	0	1	1	Status register ⇨ Data bus	Read status
0	1	0	0	Data bus ⇨ Transmit data buffer	Write transmit data
0	1	0	1	Data bus ⇨ Control byte register	Write control byte
0	1	1	x	Data bus High impedance	None
1	x	x	x	Data bus High impedance	None

Figure 1. Break Status and Break Signal



Block Diagram



μPD71051 Functions

The μPD71051 is a CMOS serial control (USART) unit that provides serial communications in microcomputer systems. The CPU handles the μPD71051 as an ordinary I/O device.

The μPD71051 can operate in synchronous or asynchronous systems. In sync mode, the character bit length, number of sync characters, and sync detection mode must be designated. In async mode, the communication rate, character bit length, stop bit length, etc., must be designated. The parity bit may be designated in either mode.

The μPD71051 converts parallel data received from the CPU into serial transmitted data (from the TxDATA pin), and converts serial input data (from the RxDATA pin) into parallel data so that the CPU can read it (receiving operation).

The CPU can read the current status of the μPD71051 and can process data after checking the status, after checking for transfer errors, and μPD71051 data buffer status.

The μPD71051 can be reset under hardware or software control to a standby mode that consumes less power and removes the device from system operation. In this mode, the μPD71051's previous operating mode is released and it waits for a mode byte to set the mode. The μPD71051 leaves standby mode and shifts to a designated operating mode when the CPU writes a mode byte to it.

Status Register

The status register allows the CPU to read the status of the μPD71051 except in standby mode. This register indicates status and allows the CPU to manage data reading, writing, and error handling during operations.

Receive Data Buffer

When the receiver has converted the serial data input from the RxDATA pin into parallel data, the converted data is stored in the receive data buffer. The CPU can then read it. Data for one character entering the receive buffer is transferred to the receive data buffer and RxRDY becomes 1, requesting that the CPU read the data.

Transmit Data Buffer

The transmit data buffer holds the parallel data from the CPU that the transmitter will convert to serial data and output from the TxDATA pin. When the CPU writes transmit data to the μPD71051, the μPD71051 stores data in the transmit data buffer. The transmit data buffer transfers the data to the transmitter, which sends the data from the TxDATA pin.

Control Register

This register stores the mode and the command bytes.

Control Logic

The control logic sends control signals to the internal blocks and controls the operation of the μPD71051 based on internal and external signals.

Synchronous Character Register

This register stores one or two SYNC characters used in sync mode. During transmission, the SYNC characters stored in this register are output from the TxDATA pin when the CPU does not send a new character and TxEMP status is set. During receiving, synchronization is established when the characters received and the SYNC characters stored in this register are the same.

Transmitter

The contents of the transmit data buffer are transferred to the transmitter, converted from parallel to serial, and output from the TxDATA pin. The transmitter adds start, stop, and parity bits.

Receiver

The receiver converts serial data input from the RxDATA pin into parallel data and transfers the parallel data to the receive data buffer, allowing the CPU to read it.

The receiver detects SYNC characters and checks parity bits in sync mode. It detects the start and stop bits, and checks parity in the async mode.

In async mode, receiving does not begin (the start bit is not detected) until one effective stop bit (high level) is input to the RxDATA pin and Receive Enable (RxEN = 1) is set after setting up the mode.

Modem Control

This block controls the $\overline{CTS}$, $\overline{RTS}$, $\overline{DSR}$, and $\overline{DTR}$ modem interface pins. The $\overline{RTS}$, $\overline{DSR}$, and $\overline{DTR}$ pins can also be used as general-purpose I/O pins.

Absolute Maximum Ratings

$T_A = +25°C$

Power supply voltage, V_{DD}	−0.5 to +7.0 V
Input voltage, V_I	−0.5 to V_{DD} + 0.3 V
Output voltage, V_O	−0.5 to V_{DD} + 0.3 V
Operating temperature, T_{OPT}	−40°C to −85°C
Storage temperature, T_{STG}	−65°C to +150°C
Power dissipation, PD_{MAX}	1.0 W

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

$T_A = +25°C$, $V_{DD} = 0$ V

Parameter	Symbol	Limits Min	Max	Unit	Test Conditions
Input capacitance	C_I		10	pF	fc = 1MHz Unmeasured pins returned to 0 V
I/O capacitance	C_{IO}		20	pF	

AC Characteristics

$T_A = -40°C$ to $+85°C$, $V_{DD} = +5$ V, ±10%

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Read Cycle					
Address set-up to $\overline{RD}\downarrow$	t_{SAR}	0		ns	$\overline{CS}$, C/$\overline{D}$
Address hold from $\overline{RD}\uparrow$	t_{HRA}	0		ns	$\overline{CS}$, C/$\overline{D}$
$\overline{RD}$ low level width	t_{RRL}	150		ns	
Data delay from $\overline{RD}\downarrow$	t_{DRD}		120	ns	C_L = 150 pF
Data float from $\overline{RD}\uparrow$	t_{FRD}	10	80	ns	
Port ($\overline{DSR}$, $\overline{CTS}$) set-up to $\overline{RD}\downarrow$	t_{SPR}	20		t_{CYK}	
Write Cycle					
Address set-up to $\overline{WR}\downarrow$	t_{SAW}	0		ns	$\overline{CS}$, C/$\overline{D}$
Address hold from $\overline{WR}\uparrow$	t_{HWA}	0		ns	$\overline{CS}$, C/$\overline{D}$
$\overline{WR}$ low level width	t_{WWL}	150		ns	
Data set-up to $\overline{WR}\uparrow$	t_{SDW}	80		ns	
Data hold from $\overline{WR}\uparrow$	t_{HWD}	0		t_{CYK}	
Port ($\overline{DTR}$, $\overline{RTS}$), delay from $\overline{WR}\uparrow$	t_{DWP}		8	t_{CYK}	
Write recovery time	t_{RV}	6		t_{CYK}	Mode Initialize
		8		t_{CYK}	Async Mode
		16		t_{CYK}	Sync Mode
Serial Transfer Timing					
CLK cycle time	t_{CYK}	125	DC	ns	
CLK high level width	t_{KKH}	50		ns	
CLK low Level width	t_{KKL}	35		ns	
CLK rise time	t_{KR}	5	20	ns	
CLK fall time	t_{KF}	5	20	ns	
TxDATA delay from TxCLK	t_{DTKTD}		0.5	μs	

AC Characteristics

$T_A = -40°C$ to $+85°C$, $V_{DD} = +5$ V, ±10%

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Serial Transfer Timing (cont)					
Transmitter input clock pulse width low level	t_{TKTKL}	12		t_{CYK}	1xBR (1)
		1		t_{CYK}	16x, 64xBR
Transmitter input clock pulse width high level	t_{TKTKH}	15		t_{CYK}	1xBR
		3		t_{CYK}	16x, 64xBR
Transmitter input clock frequency	f_{TK}(2)	DC	240	kHZ	1xBR
		DC	1536	kHz	16xBR
		DC	1536	kHz	64xBR
Receiver input clock pulse width low level	t_{RKRKL}	12		t_{CYK}	1xBR
		1		t_{CYK}	16x, 64xBR
Receiver input clock pulse width high level	t_{RKRKH}	15		t_{CYK}	1xBR
		3		t_{CYK}	16x, 64xBR
Receiver input clock frequency	f_{RK}(2)	DC	240	kHz	1xBR
		DC	1536	kHz	16xBR
		DC	1536	kHz	64xBR
RxDATA set-up to sampling pulse	t_{SRDSP}	1		μs	
RxDATA hold from sampling pulse	t_{HSPRD}	1		μs	
TxEMP delay time (TxDATA)	t_{DTXEP}		20	t_{CYK}	
TxRDY delay time (TxRDY↑)	t_{DTXR}		8	t_{CYK}	
TxRDY delay time (TxRDY↓)	t_{DWTXR}		200	ns	
RxRDY delay time (RxRDY↑)	t_{DRXR}		26	t_{CYK}	
RxRDY delay time (RxRDY↓)	t_{DRRXR}		200	ns	
SYNC output delay time (for internal sync)	t_{DRKSY}		26	t_{CYK}	
SYNC input set-up time (for external sync)	t_{SSYRK}	18		t_{CYK}	
RESET pulse width		6		t_{CYK}	

Note:

(1) BR = Baud rate

(2) 1xBR: f_{TK} or $f_{RK} \leq 1/30\, t_{CLK}$, 16x, 64xBR: f_{TK} or $f_{RK} \leq 1/4.5\, t_{CLK}$

(3) System CLK is needed during reset operation

(4) Status update can have a maximum delay of 28 t_{CYK} from the event effecting the status.

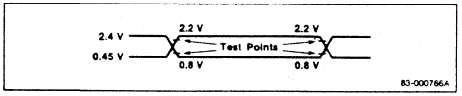
DC Characteristics

T_A = −40°C to +85°C, V_{DD} = +5 V ± 10%

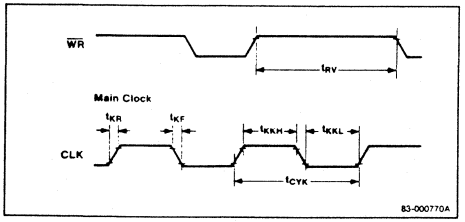
Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Input voltage high	V_{IH}	2.2	V_{DD} + 0.3	V	
Input voltage low	V_{IL}	−0.5	0.8	V	
Output voltage high	V_{OH}	.7 x V_{DD}		V	I_{OH} = −400 μA
Output voltage low	V_{OL}		0.4	V	I_{OL} = 2.5 mA
Input leakage current high	I_{LIH}		10	μA	$V_I = V_{DD}$
Input leakage current low	I_{LIL}		−10	μA	V_I = 0 V
Output leakage current high	I_{LOH}		10	μA	$V_O = V_{DD}$
Output leakage current low	I_{LOL}		−10	μA	V_O = 0 V
Supply current	I_{DD1}		10	mA	8 MHz operation
	I_{DD2}		50	μA	Stand-by mode

Timing Waveforms

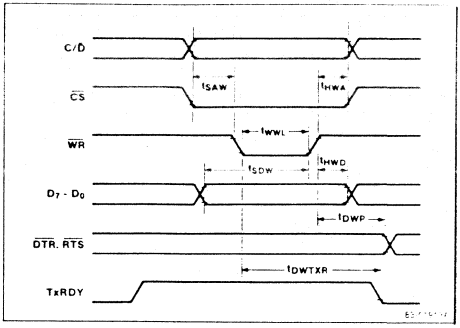
AC Test Input



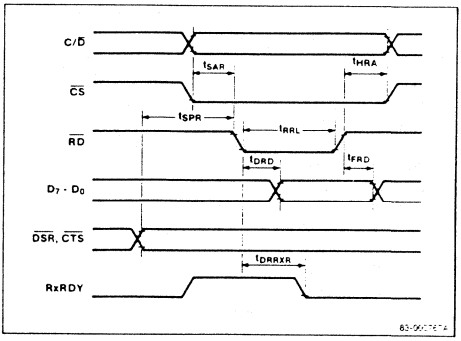
Write Recovery Time



Write Data Cycle

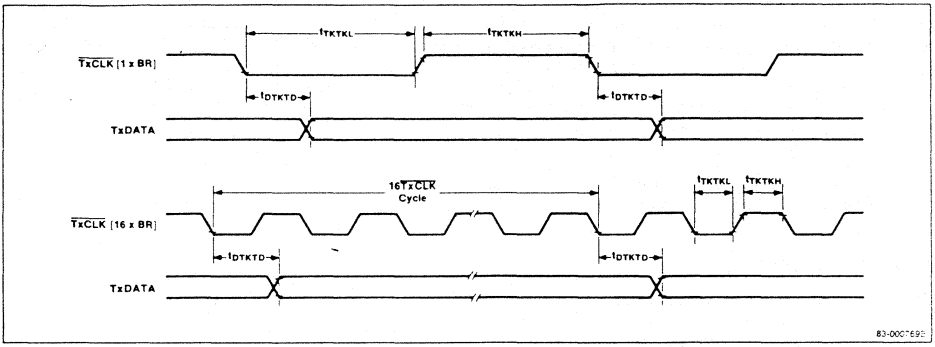


Read Data Cycle

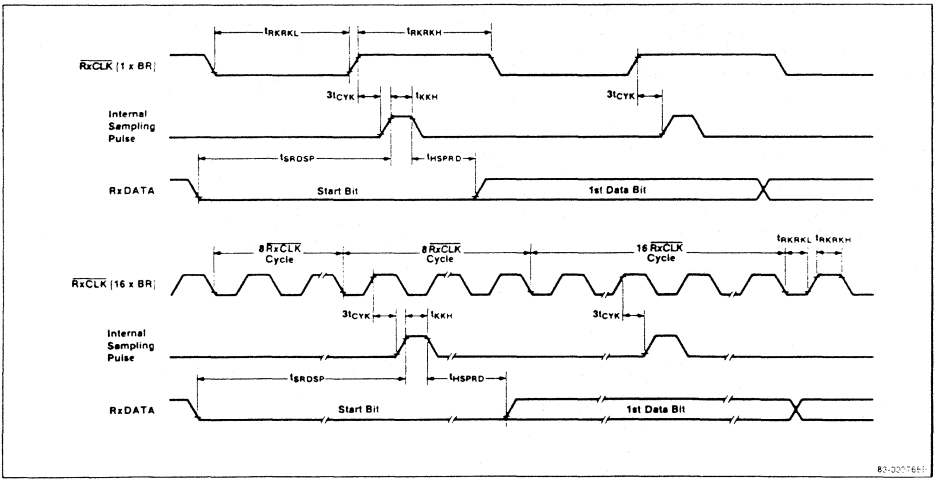


Timing Waveforms (cont)

Transmitter Clock and TxDATA



Receiver Clock and RxDATA Timing



Connecting the μPD71051 to the System

The CPU uses the μPD71051 as an I/O device by allocating two I/O addresses, set by the value of C/$\overline{D}$. One I/O address is allocated when the level of C/$\overline{D}$ is low and becomes a port to the transmit and receive data register. The other I/O address is allocated when C/$\overline{D}$ is high and becomes a port to the mode, command, and status registers. Generally, the least significant bit (A_0) of the CPU address bus is connected to C/$\overline{D}$ to get a continuous I/O address. This is shown in figure 2.

Pins TxRDY and RxRDY are connected to the CPU or, when interrupts are used, to the interrupt pin of the interrupt controller.

Operating the μPD71051

Start with a hardware reset (set the RESET pin high) after powering on the μPD71051. This puts the μPD71051 into standby mode and it waits for a mode byte. In async mode, the μPD71051 is ready for a command byte after the mode byte; the mode byte sets the communication protocol to the async mode. In sync mode, the μPD71051 waits for one or two SYNC characters to be sent after the mode byte; set C/$\overline{D}$ = 1. A command byte may be sent after the SYNC characters are written. Figure 3 shows this operation sequence.

In both modes, it is possible to write transmit data, read receive data, read status, and write more command bytes after the first command byte is written. The μPD71051 performs a reset, enters standby mode, and returns to a state where it waits for a mode byte when the command byte performs a software reset.

Figure 2. System Connection

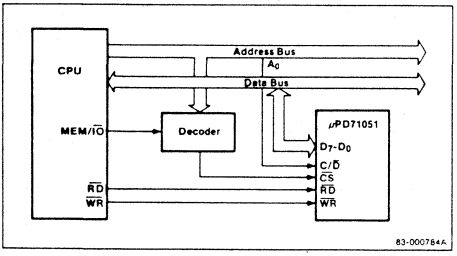
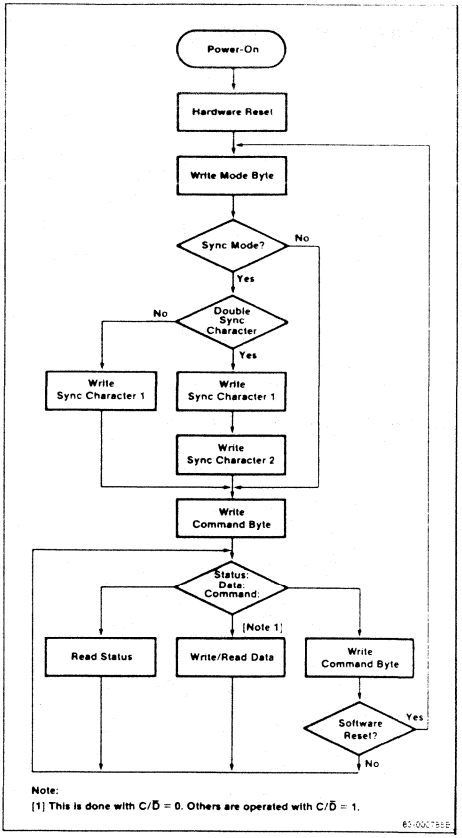


Figure 3. μPD71051 Operating Procedure



Mode Register

When the μPD71051 is in standby mode, writing a mode byte to it will release standby mode. Figure 4 shows the mode byte format for designating async mode. Figure 5 shows the mode byte format for designating sync mode. Bits 0 and 1 must be 00 to designate sync mode. Async mode is designated by all other combinations of bits 0 and 1.

The P1, P0 and L1, L0 bits are common to both modes. Bits P1 and P0 (parity) control the generation and checking (sending and receiving) functions. These parity bit functions do not operate when P0 = 0. When P1, P0 = 01, the μPD71051 generates and checks odd parity. When P1, P0 = 11, it generates and checks even parity.

Bits L1 and L0 set the number of bits per character (n). Additional bits such as parity bits are not included in this number. Given n bits, the μPD71051 receives the lower n bits of the 8-bit data written by the CPU. The upper bits (8 -n) of data that the CPU reads from the μPD71051 are set to zero.

The ST1, ST0 and B1, B0 bits are used in async mode. The ST1 and ST0 bits determine the number of stop bits added by the μPD71051 during transmission.

The B1 and B0 bits determine the relationship between the baud rates for sending and receiving, and the clocks $\overline{TxCLK}$ and $\overline{RxCLK}$. B1 and B0 select a multiplication rate of 1, 16, or 64 for the frequency of the sending and receiving clock relative to the baud rate. Multiplication by 1 is not normally used in async mode. Note that the data and clock must be synchronized on the sending and receiving sides when multiplication by 1 is used.

The SSC and EXSYNC bits are used in sync mode. The SSC bit determines the number of SYNC characters. SSC = 1 designates one SYNC character. SSC = 0 designates two SYNC characters. The number of SYNC characters determined by the SSC bit are written to the μPD71051 immediately after writing the mode byte.

The EXSYNC bit determines whether sync detection during receiving operations is internal or external. EXSYNC = 1 selects external sync detection and EXSYNC = 0 selects internal sync detection.

Figure 4. Mode Byte for Setting Asynchronous Mode

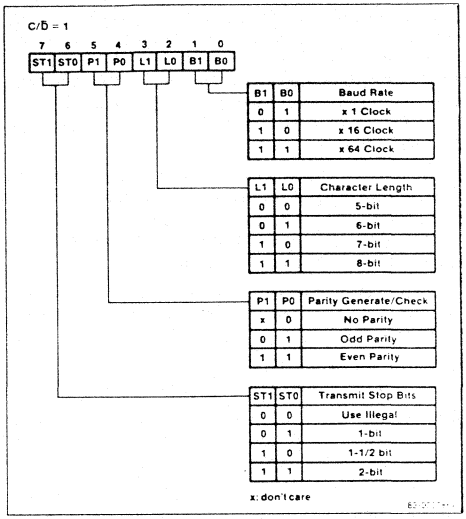
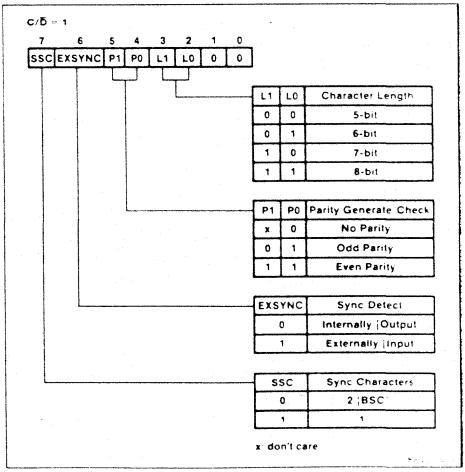


Figure 5. Mode byte for Setting Synchronous Mode



Command Register

Commands are issued to the μPD71051 by the CPU by command bytes that control the sending and receiving operations of the μPD71051. A command byte is sent after the mode byte (in sync mode, a command byte may only be sent after writing SYNC characters) and the CPU must set C/$\overline{D}$ = 1. Figure 6 shows the command byte format.

Bit EH is set to 1 when entering hunt phase to synchronize in sync mode. Bit RxEN should also be set to 1 at that time. Data reception begins when SYNC characters are detected and synchronization is achieved, thus releasing hunt phase.

When bit SRES is set to 1, a software reset is executed, and the μPD71051 goes into standby mode and waits for a mode byte.

Bit RTS controls the $\overline{RTS}$ output pin. $\overline{RTS}$ is low when the RTS bit = 1 , and goes high when RTS = 0.

Setting bit ECL to 1 clears the error flags (PE, OVE, and FE) in the status register. Set ECL to 1 when entering the hunt phase or enabling the receiver.

Bit SBRK sends a break. When SBRK = 1, the data currently being sent is destroyed and the TxDATA pin goes low. Set SBRK = 0 to release a break. Break also works when TxEN = 0 (send disable).

Bit RxEN enables and disables the receiver. RxEN = 1 enables the receiver and RxEN = 0 disables the receiver. Synchronization is lost if RxEN = 0 during sync mode.

Bit DTR controls the $\overline{DTR}$ output pin. $\overline{DTR}$ goes low when the DTR bit = 1 and goes high when the DTR bit = 0.

The TxEN bit enables and disables the transmitter. TxEN = 1 enables the transmitter and TxEN = 0 disables the transmitter. When TxEN = 0, sending stops and the TxDATA pin goes high (mark status) after all the currently written data is sent.

Status Register

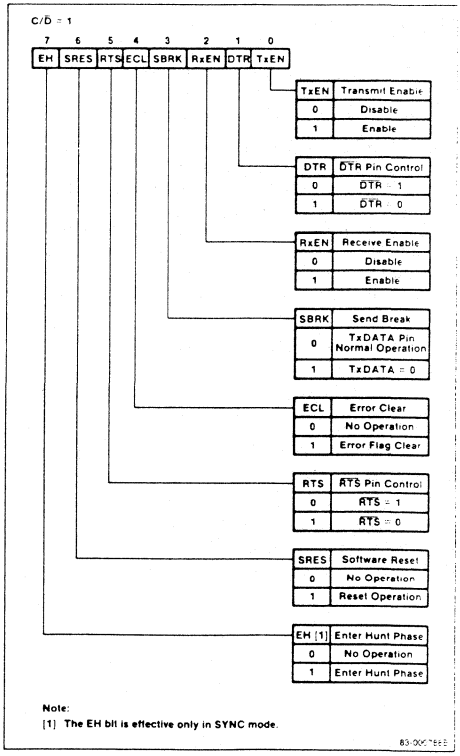
The CPU can read the status of the μPD71051 at any time except when the μPD71051 is in standby mode. Status can be read after setting C/$\overline{D}$ = 1 and $\overline{RD}$ = 0. Status is not updated while being read. Status updating is delayed at least 28 clock periods after an event that affects the status. Figure 7 shows the format of the status register.

The TxEMP and RxRDY bits have the same meaning as the pins of the same name. The SYNC/BRK bit generally has the same meaning as the SYNC/BRK pin. In external synchronization mode, the status of this bit does not always coincide with the pin. In this case, the SYNC pin becomes an input and the status bit goes to 1 when a rising edge is detected at the input. The status bit remains at 1 until it is read, even when the input level at the SYNC pin goes low. The status bit becomes 1 when a SYNC character is input with the RxDATA input, even when the pin is at a low level.

The DSR bit shows the status of the $\overline{DSR}$ input pin. The status bit is 1 when the $\overline{DSR}$ pin is low.

The FE bit (framing error) becomes 1 when less than one stop bit is detected at the end of each data block during asynchronous receiving. Figure 8 shows how a framing error can happen.

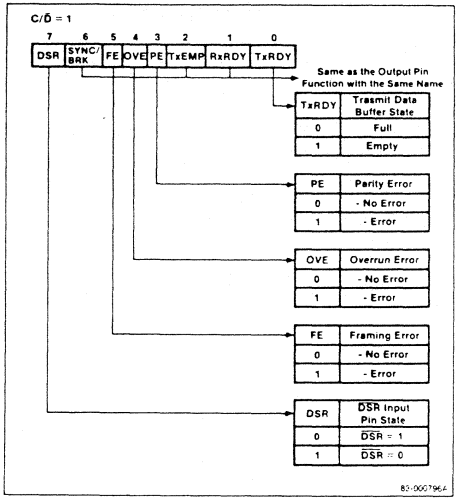
Figure 6. Command Byte Format



The OVE bit (overrun error) becomes 1 when the CPU delays reading the received data and two new data bytes have been received. In this case, the first data byte received is overwritten and lost in the receive data buffer. Figure 9 shows how an overrun can happen.

The PE bit (parity error) becomes 1 when a parity error occurs in a receive state.

Figure 7. Status Register Format



Framing, overrun, and parity errors do not disable the μPD71051's operations. All three error flags are cleared to 0 by a command byte that sets the ECL bit to 1.

The TxRDY bit becomes 1 when the transmit data buffer is empty. The TxRDY output pin becomes 1 when the transmit data buffer is empty, the $\overline{CTS}$ pin is low, and TxEN = 1. That is, bit TxRDY = Transmit Data Buffer Empty, pin TxRDY = (Transmit Data Buffer Empty)•($\overline{CTS}$ = 0)•(TxEN = 1).

Figure 8. Framing Error

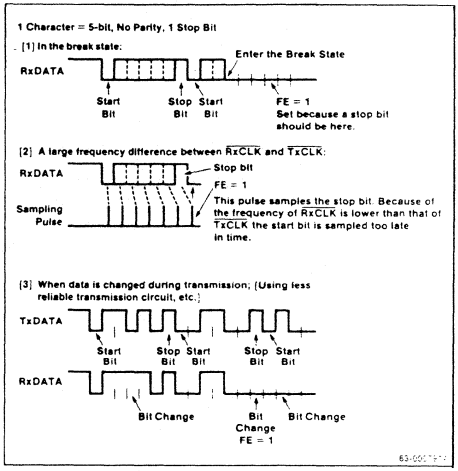
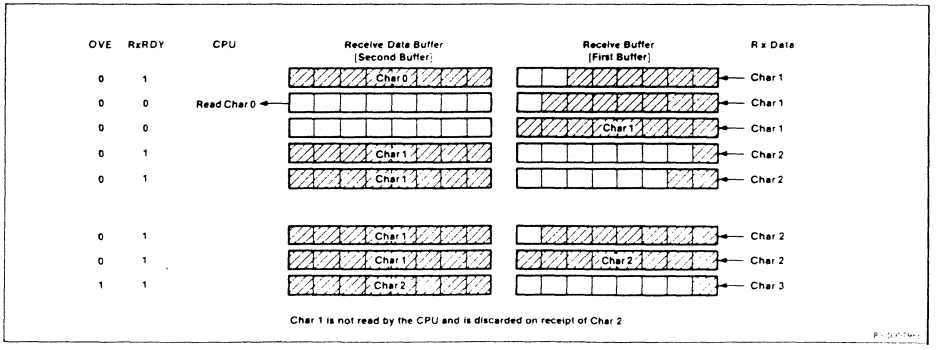


Figure 9. Overrun Error



Sending in Asynchronous Mode

The TxDATA pin is typically in the high state (marking) when data is not being sent. When the CPU writes transmit data to the μPD71051, the μPD71051 transfers the transmit data from the transmit data buffer to the send buffer and sends the data from the TxDATA pin after adding one start bit (low level) and a programmed stop bit. If parity is used, a parity bit is inserted between the character and the stop bit. Figure 10 shows the data format for async mode characters. Serial data is sent by the falling edge of the signal that divided $\overline{\text{TxCLK}}$ (1/1, 1/16, or 1/64).

When bit SBRK is set to 1, the TxDATA pin goes low (break status), regardless of whether data is being sent. Figure 11 is a fragment of a typical program to send data in the async mode. Figure 12 shows the output from pin TxDATA.

Figure 10. Asynchronous Mode Data Format

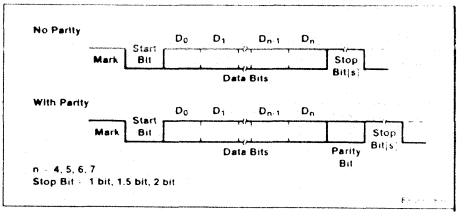
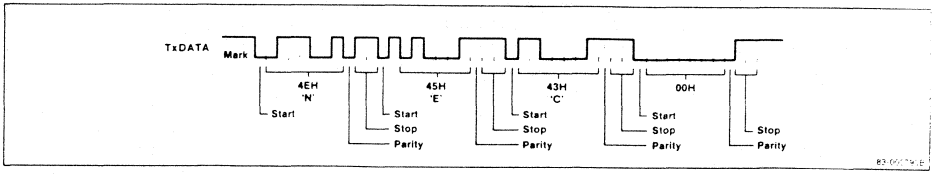


Figure 11. Asynchronous Transmitter Example

```
ASYNTX :    CALL    ASYNMOD             ;Set async mode
            MOV     AL, 00010001B       ;Command: clear error flag, transmit enable
            OUT     PCTRL,AL
            MOV     BW, OFFSET TXDADR   ;Transmit data area
TXSTART :   IN      AL, PCTRL
            AND     AL, 01H
            TEST    AL, 01H             ;Read status
            BNE     TXSTART             ;Wait until TxRDY = 1
            MOV     AL, [BW]            ;Write transmit data
            OUT     PDATA, AL
            INC     BW                  ;Set next data address
            CMP     AL, 00H
            BNE     TXSTART             ;End if data = 0
            RET
TXDADR      DB      'NEC'               ;Transmit data 4EH, 45H, 43H, 00
            DB      0
ASYNMOD :   MOV     AL, 0               ;Writes control bytes three times
            OUT     PCTRL, AL           ;with 00H to unconditionally
            OUT     PCTRL, AL           ;accept the new command byte
            OUT     PCTRL, AL
            MOV     AL, 01000000B       ;Software reset
            OUT     PCTRL, AL
            MOV     AL, 11111010B       ;Write mode byte
            OUT     PCTRL, AL           ;Stop bit = 2 bits, even parity
            RET                         ;7 bits/character, x16 clock
```

Figure 12. TxDATA Pin Output



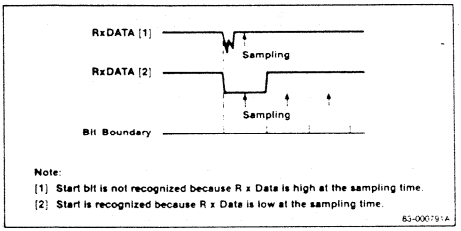
Receiving in Asynchronous Mode

The RxDATA pin is normally in the high state when data is not being received, as shown in figure 13. The μPD71051 detects the falling edge of a low level signal when a low level signal enters it.

The μPD71051 samples the level of the RxDATA input (only when x16 or x64 clock is selected) in a position 1/2 bit time after the falling edge of the RxDATA input to check whether this low level is a valid start bit. It is considered a valid start bit if a low level is detected at that time. If a low level is not detected, it is not regarded as a start bit and the μPD71051 continues testing for a valid start bit.

When a start bit is detected, the sampling points of the data bits, parity bit (when used), and stop bit are decided by a bit counter. The sampling is performed by the rising edge of the $\overline{\text{RxCLK}}$ when an X1 clock is used. When a x16 or x64 clock is used, it is sampled at the nominal middle of $\overline{\text{RxCLK}}$.

Figure 13. Start Bit Detection



Data for one character entering the receive buffer is transferred to the receive data buffer and causes RxRDY = 1, requesting that the CPU read the data. When the CPU reads the data, RxRDY becomes 0.

When a valid stop bit is detected, the μPD71051 waits for the start bit of the next data. If a low level is detected in the stop bit, a framing error flag is set; however, the receiving operation continues as if the correct high level had been detected. A parity error flag is set if a parity error is detected. An overrun error flag is set when the CPU does not read the data in time, and the next receiving data is transferred to the receive data buffer, overwriting the unread data. The μPD71051's sending and receiving operations are not affected by these errors.

If a low level is input to the RxDATA pin for more than two data blocks during a receive operation, the μPD71051 considers it a break state and the SYNC/BRK pin status becomes 1.

In async mode, the start bit is not detected until a high level of more than one bit is input to the RxDATA pin and the receiver is enabled. Figure 14 is a fragment of a typical program to receive the data sent in the previous async transmit example.

Figure 14. Asynchronous Receiver Example

```
ASYNRX :    CALL    ASYNMOD             ;Set ASYNC mode
            MOV     AL, 00010100B       ;Command: clear error flag, receive
                                        ;enable
            OUT     PCTRL,AL
            MOV     BW, OFFSET RXDADR   ;Data store area
RXSTART :   IN      AL, PCTRL
            AND     AL, 02H
            TEST    AL, 02H             ;Read status
            BNE     RXSTART             ;Wait until RxRDY = 1
            IN      AL, PDATA           ;Read and store the receive data
            MOV     [BW], AL
            INC     BW                  ;Set next store address
            CMP     AL, 00H             ;End if data = 0
            BNE     RXSTART
            RET
RXDADR      DB      256 DUP             ;Reserve receive data area
```

Sending in Synchronous Mode

Following the establishment of sync mode and the enabling of the transmitter, the TxDATA pin stays high until the CPU writes the first character (normally, SYNC characters). When data is written, the TxDATA pin sends one bit for each falling edge of $\overline{TxCLK}$ if the $\overline{CTS}$ pin is low. Unlike async mode, start and stop bits are not used. However, a parity bit may be set. Figure 15 shows these data formats.

Once sending begins, the CPU must write data to the μPD71051 at the same rate as that of $\overline{TxCLK}$. If TxEMP goes to 1 because of a delay in writing by the CPU, the μPD71051 sends SYNC characters until the CPU writes data. TxEMP goes to 0 when data is written, and the data is sent as soon as transmission of SYNC characters stops.

Figure 15. Synchronous Mode Data Format

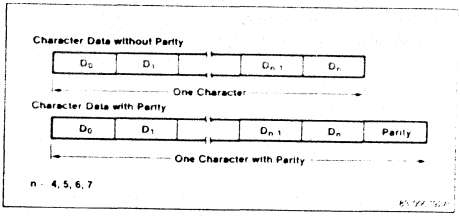


Figure 16. Synchronous Mode Transmit Timing

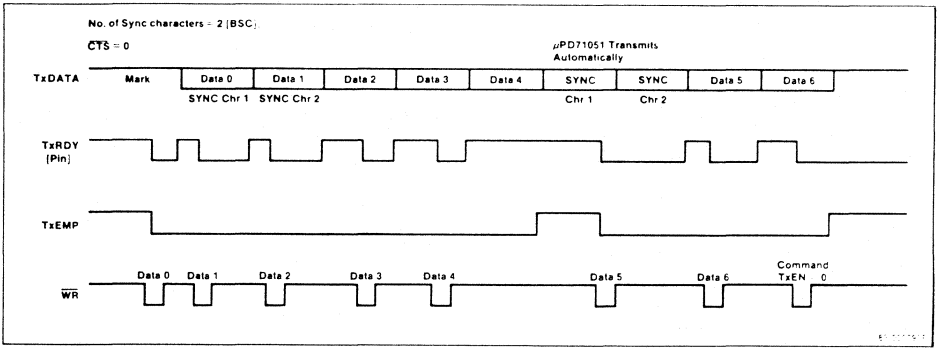
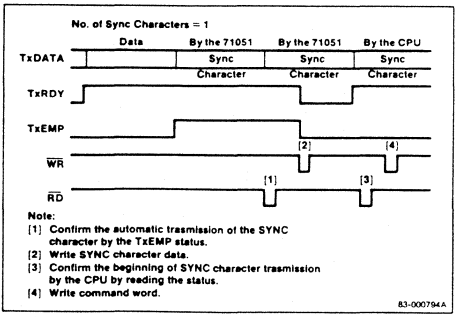


Figure 17. Issuing a Command During SYNC Character Transmission



Automatic transmission of SYNC characters begins after the CPU sends new data. SYNC characters are not automatically sent by enabling the transmitter. Figure 16 shows these timing sequences.

If a command is sent to the μPD71051 while SYNC characters are automatically being sent and TxEMP = 1, the μPD71051 may interpret the command as a data byte and transmit it as data. If a command must be sent under these conditions, the CPU should send a SYNC character to the μPD71051 and send the command while the SYNC character is being transmitted. This is shown in figure 17.

Figure 18 is a fragment of a typical program for sending in sync mode.

Figure 18. Synchronous Transmitter Example

```
SYNTX :   CALL   SYNMOD              ;Set sync mode
          MOV    AL, 00010001B       ;Command; clear error
          OUT    PCTRL, AL           ;flags, transmit enable
          MOV    BW, OFFSET TXDADR   ;Start location of data area TxDADR
          MOV    CL, LDLEN           ;Set number of bytes (LDLEN) to be transmitted
          MOV    CH, 00H
TXLEN :   IN     AL, PCTRL           ;Transmit the length byte
          AND    AL, 01H
          BNE    TXLEN
          MOV    AL, LDLEN
          OUT    PDATA, AL
TXDATA :  IN     AL, PCTRL
          AND    AL, 01H
          BNE    TXDATA              ;Transmit the number of
          MOV    AL, (BW)            ;bytes specified by LDLEN
          OUT    PDATA, AL
          INC    BW
          DBNZ   TXDATA
          MOV    AL, 00010000B       ;Command; clear error
          OUT    PCTRL, AL           ;flags, transmit disable
          RET
SYNC1     DB     ?                   ;SYNC character 1
SYNC2     DB     ?                   ;SYNC character 2
SYNMOD :  MOV    AL, 00H
          OUT    PCTRL, AL           ;Write control bytes
          OUT    PCTRL, AL           ;three times with 00H to
          OUT    PCTRL, AL           ;unconditionally accept the new
                                     ;command byte
          MOV    AL, 01000000B       ;Software reset
          OUT    PCTRL, AL
          MOV    AL, 00111100B       ;Write mode byte: 2 SYNC
          OUT    PCTRL, AL           ;characters, internal sync detect,
                                     ;even parity, 8 bits/character
          MOV    AL, SYNC1
          OUT    PCTRL, AL           ;Write SYNC characters
          MOV    AL, SYNC2
          OUT    PCTRL, AL
          RET
```

Receiving in Synchronous Mode

In order to receive in sync mode, synchronization must be established with the sending side. The first command after setting sync mode and writing the SYNC character must be EH = 1, ECL = 1, and RxEN = 1. When hunt phase is entered all the bits in the receive buffer are set to 1. In internal synchronization, data on the RxDATA pin is input to the receive buffer for each rising edge of $\overline{\text{RxCLK}}$ and is compared with the SYNC character at the same time. Figure 19 shows this internal sync detection.

When the receive buffer and the SYNC character coincide, and parity is not used, the μPD71051 ends hunt phase and SYNC is set to 1 in the center of the last SYNC bit. When parity is used, SYNC becomes 1 in the center of the parity bit. Receiving starts with the bit which follows the bit when SYNC is set to 1.

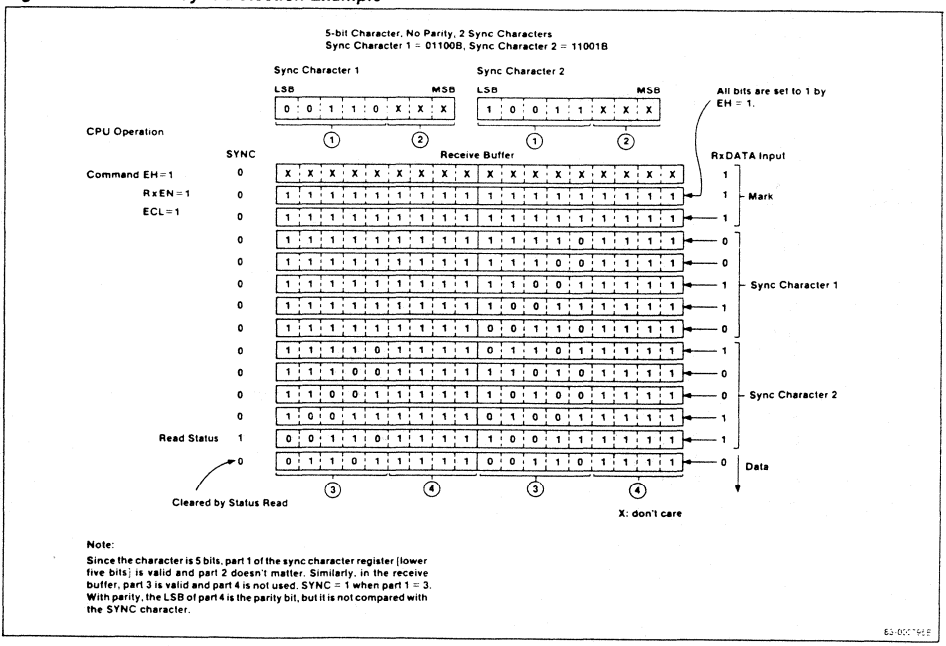
In external sync detection, synchronization is achieved by setting the SYNC pin high from an external circuit for at least one period of $\overline{\text{RxCLK}}$. Hunt phase ends, and data reception can start. At this time, the SYNC status bit becomes 1, and goes to 0 when the status is read. The SYNC status bit is set to 1 when the SYNC input has a rising edge followed by a high level of more than one period of $\overline{\text{RxCLK}}$, even after synchronization is achieved.

The μPD71051 can regain lost synchronization anytime by issuing an enter hunt phase command.

After synchronization, the SYNC character is compared with each character regardless of whether internal or external synchronization is used. When the characters coincide, SYNC becomes 1, indicating that a SYNC character has been received. SYNC (SYNC status bit only in external detection) becomes 0 when the status is read.

Overrun and parity errors are checked the same way as in async mode, affecting only the status flag. Parity checking is not performed in the hunt phase. Figure 20 is a fragment of a typical program that receives the data sent by the previous sync transmit program example. Note that the frequencies of $\overline{\text{TxCLK}}$ on the transmitter and $\overline{\text{RxCLK}}$ on the receiver must be the same.

Figure 19. Internal Sync Detection Example



Note:
Since the character is 5 bits, part 1 of the sync character register (lower five bits) is valid and part 2 doesn't matter. Similarly, in the receive buffer, part 3 is valid and part 4 is not used. SYNC = 1 when part 1 = 3. With parity, the LSB of part 4 is the parity bit, but it is not compared with the SYNC character.

Figure 20. Synchronous Receiver Example

```
SYNRX :   CALL   SYNMOD              ;Set sync mode
          MOV    AL, 10010100B       ;Command: enter hunt
          OUT    PCTRL, AL           ;phase, clear error flags, receive enable
          MOV    BW, OFFSET RXDADR   ;Set receive data store address
RXLEN :   IN     AL, PCTRL
          AND    AL, 02H
          TEST   AL, 02H
          BNE    RXLEN               ;Receive the number of
          IN     AL, DATA            ;receive data
          MOV    STLEN, AL           ;Set the number of
          MOV    CL, AL              ;receive data to both variable and
                                     ;counter
          MOV    CH, 00H
RXDATA :  IN     AL, PCTRL
          AND    AL, 02H
          TEST   AL, 02H
          BNE    RXDATA              ;Receive and store the
          IN     AL, PDATA           ;number of data bytes
          MOV    (BW),AL             ;stated by the counter
          INC    BW
          DBNZ   RXDATA
          MOV    AL, 00000000B       ;Command: receive disable
          OUT    PCTRL, AL
          RET
          STLEN  DB ?                ;Set number of receiver data
RXDADR    DB     256 DUP (0)         ;Reserve receive data area
```

Standby Mode

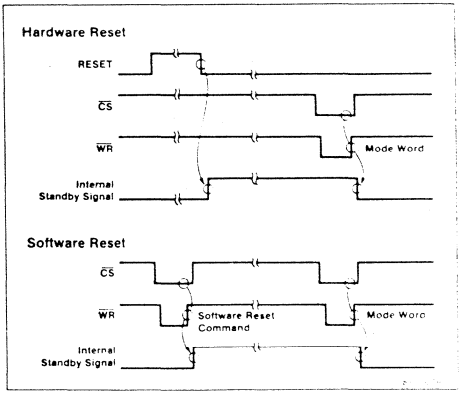
The μPD71051 is a low-power CMOS device. In standby mode, it disables the external input clocks to the inside circuitry (CLK, $\overline{TxCLK}$, and $\overline{RxCLK}$), thereby consuming less power.

A hardware reset is one way to enter standby mode. The input of a high level to the RESET pin causes the μPD71051 to enter standby mode at the falling edge of the high level. A software reset command is the other way to enter standby mode. The only way to take the μPD71051 out of standby mode is to write a mode byte.

In standby mode, the TxRDY, TxEMP, RxRDY, and SYNC/BRK pins are at low level and the TxDATA, $\overline{DTS}$, and $\overline{RTS}$ pins are at high level.

Figure 21 shows the timing for standby mode. While the internal standby signal is high, the external clocks to the μPD71051 are ignored. If data ($C/\overline{D} = 0$) is written to the μPD71051 in standby mode, the operations are undefined and unpredictable operation may result.

Figure 21. Standby Mode Timing



Description

The μPD71054 is a high-performance, programmable counter for microcomputer system timing control. Three 16-bit counters, each with its own clock input, gate input, and OUT pin, can be clocked from DC to 8 MHz. Under software control, the μPD71054 can generate accurate time delays. Initialize the counter, and the μPD71054 counts the delay, and interrupts the CPU when the task is complete. This eliminates the need for software timing loops.

The μPD71054 contains three counters capable of binary or BCD operation. There are six programmable count modes. The counters operate independently and each can be set to a different mode. Use address lines A_1, A_0 to select a counter and perform a read/write operation.

Features

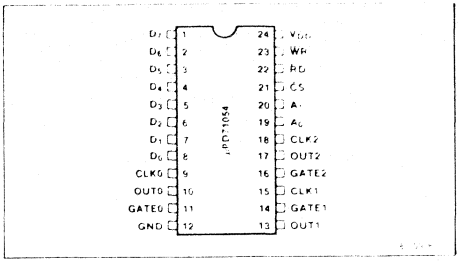
- ☐ Three independent 16-bit counters
- ☐ Six programmable counter modes
- ☐ Binary or BCD count
- ☐ Multiple latch command
- ☐ Clock rate DC (standby mode) to 8 MHz
- ☐ Low-power standby mode
- ☐ CMOS technology
- ☐ Single power supply, 5 V ±10%
- ☐ Industrial temperature range −40 to +85 °C

Ordering Information

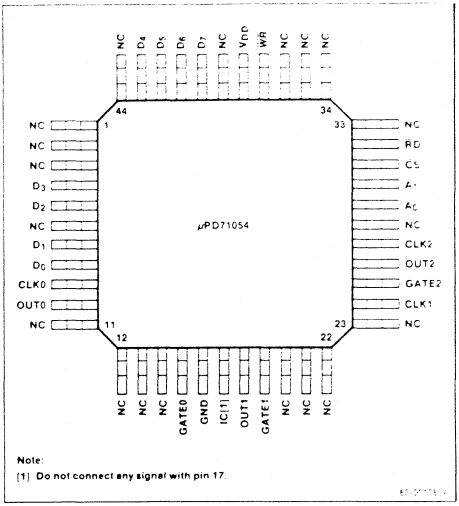
Part Number	Package Type	Max Frequency of Operation
μPD71054C	24-pin plastic DIP	8 MHz
μPD71054G	44-pin plastic miniflat	8 MHz
μPD71054L	28-pin PLCC (available 1Q87)	8 MHz

Pin Configurations

24-Pin Plastic DIP



44-Pin Plastic Miniflat



Note:
(1) Do not connect any signal with pin 17.

Pin Identification

Plastic DIP

No.	Symbol	Function
1-8	D_7-D_0	Three-state, bidirectional data bus
9, 15, 18	CLKn	Counter n clock input (n = 0-2)
10, 13, 17	OUTn	Counter n output (n = 0-2)
11, 14, 16	GATEn	Output to inhibit or trigger counter n (n = 0-2)
12	GND	Ground
19-20	A_0-A_1	Select counter input 0, 1, or 2
21	$\overline{CS}$	Chip select
22	$\overline{RD}$	Read strobe
23	$\overline{WR}$	Write strobe
24	V_{DD}	+5 V

Plastic Flatpack

No.	Symbol	Function
1-3, 6, 11-14, 20-23, 28, 33-36, 39, 44	NC	Not connected
40-43, 4, 5, 7, 8	D_7-D_0	Three-state, bidirectional data bus
9, 24, 27	CLKn	Counter n clock output (n = 0-2)
10, 19, 26	OUTn	Counter n output (n = 0-2)
15, 19, 25	GATEn	Output to inhibit or trigger counter n (n = 0-2)
16	GND	Ground
17	IC	Internally connected
29, 30	A_0-A_1	Select counter input 0, 1, or 2
31	$\overline{CS}$	Chip select
32	$\overline{RD}$	Read strobe
37	$\overline{WR}$	Write strobe
38	V_{DD}	+5 V

Pin Functions

D_7-D_0 [Data Bus]

These pins are an 8-bit three-state bidirectional data bus. This bus is used to program counter modes and to read status and count values. The data bus is active when $\overline{CS}$ = 0, and is high impedance when $\overline{CS}$ = 1.

CLKn [Counter Clock, n = 0-2]

These pins are the clock input that determine the count rate for counter n. The clock rate may be DC (standby mode) to 8 MHz.

OUTn [Counter Output, n = 0-2]

These are the output pins for counter n. A variety of outputs is available depending on the count mode. When the μPD71054 is used as an interrupt source, these pins can output an interrupt request signal.

GATEn [Counter Gate, n = 0-2]

These output pins inhibit or trigger counter n according to the mode selected.

A_1, A_0 [Address]

These input pins select the counter. A_1, A_0 equal to 00, 01, or 10 selects counter 0, 1, or 2, respectively. The control register is selected when A_1, A_0 equals 11. These pins are normally connected to the address bus.

$\overline{CS}$ [Chip Select]

When the $\overline{CS}$ input = 1, all the bits of the data bus become high impedance. $\overline{CS}$ must be low to access the μPD71054.

$\overline{RD}$ [Read Strobe]

The $\overline{RD}$ input must be low to read data from the μPD71054.

$\overline{WR}$ [Write Strobe]

The $\overline{WR}$ input must be low to write data to the μPD71054. The contents of the data bus are written to the μPD71054 at the rising edge of $\overline{WR}$.

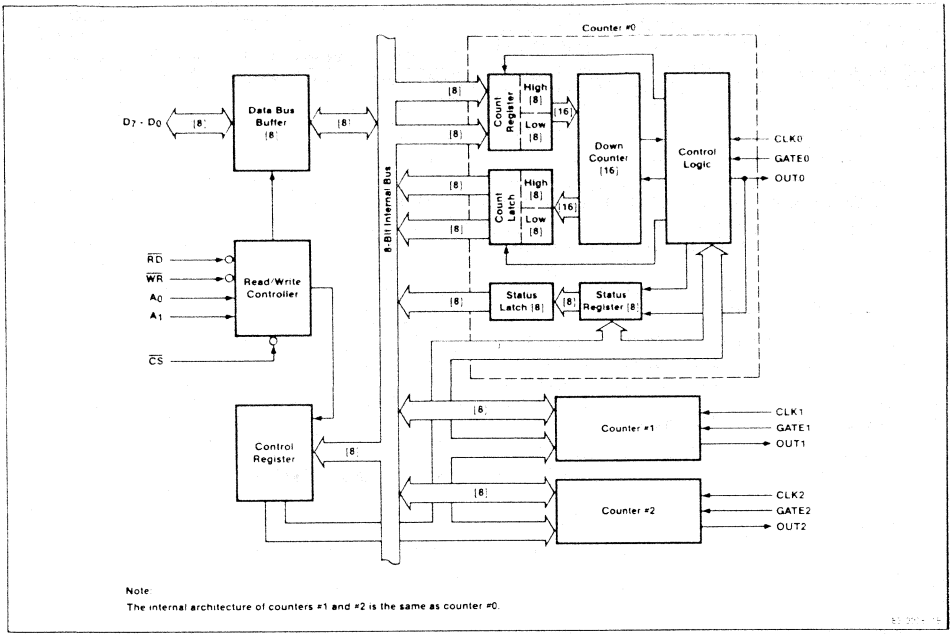
V_{DD} [Power]

+5 V.

GND [Ground]

Ground.

Block Diagram



Note
The internal architecture of counters #1 and #2 is the same as counter #0.

Block Functions

Data Bus Buffer

This is an 8-bit three-state bidirectional buffer that acts as an interface between the μPD71054 and the system data bus. The data bus buffer handles control commands, the count to be written to the count register, count data read from the count latch, and status data read from the status latch.

Read/Write Control

This circuit decodes signals from the system bus and sends control signals to other blocks of the μPD71054. A_1 and A_0 select one of the counters or the control register. A low signal on $\overline{RD}$ or $\overline{WR}$ selects a read or write operation. $\overline{CS}$ must be low to enable these operations.

Control Register

This is an 8-bit register into which is written the control command that determines the operating mode of the counter. Data is written to this register when the CPU executes an OUT command when A_1, A_0 = 11. The contents of this register cannot be read if the CPU executes an IN command when A_1, A_0 = 11. However, the multiple latch command allows you to read the mode and status of each counter.

Counter n [n = 0-2]

A 16-bit synchronous down counter performs the actual count operation within the counter. You can preset this counter and select binary or BCD operation.

The count register is a 16-bit register that stores the count when it is first written to the counter. The count is transferred to the down counter and a count operation for a specified number of counts begins.

The 8-bit width of the internal data bus permits the transfer of only eight bits at a time when the count is written to the count register. However, when data is written from the count register to the down counter, all 16 bits can be written at once. When the count is written to the count register while the counter is in read/write one byte mode, a 00H is written to the remaining byte of the register.

The count latch normally holds the current value of the down counter. If the contents of the down counter change, the contents of the count latch also change so that the two values are the same. When the μPD71054 receives a count latch command, the count latch latches the value of the down counter and holds it until the CPU can read it. When the data is read, the count latch returns to tracking the value of the down counter.

When the mode specified is written to the counter, the lower six bits of the control register are copied to the lower six bits of the 8-bit status register. The remaining two bits show the status of the OUT pin and the null count flag. When the multiple latch command is sent to the counter, the current value of the status register is latched into the status latch. This data is held in the latch until the CPU can read it.

The control logic controls each internal block according to the mode and the state of the CLK and GATE pins. The result is output to and sets the state of the OUT pin.

Absolute Maximum Ratings

T_A = +25°C

Power supply voltage, V_{DD}	−0.5 to +7.0 V
Input voltage, V_I	−0.5 to V_{DD} + 0.3 V
Output voltage, V_O	−0.5 to V_{DD} + 0.3 V
Operating temperature, T_{OPT}	−40°C to 85°C
Storage temperature, T_{STG}	−65°C to +150°C
Power dissipation, PD_{Max}	1.0 W

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

T_A = +25°C, V_{DD} = 0 V

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Input capacitance	C_{IN}		10	pF	fc = 1 MHz
I/O capacitance	$C_{I/O}$		20	pF	Unmeasured pins returned to 0 V

DC Characteristics

T_A = −40°C to +85°C, V_{DD} = +5 V ±10%

Parameter	Symbol	Limits Min	Limits Typ	Limits Max	Unit	Test Conditions
Input voltage high	V_{IH}	2.2		V_{DD} + 0.3	V	
Input voltage low	V_{IL}	−0.5		0.8	V	
Output voltage high	V_{OH}	0.7 x V_{DD}			V	I_{OH} = −400 μA
Output voltage low	V_{OL}			0.4	V	I_{OL} = 2.5 mA
Input leakage current high	I_{LIH}			10	μA	V_I = V_{DD}
Input leakage current low	I_{LIL}			−10	μA	V_I = 0 V
Output leakage current high	I_{LOH}			10	μA	V_O = V_{DD}
Output leakage current low	I_{LOL}			−10	μA	V_O = 0 V
Supply current	I_{DD1}			30	mA	8 MHz
	I_{DD2}		2	50	μA	Stand-by mode

AC Characteristics

T_A = −40°C to +85°C, V_{DD} = 5 V ±10%

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Read Cycle					
Address set-up to $\overline{RD}$ ↓	t_{SAR}	30		ns	
Address hold from $\overline{RD}$ ↑	t_{HRA}	10		ns	
$\overline{CS}$ set-up to $\overline{RD}$ ↓	t_{SCR}	0		ns	
$\overline{RD}$ low level width	t_{RRL}	150		ns	
Data delay from $\overline{RD}$ ↓	t_{DRD}		120	ns	C_L = 150 pF
Data float from $\overline{RD}$ ↑	t_{FRD}	10	85	ns	C_L = 20 pF R_L = 2 kΩ
Data delay from address	t_{DAD}		220	ns	C_L = 150 pF
Read recovery time	t_{RV}	200		ns	
Write Cycle					
Address set-up to $\overline{WR}$ ↓	t_{SAW}	0		ns	
Address hold from $\overline{WR}$ ↑	t_{HWA}	0		ns	
$\overline{CS}$ set-up to $\overline{WR}$ ↓	t_{SCW}	0		ns	
$\overline{WR}$ low level width	t_{WW}	160		ns	

AC Characteristics (cont)

T_A = 40°C to +85°C, V_{DD} = 5 V ± 10%

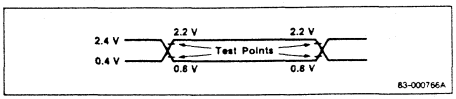
Parameter	Symbol	Limits Min	Max	Unit	Test Conditions
Write Cycle (cont)					
Data hold to $\overline{WR}$ ↑	t_{SDW}	120		ns	
Data hold from $\overline{WR}$ ↑	t_{HWD}	0		ns	
Write recovery time	t_{RV}	200		ns	
CLK and Gate Timing					
CLK cycle time	t_{CYK}	125	DC	ns	
CLK high level width	t_{KKH}	60		ns	
CLK low level width	t_{KKL}	60		ns	
CLK rise time	t_{KR}		25	ns	
CLK fall time	t_{KF}		25	ns	
GATE high level width	t_{GGH}	50		ns	
GATE low level width	t_{GGL}	50		ns	
GATE set-up to CLK ↑	t_{SGK}	50		ns	
GATE hold from CLK ↑	t_{HKG}	50		ns	
Clock delay from WR ↑ (count transfer)	t_{DWK}	100		ns	$t_{KKH} \geq 125$ ns
		225 − t_{KKH}		ns	$t_{KKH} \leq 125$ ns
Clock set-up to WR ↑ (latch)	t_{SKW}	85		ns	
GATE delay from WR ↑	t_{DWG}	0		ns	
OUT delay from GATE ↓	t_{DGO}		120	ns	C_L = 150 pF
OUT delay from CLK ↓	t_{DKO}		150	ns	C_L = 150 pF
OUT delay from WR ↑ (initial out)	t_{DWO}	295		ns	C_L = 150 pF

Note:

AC timing test points for output V_{OH} = 2.2 V, V_{OL} = 0.8 V

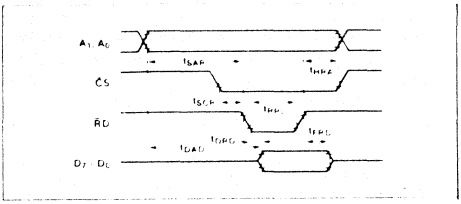
Timing Waveforms

AC Test Input

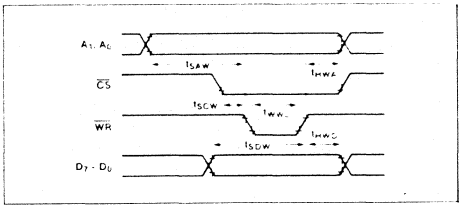


Timing Waveforms (cont)

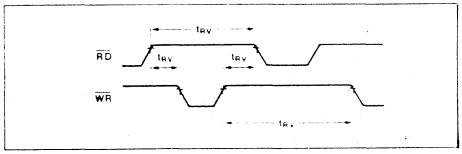
Read Cycle



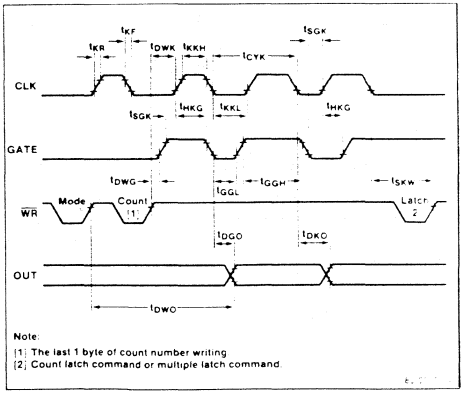
Write Cycle



Read/Write Recovery



CLK and GATE Timing



Functional Description

μPD71054 System Configuration Example

The CPU views the three counters and the control register as four I/O ports. A_1 and A_0 are connected to the A_1 and A_0 pins of the system address bus. $\overline{CS}$ is generated by decoding the address and $\overline{IO}$/MEM signals so that $\overline{CS}$ goes low when the address bus is set to the target I/O address and I/O is selected. These connections are shown in figure 1.

You can use the μPD71054 in memory-mapped I/O configurations. However, the decoding should be such that $\overline{CS}$ goes low when memory is selected.

Programming and Reading the Counter

The counter must be programmed and the operating mode specified before you can use the μPD71054. Once a mode has been selected for a counter, it operates in that mode until another mode is set. The count is written to the count register and when that data is transferred to the down counter, a new count operation begins. The current count and status can be read while the counter is in operation. Figure 2 outlines the steps of operation.

Programming the Counter

The μPD71054 is controlled by a microcomputer program. The program must write a control command to set the counter mode and write the count data that determines the length of the count operation. Table 1 shows the values for A_1 and A_0 that determine the target counter for write operations.

Table 1. Write Operations ($\overline{CS}$ = 0, $\overline{RD}$ = 1, $\overline{WR}$ = 0)

A_1	A_0	Write Target
0	0	Counter 0
0	1	Counter 1
1	0	Counter 2
1	1	Control word register

Control and Mode Setting

The control command must be written to set the counter mode before operating the counter. If a write operation is performed when A_1, A_0 = 11, a control command is written to the control register. Figure 3 shows the format of the 8-bit control command.

Bits SC1 and SC0 specify a counter or the multiple latch command. When a counter is chosen, the specifications described below apply to the counter.

Bits RMW1 and RMW2 specify the read/write operation to the counter or select the count latch command.

Bits CM2, CM1, and CM0 set the counter mode (0 to 5).

Bit BCD selects binary or BCD operation. The count may be 0 to FFFFH in binary mode or 0 to 9999 in BCD.

If a control command written to the counter specifies a mode, the lower six bits of the control command are copied to the lower six bits of the status register of the counter selected by SC1 and SC0. The mode selected remains in effect until a new mode is set. This is not true if the control command specifies the count latch or multiple latch command.

Writing the Count

The count is written to the counter after the mode is set. Set A_1, A_0 to specify the target counter as shown in table 1. A new count can be written to a counter at any time, but the read/write mode selected (when the mode was written) must be used when writing the count.

In high 1-byte and low 1-byte modes only, the higher or lower byte of the count register is written by the first write. The write operation ends and 00H is automatically written to the remaining byte by the μPD71054. In the 2-byte modes, the lower byte is written by the first write and the higher byte by the second.

For example, if the 2-byte count 8801H is written to a counter set in lower 1-byte mode, the lower byte (01H) is written first, followed by the higher byte (88H). Therefore, the data written to the count register is 0001H for the first write and 0088H for the second. This is shown in Table 2.

Table 2. Read/Write Mode and Count Write

Read/Write Mode	No. of Writes	Count Register	
		Higher Byte	Lower Byte
Low 1-byte	1	00H	nnH
High 1-byte	1	nnH	00H
Low/High 2-byte	2	nnH (2nd write)	nnH (1st write)

nnH = Two-digit hexadecimal value

Reading the Counter

The following three methods allow you to read the contents of the down counter during operation. In particular, the multiple latch command reads the current count data and the counter mode or the state of the OUT pin. Table 3 shows the values of A_1, A_0 used to select the counter to be read.

Figure 1. Typical System Configuration

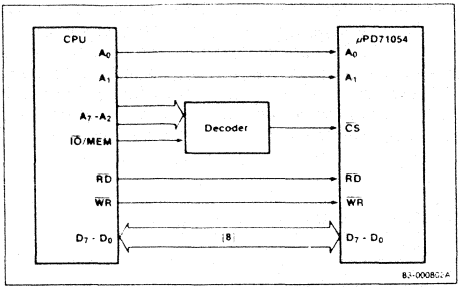


Figure 2. Basic Operating Procedure

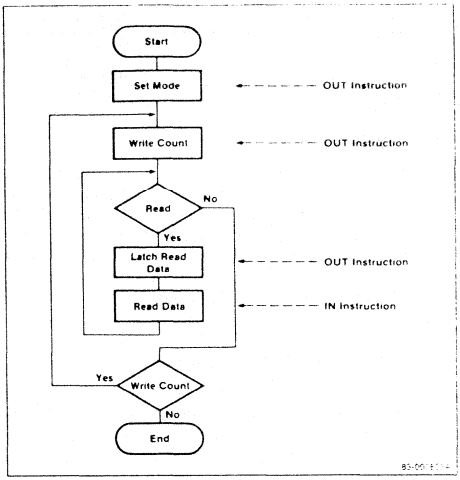


Figure 3. Control Register Format

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
SC1	SC0	RWM1	RWM0	CM2	CM1	CM0	BCD

BCD	Binary or BCD
0	Binary Count (16 Bits)
1	BCD Count (4 Digits)

CM2	CM1	CM0	Count Mode (1)
0	0	0	Mode 0
0	0	1	Mode 1
X	1	0	Mode 2
X	1	1	Mode 3
1	0	0	Mode 4
1	0	1	Mode 5

RWM1	RWM0	Read/Write Mode
0	0	Count Latch Command (2)
0	1	Lower Byte Only
1	0	Higher Byte Only
1	1	Lower Byte then Higher

SC1	SC0	Select Counter or Multiple Latch Command
0	0	Counter # 0
0	1	Counter # 1
1	0	Counter # 2
1	1	Multiple Latch Command (2)

X: Don't Care

Note:
(1) $\overline{CS}$ = 0, $\overline{RD}$ = 0, $\overline{WR}$ = 1
(2) See: Reading the Counter

Table 3. Read Operations ($\overline{CS}$ = 0, $\overline{RD}$ = 0, $\overline{WR}$ = 1)

A_1	A_0	Read Target
0	0	Counter 0
0	1	Counter 1
1	0	Counter 2

Directly Reading the Counter

You can read the current value of the counter by reading the counter selected by A_1, A_0 as shown in table 3. This involves reading the count latch; since the value of the down counter may change while the the count latch is read, this method may not provide an accurate reading. You must control the CLK or GATE input to stop the counter and read it for a correct reading.

Using the Count Latch Command

When the count latch command is executed, the current counter value is latched into the counter latch. This value is held by the latch until it is read or until a new mode is set. This provides an accurate reading of the counter value when the command is executed without affecting counter operation. Figure 4 shows the format for the count latch command.

If the counter value that was latched into the count latch is not read before a second count latch command is executed, the second command is ignored. This is because the counter value latched by the first command is held until it is read or until a new mode is set. When the data in the count latch is read, the latch is released and continues tracking the value of the down counter.

Using the Multiple Latch Command

When the multiple latch command is received, the counter value and status register for any counter may be selectively latched into the count latch and status latch. Bits D_1-D_5 of the multiple latch command specify the counter latching. The CPU can then read the status and counter value for the selected counter. Figure 5 shows the format for this command.

Bits CNT2, CNT1, and CNT0 correspond to counters 2, 1, and 0. The command is executed for all counters whose corresponding bit is 1. This allows the data for more than one counter to be latched by a single count latch command.

When the count bit is 0, the counter value of the selected counters is latched into the count latches.

When the status bit is 0, the status of the selected counters is latched into the status latches. Bits D_5-D_0 of the status register show the mode status of the counter. The output bit (D_7) shows the state of the OUT pin of that counter. These bits are shown in figure 6. The null count bit (D_6) indicates whether the count data is valid. When the count is transferred from the count register to the down counter, this bit changes to 0 to show that the data is valid. Table 4 shows how the null count flag operates.

Table 4. Null Count Flag Operation

Operation	Null Count Flag
Write control word for mode set	1
Write count to count register(1)	1
Transfer count from count register to down counter	0

Note:

(1) When 2-byte mode is selected, the flag becomes 1 when the second byte is written.

Figure 4. Control Register Format for Count Latch Command

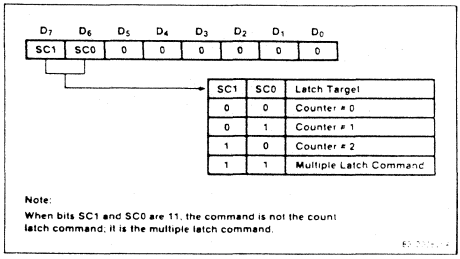
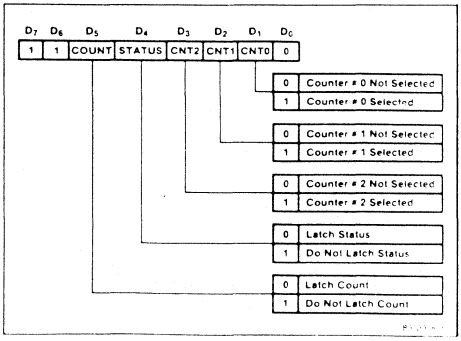


Figure 5. Control Register Format for Multiple Latch Command



If the data that was latched is not read before a second multiple latch command is executed, the second command is ignored for those latches whose contents have not been read. This is because the data latched by the first command is held until it is read or until a new mode is set. When the data in the latch is read, the latch is released. See figure 7.

It is possible to latch both the count and status using two multiple latch commands. However, regardless of which data is latched first, the status is always read first. The count data is read by the next read operation (1- or 2-step read as determined by read/write mode). If additional read commands are received, the count data that has not been latched (the contents of the down counter as reflected by the current counter value) is read.

Read operations must be performed in accordance with read/write mode. In 2-byte mode, two bytes of data must always be read. This does not imply that the second byte must be read immediately after the first; other counter operations may be performed between the two reads. For example, you could read the lower byte, write a new lower byte, read the higher byte, and write a new higher byte.

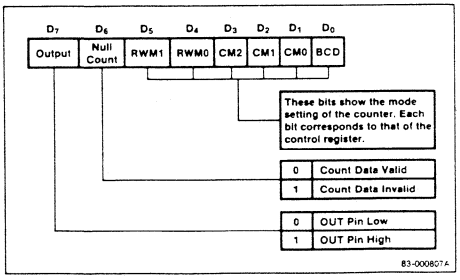
Definitions

CLK pulse refers to the time from the rising to the falling edge of the CLKn input.

Trigger refers to the rising edge of the GATEn input.

The GATEn input is sampled at each rising edge of the CLKn input. The GATE input can be level or rising edge sensitive. In the latter case, counter n's internal flip-flop is set at the rising edge of the GATE signal, sensed at the rising edge of the next CLK pulse, and reset immediately. This allows edge-triggering to be sensed whenever it occurs.

Figure 6. Status Data



Initial OUT refers to the state of the OUT pin immediately after the mode is set.

Count transfer refers to the transfer from the count register to the down counter. The down counter is decremented at the falling edge of the CLK pulse.

Count zero is the state of the down counter when the counter is decremented to zero.

PCNT0, PCNT1, and PCNT2 are the I/O ports for counters 0, 1, and 2, respectively. PCTRL is the I/O port for the control command.

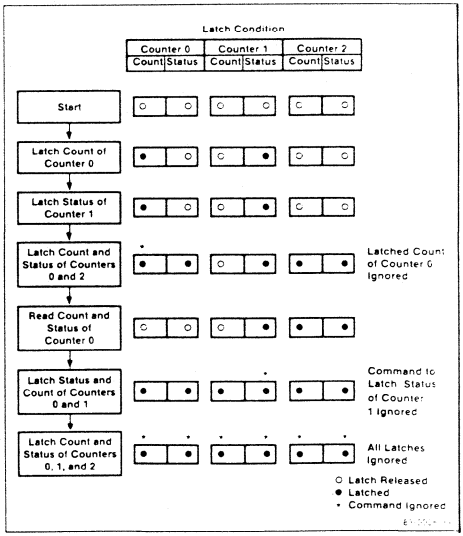
CW is the control command.

HB is the higher byte of the count.

LB is the lower byte of the count.

In the timing charts for each counter mode, counter 0 is in the read/write 1-byte and binary count mode. When no GATE signal appears in the charts, assume a high level signal. The value shown below the OUT signal is the counter value. The maximum value that can be set for the count in each mode is 0. When this value is set, a maximum value of 10000H (hexadecimal count) or 10000 (BCD count) is obtained.

Figure 7. Multiple Latch Command Execution Example



Counter Modes

Mode 0: Interrupt on End of Count. In this mode, the OUT output changes from low to high level when the end of the specified count is reached. See table 5 and figure 8.

Table 5. Mode 0 Operation

Function	Result
Initial OUT	Low level
GATE High	Count enable
GATE Low	Count disable
Count Write	The OUT pin goes low independent of the CLK pulse. In 2-byte mode, the count is disabled when the first byte is written. The OUT pin goes low. OUT goes low when a new mode or new count is written.
Count Transfer and Operation	When the count is written with GATE high: Transfer is performed at the first CLK pulse after the count value is written. The down counter is decremented beginning at the first CLK pulse after data transfer. If a count of n is set, the OUT pin goes high after n + 1 CLK pulses. When the count is written with GATE low: Transfer is performed at the first CLK pulse after the count is written. The down counter is decremented beginning at the first CLK pulse after the GATE signal goes high. If a count of n is set, OUT is low for a period of n CLK pulses after GATE goes high.
Count Zero	The signal at the OUT pin goes high. The count operation does not stop and counts down to FFFFH (hexadecimal) or 9999 (BCD) and continues to count down.
Minimum Count	1

Mode 0 Program Example. This subroutine causes a delay of 10004 (decimal, or 2710H) CLK pulses. In this program, counter 2 is set to 2-byte mode and binary count. See figure 9.

```
SUBR0:  MOV   AL,10110000B   ;set mode: counter 2,
                             ;2-byte mode,
        OUT   PCTRL,AL       ;count mode 0, binary
        MOV   AL,10H
        OUT   PCNT2,AL
        MOV   AL,27H         ;write count 10000 (decimal)
        OUT   PCNT2,AL
        RET
```

Mode 1: GATE Retriggerable One-Shot. In mode 1, the μPD71054 functions as a retriggerable one-shot. A low-level pulse triggered by the GATE input is output from the OUT pin. See table 6 and figure 10.

Table 6. Mode 1 Operation

Function	Result
Initial OUT	High level
GATE Trigger(1)	Count data is transferred at the CLK pulse after the trigger.
Count Write	The count is written without affecting the current operation.
Count Transfer and Operation	Transfer is performed at the first CLK pulse after the trigger. At the same time, the signal at the OUT pin goes low to start the one-shot pulse operation. The count is decremented beginning at the next CLK pulse. If a count of n is set, the one-shot output from the OUT pin continues for n CLK pulses.
Count Zero	The signal at the OUT pin becomes high. Count operation does not stop and wraps to FFFFH (hexadecimal) or 9999 (BCD) and continues to count.
Minimum Count	1

Note:

(1) The trigger is ignored when the count has not been written after the mode is set, or when only one byte of the count has been written in 2-byte count mode.

Figure 8. Mode 0 Timing Chart

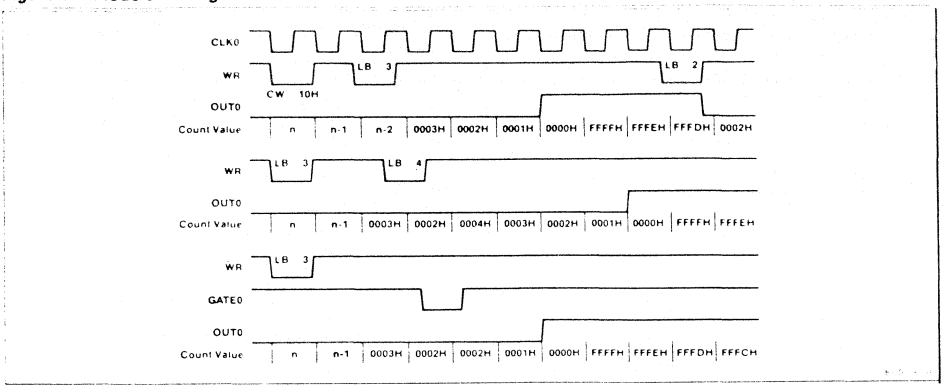


Figure 9. Mode 0 Program Example Timing Chart

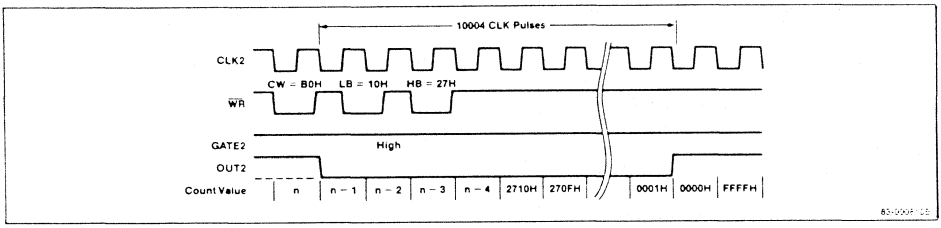
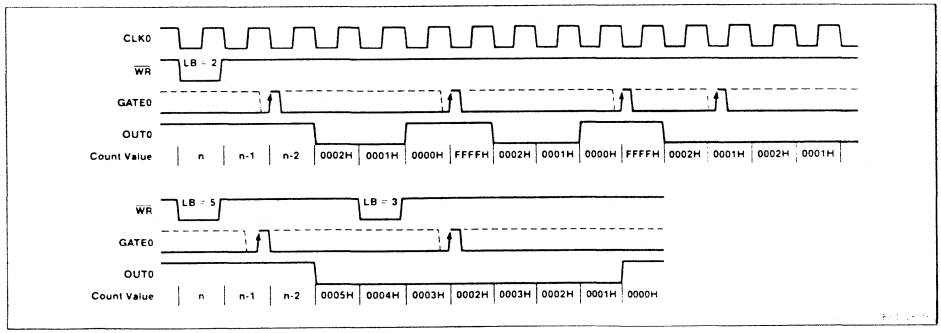


Figure 10. Mode 1 Timing Chart



Mode 1 Program Example. This subroutine waits until no trigger is generated for an interval of 200 or more CLK pulses after the first gate trigger and returns to the main program. Counter 1 is set to low-byte read/write mode and binary count. See figure 11.

```
SUBR1:  MOV   AL,01010010B  ;set mode: counter 1, low-byte
        OUT   PCTRL,AL      ;read/write mode, count mode 1,
        MOV   AL,200        ;binary
        OUT   PCNT1,AL      ;write low byte of count
        ;
FSTTRG: MOV   AL,11100100B  ;multiple latch command:
                            ;counter 1,
        OUT   PCNT1,AL      ;status
        IN    AL,PCNT1
        AND   AL,40H        ;zero all bits except null count (D6)
        TEST  AL,40H        ;wait for first trigger
        BNZ   FSTTRG
        ;
WAIT:   MOV   AL,11100100B  ;multiple latch command:
                            ;counter 1,
        OUT   PCTRL,AL      ;status
        IN    AL,PCNT1
        AND   AL,80H        ;zero all bits except output (D7)
        TEST  AL,80H        ;wait until output goes high
        BZ    WAIT
        RET
```

Mode 2: Rate Generator. In mode 2, the signal from the OUT pin cyclically goes low for one clock period when the counter reaches 0001H. The counter operates as a frequency divider. See table 7 and figure 12.

Table 7. Mode 2 Operation

Function	Result
Initial OUT	High level
GATE High	Count enable
GATE Low	Count disabled. If GATE goes low when OUT is low, OUT will go high (independent of the CLK pulse)
GATE Trigger(1)	Transfer is performed at the first CLK pulse after the trigger.
Count Write	Count is written without affecting the current operation.
Count Transfer and Operation	Transfer is performed at the CLK pulse after the count is written following the mode setting. The counter is then decremented. Transfer is again performed at the first CLK pulse after the count becomes 1. When the trigger is used, transfer is performed at the next CLK pulse. When the contents of the down counter becomes 1, OUT goes low for one CLK pulse and returns to high. If a count of n is set, OUT repeats this sequence every n CLK pulses.
Count Zero	Never occurs in this mode
Minimum Count	2

Note:

(1) The trigger is ignored when the count has not been written or when only one byte of the count has been written in 2-byte mode.

Figure 11. Mode 1 Program Example Timing Chart

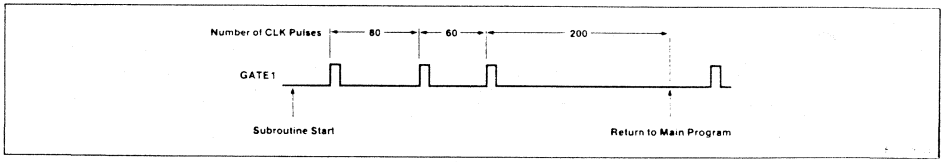
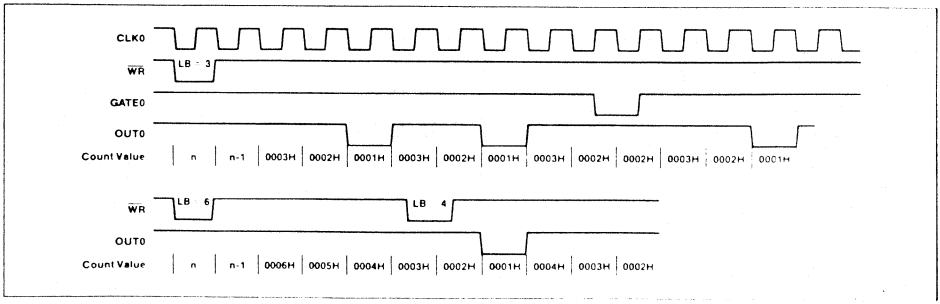


Figure 12. Mode 2 Operation Timing Chart



Mode 2 Program Example. This subroutine generates an interrupt to the CPU each time 10000 (decimal) clock pulses elapse. Counter 0 is in 2-byte mode and binary counting. See figure 13.

```
SUBR3:  MOV   AL,00110100B      ;mode setting: counter 0, 2-byte
        OUT   PCTRL,AL          ;mode, count mode 2, binary
        MOV   AL,10H
        OUT   PCNT0,AL
        MOV   AL,27H            ;write count 10000 (decimal)
        OUT   PCNT0,AL
        RET
```

Mode 3: Square Wave Generator. Mode 3 is a frequency divider similar to mode 2, but with a different duty cycle. See table 8 and figure 14.

Figure 13. Mode 2 Configuration

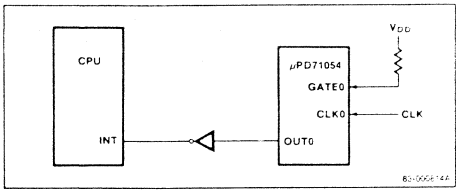


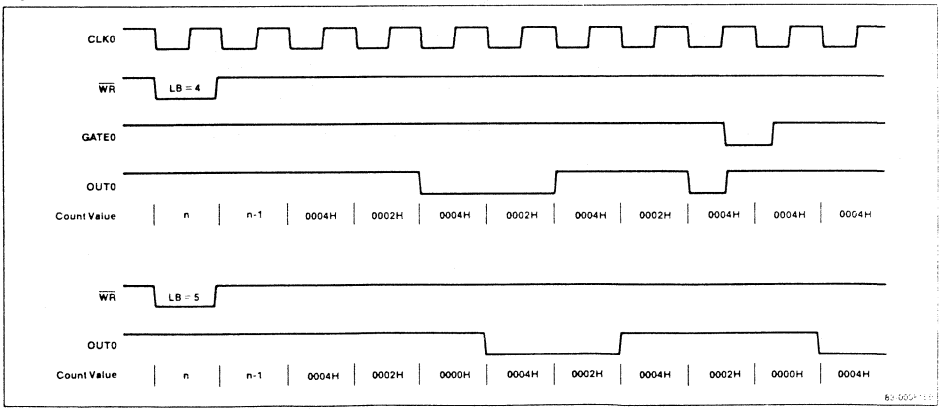
Table 8. Mode 3 Operation

Function	Result
Initial OUT	High level
GATE High	Count enable
GATE Low	Count disable. If GATE goes low when OUT is low, OUT will go high (independent of the CLK pulse)
GATE Trigger(1)	Transfer is performed at the first CLK pulse after the trigger
Count Write	Current operation is not affected. The count is transferred at the end of the half-period of the current square wave and the OUT pin goes high
Count Transfer and Operation	Count data is transferred at the first CLK pulse after the count write following the mode setting. Transfer is performed at the end of the current half-cycle and the OUT pin is inverted. Transfer is also performed at the CLK pulse after the trigger. The operation performed depends on whether count n is even or odd. When n is even, the count is decremented by two on each following clock pulse. At the end of the count of two, the count is again transferred and the OUT pin is inverted. This is taken as a half-cycle and repeated. When n is odd, n − 1 is transferred and the count is decremented by two on each following clock pulse. The half-cycle when the OUT pin is high continues until the end of count 0, and n − 1 is transferred again at the next CLK pulse. The half-cycle while OUT is low continues until the end of count 2. Thus, the half-cycle while OUT is high is one CLK longer than the half-cycle while OUT is low.
Count Zero	Occurs only when the count is odd
Minimum Count	2

Note:

(1) The trigger is ignored when the count has not been written after the mode is set or when only one byte of count has been written in 2-byte mode.

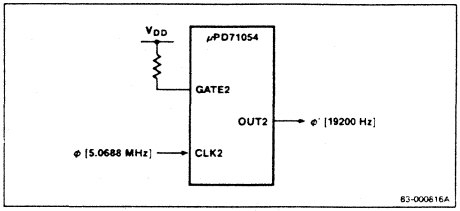
Figure 14. Mode 3 Timing Chart



Mode 3 Program Example. This subroutine divides the input CLK frequency (5.0688 MHz) by 264 to get a 19,200 Hz clock. Counter 2 is in 2-byte binary mode. See figure 15.

```
SUBR4:  MOV   AL,10110110B   ;mode setting: counter 2, 2-byte
        OUT   PCTRL,AL       ;mode, count mode 3, binary
        MOV   AL,08H
        OUT   PCNT2,AL
        MOV   A,01H          ;264 frequency division
        OUT   PCNT2,AL
        RET
```

Figure 15. Frequency Division



Mode 4: Software-Triggered Strobe. In mode 4, when the specified count is reached, OUT goes low for one CLK pulse. See table 9 and figure 16.

Table 9. Mode 4 Operation

Function	Result
Initial OUT	High level
GATE High	Count enable
GATE Low	Count disable
Count Write	Count is transferred at the next CLK pulse when the count is written. In 2-byte mode, data is transferred after the second byte is written.
Count Transfer and Operation	Count is transferred at the first CLK following the count write. If GATE is high, the down counter begins to decrement from the next CLK. If GATE is low, decrement begins at the first CLK after GATE goes high.
Count Zero	OUT is low for one CLK pulse and returns to high. The down counter wraps to FFFFH (hexadecimal) or 9999 (BCD) without stopping counter operation.
Minimum Count	1

Figure 16. Mode 4 Timing Chart

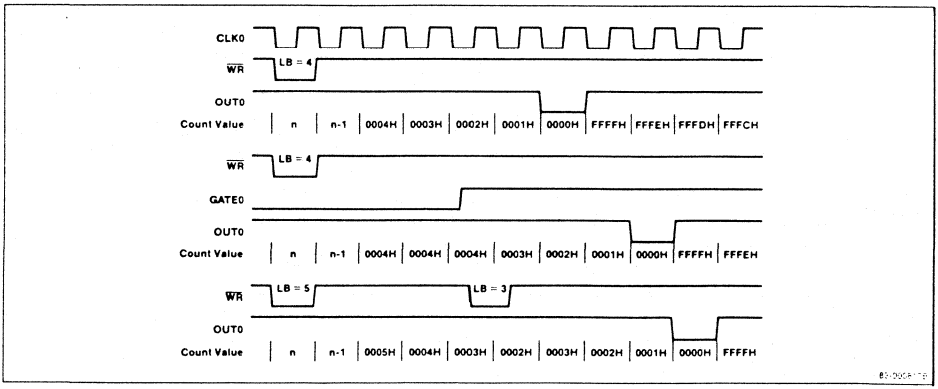
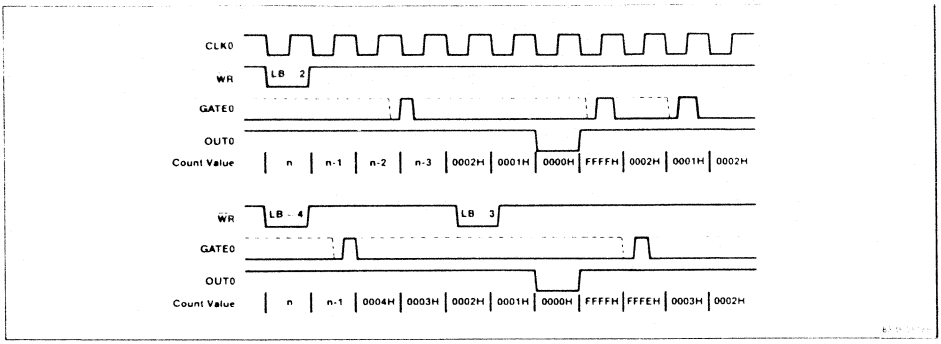


Figure 17. Mode 5 Timing Chart



Mode 5: Hardware-Triggered Strobe (Retriggerable). Mode 5 is similar to mode 4 except that operation is triggered by the GATE input and can be retriggered. See table 10 and figure 17.

Table 10. Mode 5 Operation

Function	Result
Initial OUT	High level
GATE Trigger(1)	The count is transferred at the CLK pulse after the trigger. The GATE has no effect on the OUT signal.
Count Write	The count is written without affecting the current operation.
Count Transfer and Operation	Count is transferred at the first CLK pulse after a trigger, providing that the mode and count have been written. Decrement begins from the first CLK pulse after a data transfer. If a count of n is set, OUT goes low for n + 1 CLK pulses after the trigger.
Count Zero	OUT is low for one CLK and goes high again. The down counter counts to FFFFH (hexadecimal) or 9999 (BCD) without stopping the counter operation.
Minimum Count	1

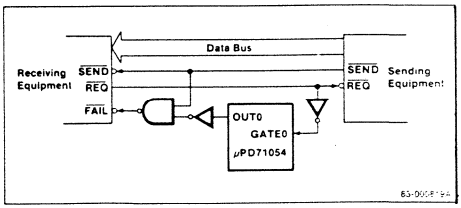
Note:

(1) The trigger is ignored when the count has not been written after the mode is set or when only one byte has been written in 2-byte mode.

Mode 5 Program Example. Use mode 5 to add a fail-safe function to an interface. For example, the receiving equipment requests data by issuing a $\overline{REQ}$ signal to the sending equipment. The sending equipment responds by outputting data to the data bus and returning a $\overline{SEND}$ signal to the receiving equipment. In this type of system, if a malfunction exists in the sending equipment and no $\overline{SEND}$ signal is sent, the receiving equipment waits indefinitely for the $\overline{SEND}$ signal and system operation stops. The following subroutine remedies this situation. If no $\overline{SEND}$ signal is output within a given period (50 CLK cycles in this example) after the $\overline{REQ}$ signal is output, the system assumes the sending equipment is malfunctioning and a $\overline{FAIL}$ signal is sent to the receiving equipment.

```
SUBR5:  MOV  AL,00011010B  ;mode setting: counter 0, low
                           ;1-byte
        OUT  PCTRL,AL      ;mode, count mode 5, binary
        MOV  AL,50         ;set interval: 50 CLK pulses
        OUT  PCNT0,AL
        RET
```

Figure 18. Interface Fail-safe Example



Description

The μPD71055 is a low-power CMOS programmable parallel interface unit for use in microcomputer systems. The μPD71055 has three I/O ports and is typically used to interface peripheral devices to a microcomputer system bus.

Features

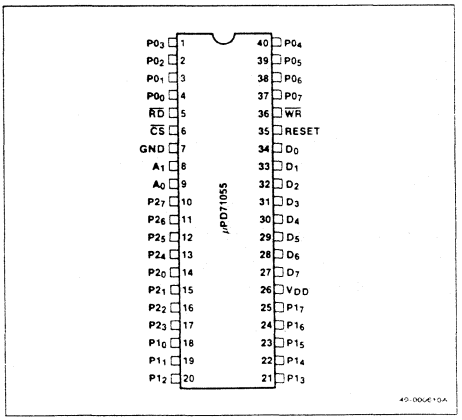
- Three 8-bit I/O ports
- Three programmable operation modes
- Bit manipulation command
- Microcomputer compatible
- 8 MHz operation
- CMOS technology
- Single +5 V ±10% power supply
- Industrial temperature range: −40 to +85 °C

Ordering Information

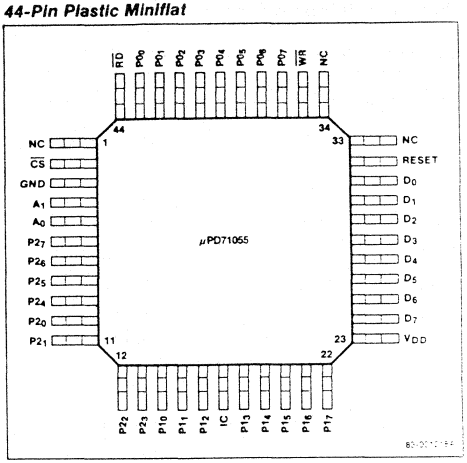
Part Number	Package Type
μPD71055C	40-pin plastic DIP
μPD71055G	44-pin plastic miniflat
μPD71055L	44-pin PLCC (available 1Q87)

Pin Configurations

40-Pin Plastic DIP



44-Pin Plastic Miniflat



Pin Identification

Plastic DIP

No.	Symbol	Function
1-4	PO_3-PO_0	I/O port 0, bits 3-0
5	$\overline{RD}$	Read strobe input
6	$\overline{CS}$	Chip select input
7	GND	Ground
8, 9	A_1, A_0	Address inputs 1 and 0
10-13	$P2_7$-$P2_4$	I/O port 2, bits 7-4
14-17	$P2_0$-$P2_3$	I/O port 2, bits 0-3
18-25	$P1_0$-$P1_7$	I/O port 1, bits 0-7
26	V_{DD}	+5 V
27-34	D_7-D_0	I/O data bus
35	RESET	Reset input
36	$\overline{WR}$	Write strobe input
37-40	PO_7-PO_4	I/O port 0, bits 7-4

Pin Identification (cont)

Plastic Flatpack

No.	Symbol	Function
1	NC	No connection
2	$\overline{CS}$	Chip select input
3	GND	Ground
4,5	A_1, A_0	Address inputs 1 and 0
6-9	$P2_7$-$P2_4$	I/O port 2, bits 7-4
10-13	$P2_0$-$P2_3$	I/O port 2, bits 0-3
14-16	$P1_0$-$P1_2$	I/O port 1, bits 0-2
17	IC	Internally connected
18-22	$P1_3$-$P1_7$	I/O port 1, bits 3-7
23	V_{DD}	+5 V
24-31	D_7-D_0	I/O data bus
32	RESET	Reset input
33, 34	NC	No connection
35	$\overline{WR}$	Write strobe input
36-43	$P0_7$-$P0_0$	I/O port 0, bits 7-0
44	$\overline{RD}$	Read strobe input

Pin Functions

D_7-D_0 [Data Bus]

D_7-D_0 make up an 8-bit, three-state, bidirectional data bus. The bus is connected to the system data bus. It is used to send commands to the μPD71055 and to send data to and from the μPD71055.

$\overline{CS}$ [Chip Select]

The $\overline{CS}$ input is used to select the μPD71055. When $\overline{CS}$ = 0, the μPD71055 is selected. When $\overline{CS}$ = 1, the μPD71055 is not selected and its data bus is high-impedance.

$\overline{RD}$ [Read Strobe]

The $\overline{RD}$ input is set low when data is being read from the μPD71055 data bus.

$\overline{WR}$ [Write Strobe]

The $\overline{WR}$ input should be set low when data is to be written to the μPD71055 data bus. The contents of the data bus are written to the μPD71055 at the rising edge (low to high) of the $\overline{WR}$ signal.

A_1, A_0 [Address]

The A_1 and A_0 inputs are used in combination with the $\overline{RD}$ and $\overline{WR}$ signals to select one of the three ports or the command register. A_1 and A_0 are usually connected to the lower two bits of the system address bus (table 1).

Table 1. Control Signals and Operation

$\overline{CS}$	$\overline{RD}$	$\overline{WR}$	A_1	A_0	Operation	μPD71055 Operation
0	0	1	0	0	Port 0 to data bus	Input
0	0	1	0	1	Port 1 to data bus	Input
0	0	1	1	0	Port 2 to data bus	Input
0	0	1	1	1	Use prohibited	
0	0	0	x	x		
0	1	0	0	0	Data bus to port 0	Output
0	1	0	0	1	Data bus to port 1	Output
0	1	0	1	0	Data bus to port 2	Output
0	1	0	1	1	Data bus to command register	Output
0	1	1	x	x	Data bus high impedance	
1	x	x	x	x		

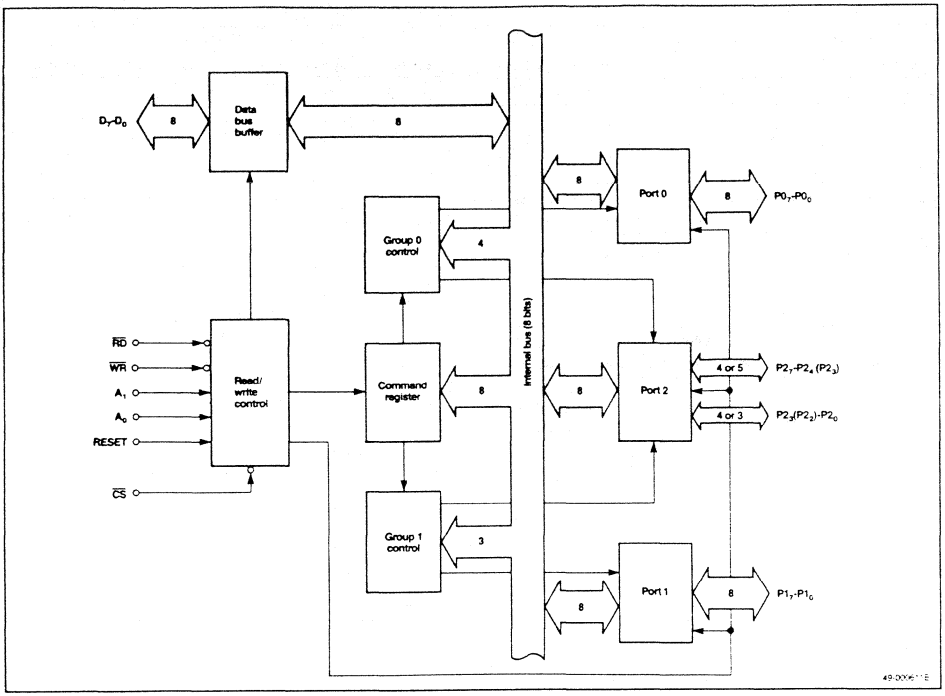
RESET [Reset]

When the RESET input is high, the μPD71055 is reset. The group 0 and the group 1 ports are set to mode 0 (basic I/O port mode). All port bits are cleared to zero and all ports are set for input.

$P0_7$-$P0_0$, $P1_7$-$P1_0$, $P2_7$-$P2_0$ [Ports 0, 1, 2]

Pins $P0_7$-$P0_0$, $P1_7$-$P1_0$, and $P2_7$-$P2_0$ are the port 0, 1, and 2 I/O pins, bits 7-0, respectively.

Block Diagram



Functional Description

Ports 0, 1, 2

The μPD71055 has three 8-bit I/O ports, referred to as port 0, port 1, and port 2. These ports are divided into two groups, group 0 and group 1. The groups can be in one of three modes, mode 0, mode 1, and mode 2. Modes can be set independently for each group.

When port 0 is in mode 0, port 0 and the four upper bits of port 2 belong to group 0, and port 1 and the four lower bits of port 2 belong to group 1. When port 0 is in mode 1 or 2, port 0 and the 5 upper bits of port 2 belong to group 0 and port 1 and the three lower bits of port 2 belong to group 1.

Command Register

The host writes command words to the μPD71055 in this register. These commands control group 0 and group 1. Note that the contents of this register cannot be read.

Group 0 Control and Group 1 Control

These blocks control the operation of group 0 and group 1.

Read/Write Control

The read/write control controls the read/write operations for the ports and the data bus in response to the $\overline{RD}$, $\overline{WR}$, $\overline{CS}$, and address signals. It also handles RESET signals and the A_0, A_1 address inputs.

Data Bus Buffer

The data bus buffer latches information going to or from the system data bus.

Absolute Maximum Ratings

(T_A = 25°C)

Power supply voltage, V_{DD}	−0.5 to +7.0 V
Input voltage, V_I	−0.5 to V_{DD} + 0.3 V
Output voltage, V_O	−0.5 to V_{DD} + 0.3 V
Power dissipation, P_{DMAX}	500 mW
Operating temperature, T_{opt}	−40 to +85°C
Storage temperature, T_{stg}	−65 to +150°C

Comment: These devices are not meant to be operated outside the limits specified above. Exposure to stresses beyond those listed in Absolute Maximum Ratings could cause damage. Exposure to an absolute maximum rating for extended periods may affect reliability.

Capacitance

(T_A = 25°C, V_{DD} = GND = 0 V)

Parameter	Symbol	Limits Min	Typ	Max	Units	Test Conditions
Input capacitance	C_I			10	pF	fc = 1 MHz Unmeasured pins returned to 0 V
I/O capacitance	C_{IO}			20	pF	

DC Characteristics

(T_A = −40 to +85°C, V_{DD} = 5 V ±10%)

Parameter	Symbol	Limits Min	Typ	Max	Units	Test Conditions
Input voltage high	V_{IH}	2.2		V_{DD} + 0.3	V	
Input voltage low	V_{IL}	−0.5		0.8	V	
Output voltage high	V_{OH}	0.7 x V_{DD}			V	I_{OH} = −400 μA
Output voltage low	V_{OL}			0.4	V	I_{OL} = 2.5 mA
Input leakage current high	I_{LIH}			10	μA	$V_I = V_{DD}$
Input leakage current low	I_{LIL}			−10	μA	V_I = 0 V
Output leakage current high	I_{LOH}			10	μA	$V_O = V_{DD}$
Output leakage current low	I_{LOL}			−10	μA	V_O = 0 V
Supply current (dynamic)	I_{DD1}			15	mA	
Supply current (standby)	I_{DD2}		2	50	μA	

AC Characteristics

(T_A = −40 to +85°C, V_{DD} = 5 V ±10%)

Parameter	Symbol	Limits Min	Typ	Max	Units	Test Conditions
Read Timing						
A_1, A_0, $\overline{CS}$ set-up to $\overline{RD}$ ↓	t_{SAR}	0			ns	
A_1, A_0, $\overline{CS}$ hold from $\overline{RD}$ ↑	t_{HRA}	0			ns	
$\overline{RD}$ pulse width	t_{RRL}	160			ns	
Data delay from $\overline{RD}$ ↓	t_{DRD}			120	ns	C_L = 150 pF
Data float from $\overline{RD}$ ↑	t_{FRD}	10		85	ns	C_L = 20 pF R_L = 2 kΩ
Read recovery time	t_{RV}	200			ns	
Write Timing						
A_1, A_0, $\overline{CS}$ set-up to $\overline{WR}$ ↓	t_{SAW}	0			ns	
A_1, A_0, $\overline{CS}$ hold from $\overline{WR}$ ↑	t_{HWA}	0			ns	
$\overline{WR}$ pulse width	t_{WWL}	120			ns	
Data set-up to $\overline{WR}$ ↑	t_{SDW}	100			ns	
Data hold from $\overline{WR}$ ↑	t_{HWD}	0			ns	
Write recovery time	t_{RV}	200			ns	
Other Timing						
Port set-up time to $\overline{RD}$ ↓	t_{SPR}	0			ns	
Port hold time from $\overline{RD}$ ↑	t_{HRP}	0			ns	
Port set-up time to $\overline{STB}$ ↓	t_{SPS}	0			ns	
Port hold time from $\overline{STB}$ ↑	t_{HSP}	150			ns	

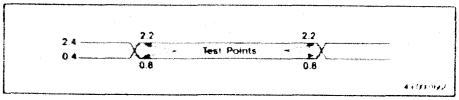
AC Characteristics (cont)

(T_A = −40 to +85°C, V_{DD} = 5 V ±10%)

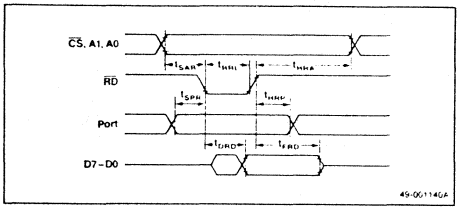
Parameter	Symbol	Limits Min	Typ	Max	Units	Test Conditions
Other Timing (cont)						
Port delay time from $\overline{WR}$ ↑	t_{DWP}			350	ns	C_L = 150 pF
$\overline{STB}$ pulse width	t_{SSL}	350			ns	
$\overline{DAK}$ pulse width	t_{DADAL}	300			ns	
Port delay time from $\overline{DAK}$ ↓(mode 2)	t_{DDAP}			300	ns	CL = 150 pF
Port float time from $\overline{DAK}$ ↑(mode 2)	t_{FDAP}	20		250	ns	C_L = 20 pF R_L = 2 kΩ
$\overline{OBF}$ set delay from $\overline{WR}$ ↑	t_{DWOB}			300	ns	C_L = 150 pF
$\overline{OBF}$ clear delay from $\overline{DAK}$ ↓	t_{DDAOB}			350	ns	
IBF set delay from $\overline{STB}$ ↓	t_{DSIB}			300	ns	
IBF clear delay from $\overline{RD}$ ↑	t_{DRIB}			300	ns	
INT set delay from $\overline{DAK}$ ↑	t_{DDAI}			350	ns	
INT clear delay from $\overline{WR}$ ↓	t_{DWI}			450	ns	
INT set delay from $\overline{STB}$ ↑	t_{DSI}			300	ns	
INT clear delay from $\overline{RD}$ ↓	t_{DRI}			400	ns	
RESET pulse width	t_{RESET1}	50			μs	During right after power on
	t_{RESET2}	500			ns	During operation

Timing Waveforms

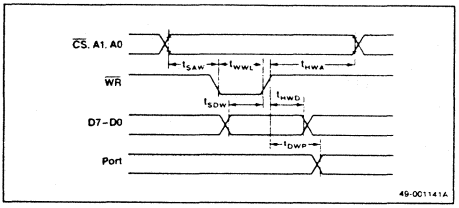
AC Test Waveform



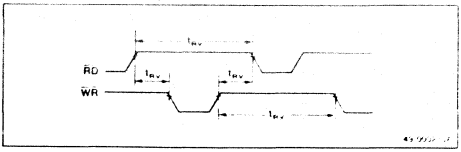
Timing Mode 0: Input



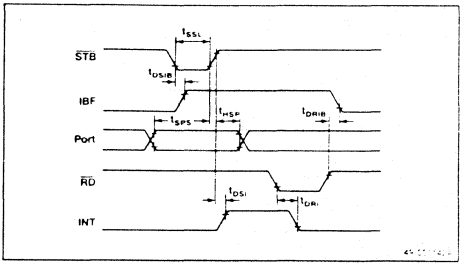
Mode 0: Output



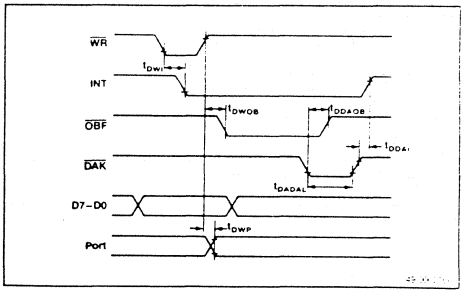
Recovery Time



Mode 1: Input

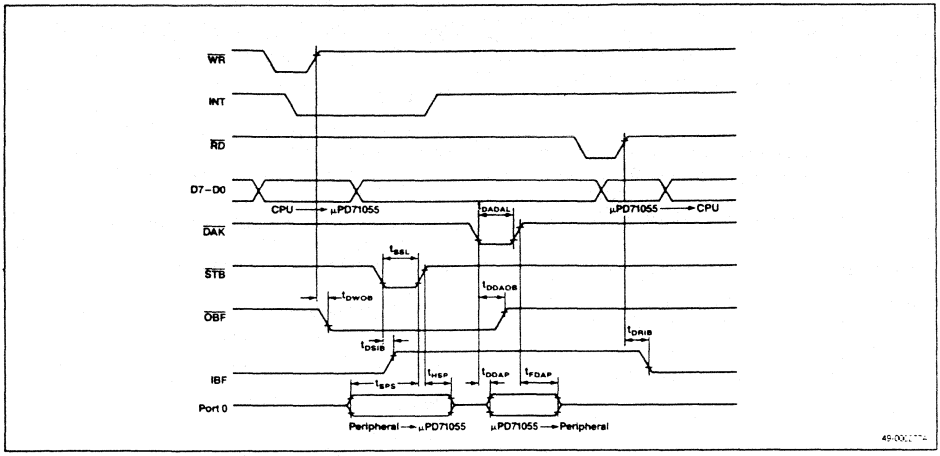


Mode 1: Output



Timing Waveforms (cont)

Mode 2



μPD71055 Commands

Two commands control μPD71055 operation. The mode select command determines the operation of group 0 and group 1 ports. The bit manipulation command sets or resets the bits of port 2. These commands are executed by writing an 8-bit command word to the command register ($A_1A_0 = 11$).

Mode Select

The μPD71055 port groups have three modes. Modes 0 and 1 can be specified for groups 0 and 1, but mode 2 can only be specified for group 0. The bits of all ports are cleared when a mode is selected or when the μPD71055 is reset.

Mode 0. Basic input/output port operation.

Mode 1. Strobed input/output operation controlled by three or four bits of port 2 used as control/status signals.

Mode 2. (Only available for group 0). Port 0 is the bidirectional I/O port and the higher 5 bits of port 2 are used for status and control signals.

To specify the mode, set the command word as shown in figure 1 and write it to the command register.

Bit Manipulation Command

This command (figure 2) affects only port 2. It is mainly used in mode 1 and mode 2 to control the port 2 bits which are used as control/status signals. It is also used to enable and disable μPD71055-generated interrupts and to set and reset port 2 general input/output pins.

For example, to set bit 2 of port 2 to 1 ($P2_2 = 1$), set the command word as shown in figure 3 (05H) in the command register.

Operation in Each Mode

The operation mode for each group in the μPD71055 can be set according to the application. Group 0 can be in modes 0, 1, or 2, while group 1 is in mode 0 or 1. Group 1 cannot be used in mode 2.

The $\overline{RD}$ and $\overline{WR}$ signals that appear in the descriptions of each mode refer to the port in question as addressed by A_1 and A_0. These signals only affect the port addressed by A_1 and A_0.

Where the port addressed may not be clear, 0 or 1 is appended to the signal name to indicate the port

Mode 0

In this mode the ports of the μPD71055 are used to perform basic I/O operations. Each port operates with a buffered input and a buffered latched output. See figure 4.

Depending on the control word sent to the μPD71055 from the system bus, ports 0, 1, and 2 can be independently specified for input or output.

Input Port Operation

While the $\overline{RD}$ signal is low, data from the port selected by the A_1A_0 signals is put on the data bus. See figure 5.

Output Port Operation

When the μPD71055 is written to ($\overline{WR} = 0$), the data on the data bus will be latched in the port selected by the A_1A_0 signals at the rising edge of $\overline{WR}$ and output to the port pins. See figure 6.

By reading a port which is set for output, the output value of the port can be obtained.

Note: When group 0 is in mode 1 or mode 2, only bits $P2_2$-$P2_0$ of port 2 can be used by group 1. Bit $P2_3$ belongs to group 0.

Mode 0 Example

This is an example of a CPU connected to an A/D converter via a μPD71055 (figure 7). Here both group 0 and group 1 are set to mode 0 and port 2 is used to start conversion and detect the end of the conversion process.

Figure 8 is a subroutine that reads the converted data from an A/D converter.

Figure 1. Mode Select Command Word

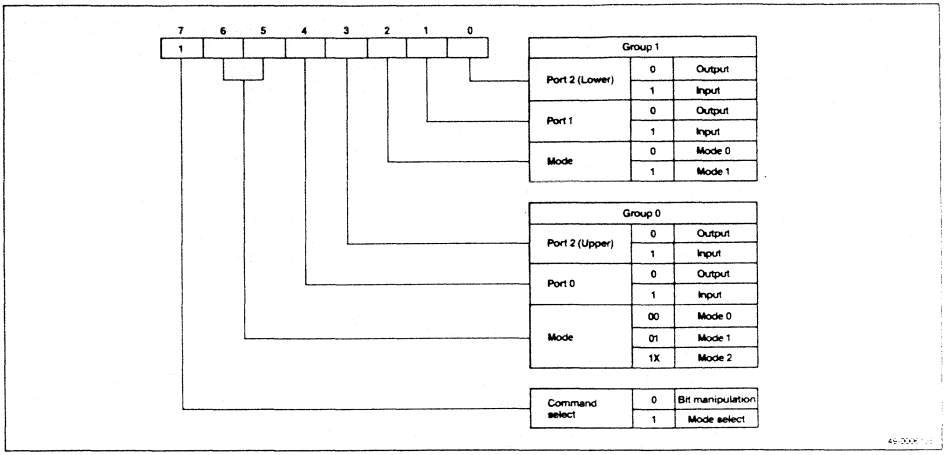


Figure 2. Bit Manipulation Command Word

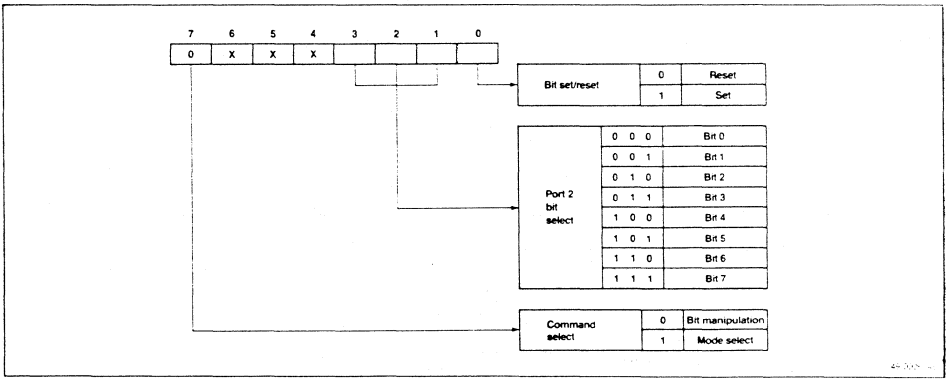


Figure 3. Bit Manipulation Command Example

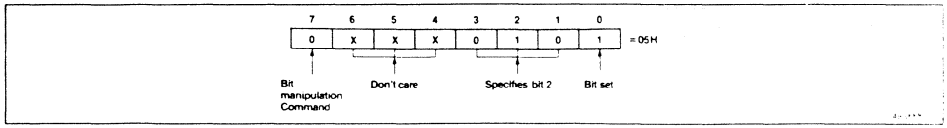


Figure 4. Mode 0

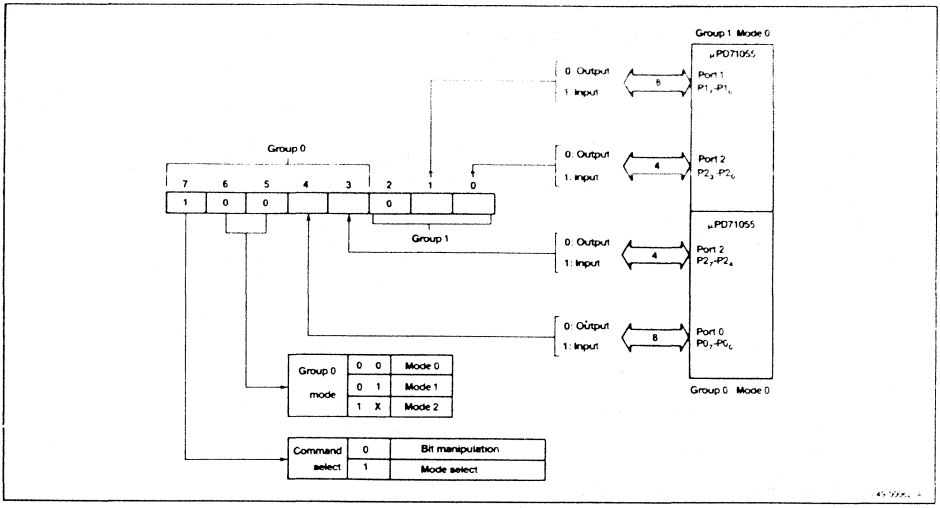


Figure 5. Mode 0 Input Timing

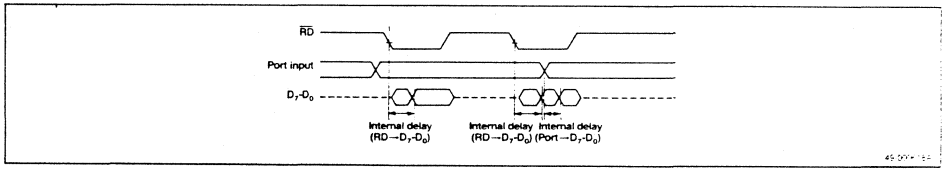


Figure 6. Mode 0 Output Timing

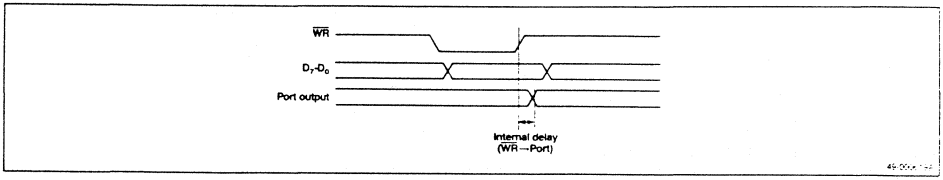


Figure 7. A/D Converter Connection Example

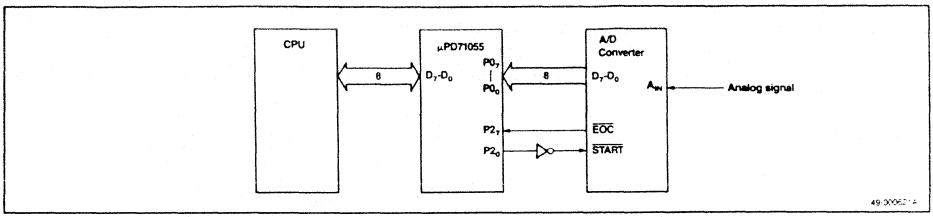


Figure 8. A/D Converter Example

```
READ_A/D:  MOV   AL,10011000B     ;μPD71055 Mode Setting:
           OUT   CTRLPORT,AL      ;Group 0, group 1 in mode 0
                                  ;Port 0 & port 2 (upper) are inputs
                                  ;Port 1 & port 2 (lower) are outputs
           MOV   AL,00000001B
           OUT   CTRLPORT,AL      ;Conversion starts by setting P20 high
WAIT_EOC:  IN    AL,PORT2        ;End of conversion wait loop
           AND   AL,80H
           TEST  AL,80H           ;Conversion ends when P27 = 0
           BNZ   WAIT_EOC
           IN    AL,PORT0        ;Read A/D converted values
           RET
```

Mode 1

In this mode, the control and status signals control the I/O data. In group 0, port 0 functions as the data port and the upper five bits of port 2 function as control/status. In group 1, port 1 functions as the data port and the lower three bits of port 2 function as control/status.

In mode 1, the bit manipulation command is used to write the bits of port 2.

Group 0 Mode 1

When group 0 is used in mode 1, the upper five bits of port 2 become part of group 0. Of these five bits, three are used for control/status and the remaining two can be used for I/O (using the bit manipulation command). See figure 9.

Group 1 Mode 1

When group 1 is used in mode 1, the lower three or four bits of port 2 become part of group 1. Of these four bits, three are used for control/status. The remaining bit, $P2_3$, can be used for I/O only if group 0 is in mode 0. Otherwise, $P2_3$ belongs to group 0 as a control/status bit. See figure 9 and table 4.

Mode 1 Input Operation

In mode 1, port 0 is the data port for group 0, and port 1 for group 1. The control/status bits (port 2) are used as listed below. Figure 10 shows the signal timing.

$\overline{STB}$ [Strobe]. The data input at port 0 is latched in port 0 when the $\overline{STB0}$ input is brought low. The data input at port 1 is latched in port 1 by $\overline{STB1}$.

IBF [Input Buffer Full F/F]. The IBF output goes high to indicate that the input buffer has become full. IBF goes high when the $\overline{STB}$ signal goes low. IBF goes low at the rising edge of the $\overline{RD}$ signal when $\overline{STB}$ = 1.

INT [Interrupt Request]. INT goes high when the data is latched in the input port, when RIE is 1 and $\overline{STB}$, IBF and $\overline{RD}$ are all high. INT goes low at the falling edge of the $\overline{RD}$ signal. It can function as a data read request interrupt signal to a CPU.

Figure 9. Mode 1 Input

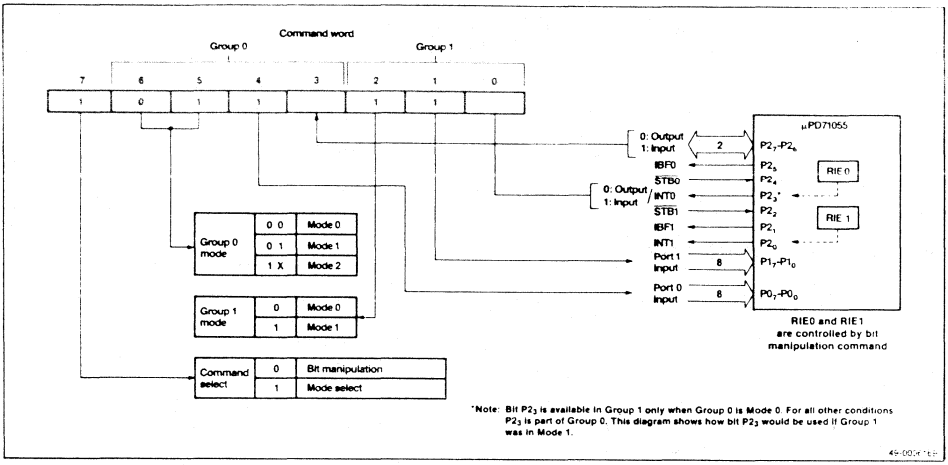
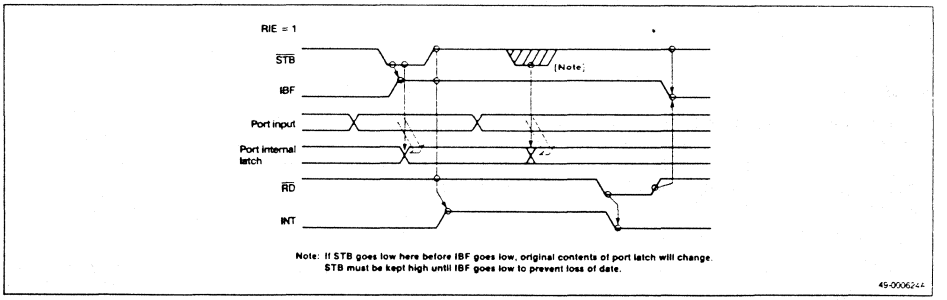


Figure 10. Mode 1 Input Timing



RIE [Read Interrupt Enable Flag]. RIE controls the interrupt output. Interrupts can be enabled by using the bit manipulation command to set this bit to 1, and disabled by resetting it to 0. This signal is internal to the μPD71055 and is not an output. The state of RIE does not affect the function of $\overline{STB0}$ or $\overline{STB1}$, which are inputs to the same bits ($P2_4$ and $P2_2$) of port 2.

When input is specified in mode 1, the status of IBF, INT and RIE can be read by reading the contents of port 2.

Mode 1 Output Operation

In mode 1 output operation (figure 11), the status/control bits (port 2) are used as listed below. Figure 12 shows the signal timing.

$\overline{OBF}$ [Output Buffer Full F/F]. $\overline{OBF}$ goes low when data is received by the μPD71055 and is latched in output ports 1 or 0. $\overline{OBF}$ functions as a data receive flag. $\overline{OBF}$ goes low at the rising edge of $\overline{WR}$ when $\overline{DAK} = 1$ (write complete). It goes high when the $\overline{DAK}$ signal goes low.

Figure 11. Mode 1 Output

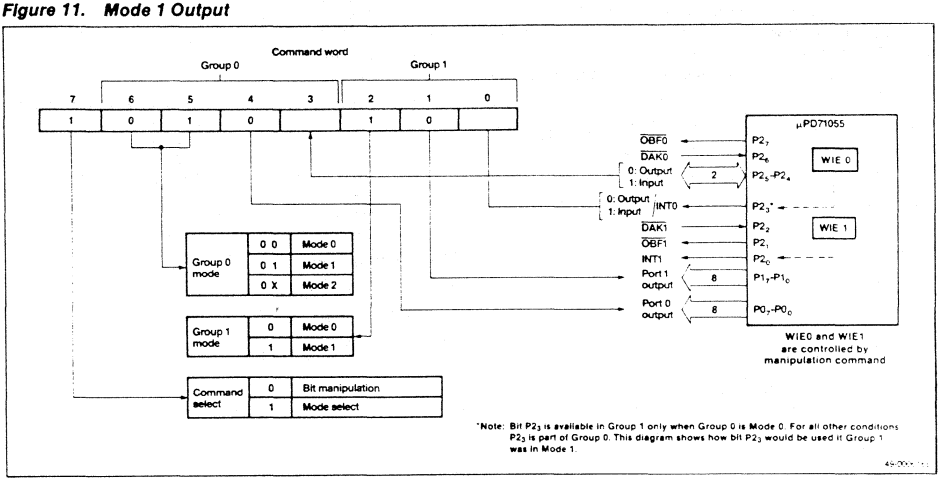
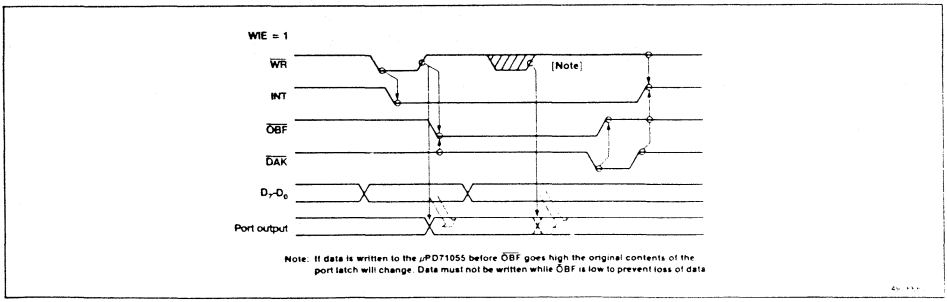


Figure 12. Mode 1 Output Timing



$\overline{DAK}$ [Data Acknowledge]. When this input is low, it signals the μPD71055 that output port data has been taken from the 71055.

INT [Interrupt Request]. INT goes high when the output data is taken when WIE is set to 1 and $\overline{WR}$, $\overline{OBF}$ and $\overline{DAK}$ are all high. It goes low at the falling edge of the $\overline{WR}$ signal. INT therefore functions as a write request signal, indicating that new data should be sent to the μPD71055.

WIE [Write Interrupt Enable Flag]. WIE controls the interrupt output. Interrupts can be enabled by using the bit manipulation command to set this bit to 1 and disabled by resetting it to 0. This signal is internal to the μPD71055 and is not an output. The state of WIE does not affect the function of $\overline{DAK}$ addressed to the same bits of port 2.

When output is specified in mode 1, the status of $\overline{OBF}$, INT and WIE can be obtained by reading the contents of port 2.

Table 2 shows a summary of these signals.

Table 2. Functions of Port 2 Bits in Mode 1

Group	Bit	Data Input	Data Output
1	$P2_0$	INT1 (Interrupt request)	INT1 (Interrupt request)
	$P2_1$	IBF1 (Input buffer full f/f)	$\overline{OBF1}$ (Output buffer full f/f)
	$P2_2$	$\overline{STB1}$ (Strobe input) RIE1 (Read interrupt enable flag)	$\overline{DAK1}$ (Data acknowledge input) WIE1 (Write interrupt enable flag)
	$P2_3$	I/O (Note)	I/O (Note)
0	$P2_3$	INT0 (Interrupt request)	INT0 (Interrupt request)
	$P2_4$	$\overline{STB0}$ (Strobe input) RIE0 (Read interrupt enable flag)	I/O
	$P2_5$	IBF0 (Input buffer full f/f)	I/O
	$P2_6$	I/O	$\overline{DAK0}$ (Data acknowledge input) WIE0 (Write interrupt enable flag)
	$P2_7$	I/O	$\overline{OBF0}$ (Output buffer full f/f)

Note: Can be used with group 1 only when group 0 is set to mode 0. In other modes, $P2_3$ belongs to group 0.

Mode 1 Example

This example (figure 13) demonstrates connecting a printer to the μPD71055. Group 0 is used in mode 1 output. Group 1 can operate in mode 0 or 1; in this example it is set to mode 0.

Figure 13. Connection to Printer

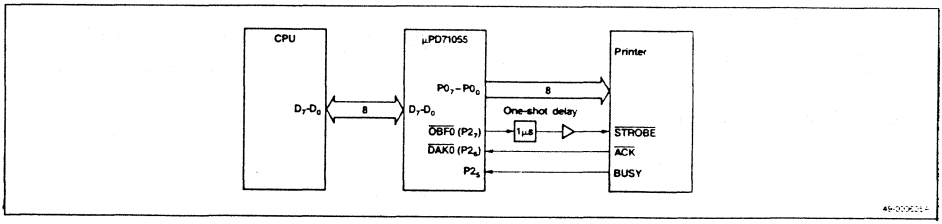


Figure 14. Printer Example Subroutine

```
;This subroutine sends character strings to the printer
INIT:     MOV    AL,10101000B     ;μPD71055 Mode Setting:
                                  ;Group 0: mode 1 output
                                  ;Group 1: mode 0
          OUT    CTRLPORT,AL
          RET
SENDPRN:  MOV    BW,DATA          ;Output data address
PRNLOOP:  MOV    AL,[BW]
          CMP    AL,0FFH          ;End if data = 0FFH
          BNZ    WAIT
          RET
WAIT:     IN     AL,PORT2
          MOV    CL,AL
          AND    AL,80H
          TEST   AL,80H           ;Wait until output buffer is empty
          BZ     WAIT
          MOV    AL,CL
          AND    AL,20H
          TEST   AL,20H           ;Wait until printer can accept data
          BNZ    WAIT
          MOV    AL,[BW]          ;Send data to printer
          OUT    PORT0,AL
          INC    BW
          BR     PRNLOOP
```

Mode 2

Mode 2 can only be used by group 0. In this mode, port 0 functions as a bidirectional 8-bit data port operating under the control of the upper five bits of port 2 as control/status signals. In this mode, port 0 combines the input and output operations of mode 1. See figures 15 and 16.

In mode 2, the status of the following signals can be determined by reading port 2: $\overline{OBF0}$, IBF0, INT0, WIE0, and RIE0.

The $\overline{DAK0}$ and $\overline{STB0}$ signals are used to select input or output for port 0. By using these signals, bidirectional operation between the μPD71055 and peripheral can be realized.

In mode 2, the bit manipulation command is used to write to port 2.

Control/Status Port Operation

The following control/status signals are used for output:

$\overline{OBF0}$ [Output Buffer Full]. $\overline{OBF0}$ goes low when data is received from the D_0-D_7 data bus and is latched in the port 0 output buffer. It therefore functions as a receive request signal to the peripheral. $\overline{OBF0}$ goes low at the rising edge of the $\overline{WR0}$ signal (end of data write). It goes high when $\overline{DAK0}$ is low (output data from port 0 received).

$\overline{DAK0}$ [Data Acknowledge]. $\overline{DAK0}$ is sent to the μPD71055 in response to the $\overline{OBF0}$ signal. It should be set low when data is received from port 0 of the μPD71055.

WIE0 [Write Interrupt Enable Flag]. WIE0 controls the write interrupt request output. Interrupts are enabled by using the bit manipulation command to set this bit to 1 and disabled by setting it to 0. The state of WIE does not affect the $\overline{DAK}$ function of this pin.

The following control/status signals are used for input:

$\overline{STB0}$ [Strobe Input]. When $\overline{STB0}$ goes low, the data being sent to the μPD71055 is latched in port 0.

IBF0 [Input Buffer Full F/F]. When IBF0 goes high, it indicates that the input buffer is full. It functions as a signal which can be used to prohibit further data transfer. IBF0 goes high when $\overline{STB0}$ goes low. It goes low at the rising edge of $\overline{RD0}$ when $\overline{STB0}$ = 1 (read complete).

Figure 15. Mode 2

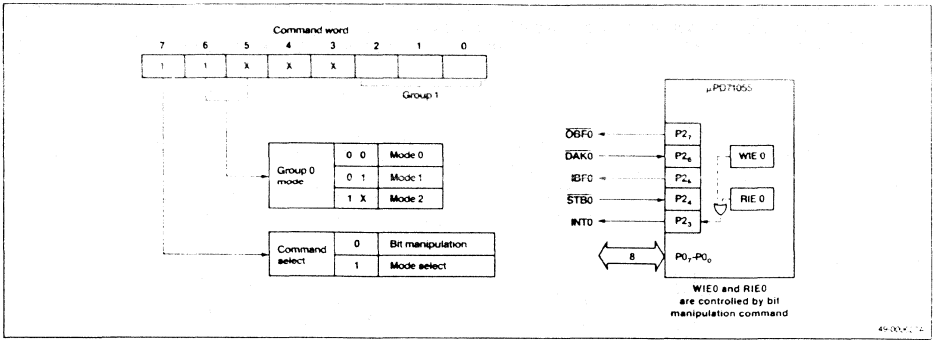
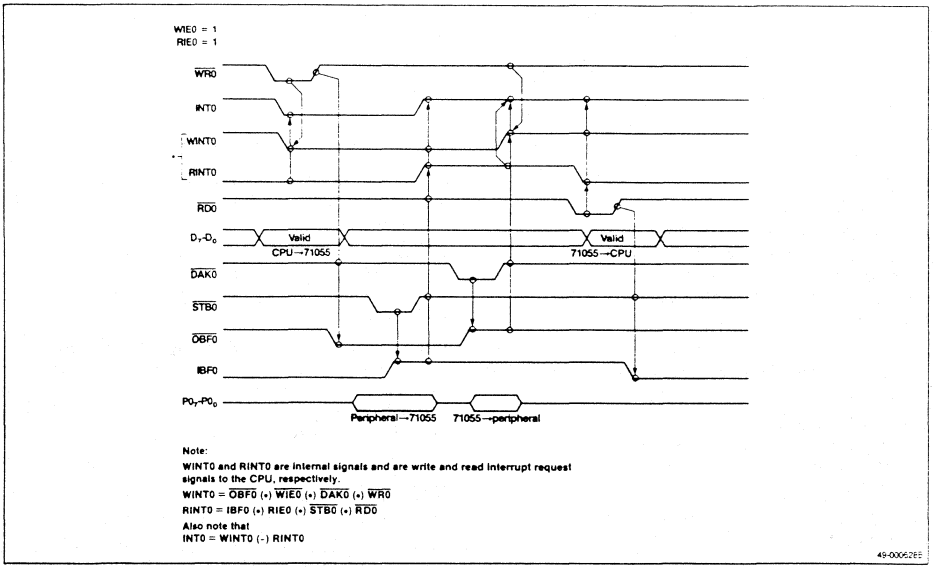


Figure 16. Mode 2 Timing



Note:

WINT0 and RINT0 are internal signals and are write and read interrupt request signals to the CPU, respectively.

WINT0 = $\overline{OBF0}$ (•) $\overline{WIE0}$ (•) $\overline{DAK0}$ (•) $\overline{WR0}$

RINT0 = IBF0 (•) RIE0 (•) $\overline{STB0}$ (•) $\overline{RD0}$

Also note that

INT0 = WINT0 (–) RINT0

RIE0 [Read Interrupt Enable Flag]. RIE0 controls the read interrupt request output. Interrupts are enabled by using the bit manipulation command to set this bit to 1 and disabled by setting it to 0. The state of RIE0 does not affect the $\overline{STB0}$ function of this pin.

This control/status signal is used for both input and output:

INT0 [Interrupt Request]. During input operations, INT0 functions as a read request interrupt signal. During output, it functions as a write request interrupt signal. This signal is the logical OR of the INT signal for data read (RINT0) and the INT signal for write (WINT0) in mode 1 (RINT0 OR WINT0).

In mode 2, the status of $\overline{OBF0}$, IBF0, INT0, WIE0, and RIE0 can be determined by reading port 2.

Table 3 is a summary of these signals.

Table 3. Functions of Port 2 In Mode 2

Bit	Function
$P2_3$	INT0 (Interrupt request)
$P2_4$	$\overline{STB0}$ (Strobe input) RIE0 (Read interrupt enable flag)
$P2_5$	IBF0 (Input buffer full f/f)
$P2_6$	$\overline{DAK0}$ (Data acknowledge input) WIE0 (Write interrupt enable flag)
$P2_7$	$\overline{OBF0}$ (Output buffer full f/f)

Mode 2 Example

Figures 17, 18, and 19 show data transfer between two CPUs.

Figure 17. Connecting Two CPUs

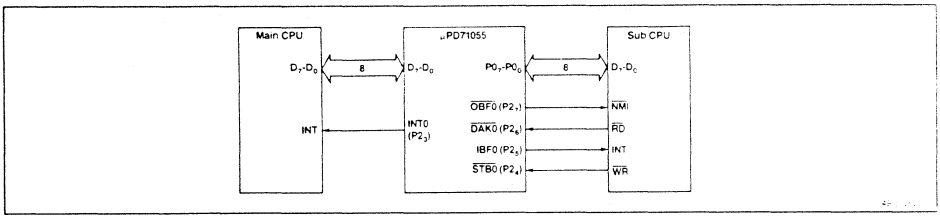


Figure 18. Main CPU Flowchart

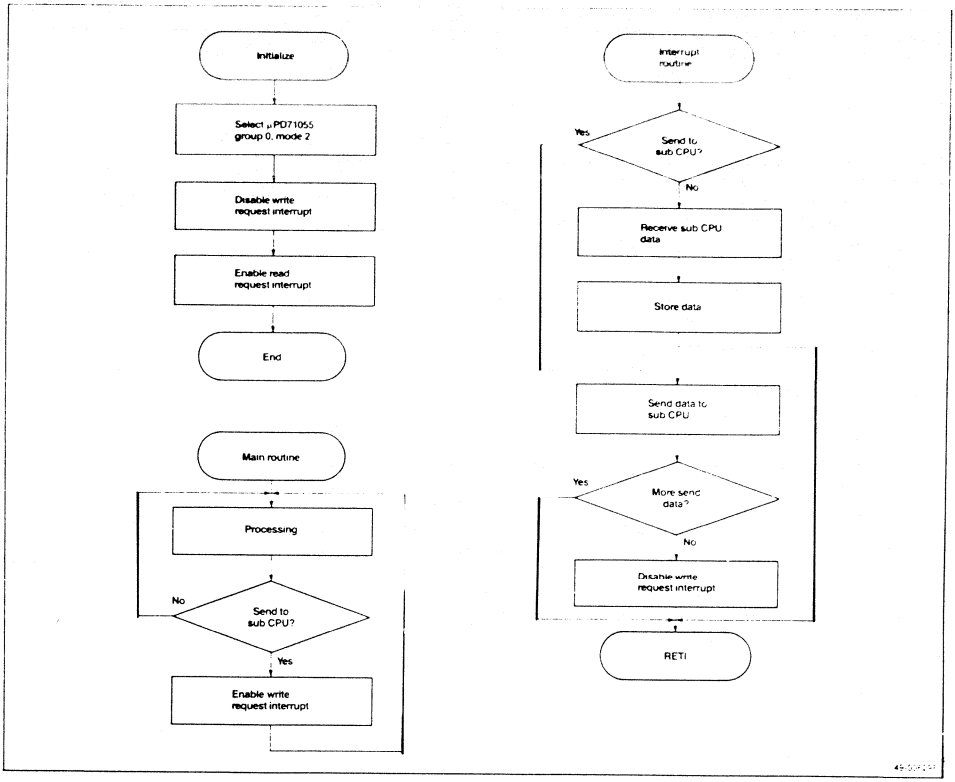
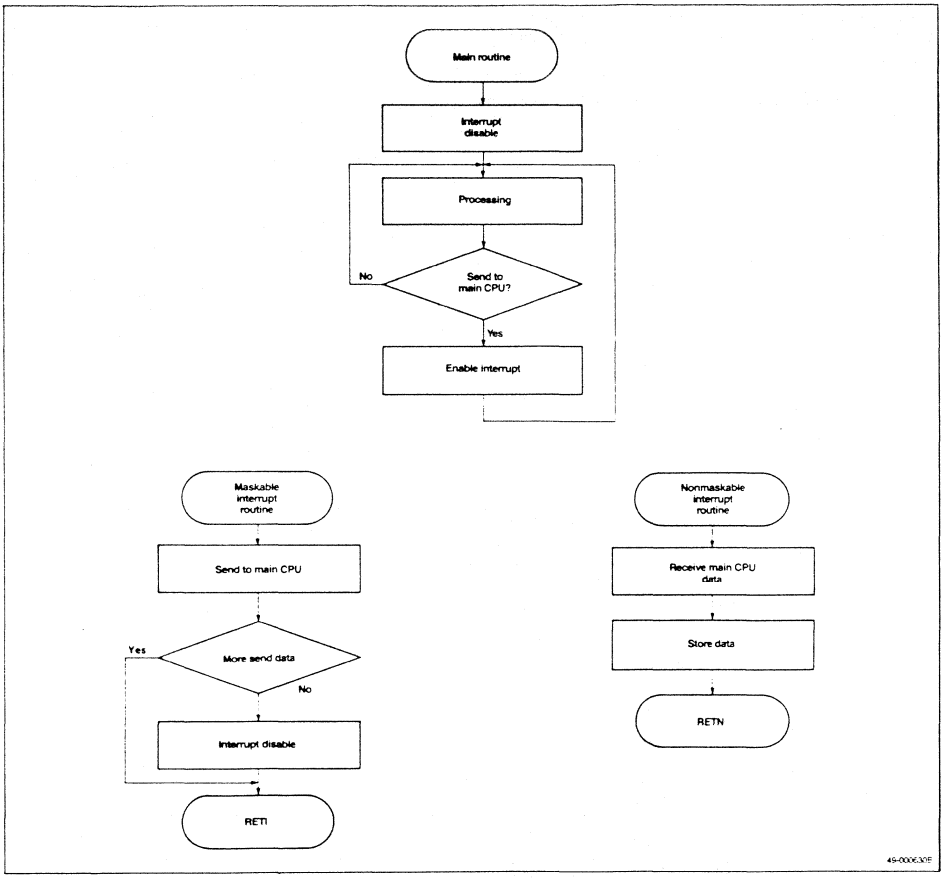


Figure 19. Sub CPU Flowchart



Mode Combinations

Table 4 is a complete list of all the combinations of modes and groups, and the function of the port 2 bits in each mode.

Table 4. Mode Combinations and Port 2 Bit Functions

Group 0							Group 1					
Mode	$P0_7$-$P0_0$	$P2_7$	$P2_6$	$P2_5$	$P2_4$	$P2_3$	Mode	$P1_7$-$P1_0$	$P2_3$	$P2_2$	$P2_1$	$P2_0$
0	In	D	D	D	D	NA	0	In	D	D	D	D
0	In	D	D	D	D	NA	0	Out	D	D	D	D
0	In	D	D	D	D	NA	1	In	B	$\overline{STB1}$ (RIE1)	IBF1	INT1
0	In	D	D	D	D	NA	1	Out	B	$\overline{DAK1}$ (WIE1)	$\overline{OBF1}$	INT1
0	Out	D	D	D	D	NA	0	In	D	D	D	D
0	Out	D	D	D	D	NA	0	Out	D	D	D	D
0	Out	D	D	D	D	NA	1	In	B	$\overline{STB1}$ (RIE1)	IBF1	INT1
0	Out	D	D	D	D	NA	1	Out	B	$\overline{DAK1}$ (WIE1)	$\overline{OBF1}$	INT1
1	In	B	B	IBF0	$\overline{STB0}$ (RIE0)	INT0	0	In	NA	D	D	D
1	In	B	B	IBF0	$\overline{STB0}$ (RIE0)	INT0	0	Out	NA	D	D	D
1	In	B	B	IBF0	$\overline{STB0}$ (RIE0)	INT0	1	In	NA	$\overline{STB1}$ (RIE1)	IBF1	INT1
1	In	B	B	IBF0	$\overline{STB0}$ (RIE0)	INT0	1	Out	NA	$\overline{DAK1}$ (WIE1)	$\overline{OBF1}$	INT1
1	Out	$\overline{OBF0}$	$\overline{DAK0}$ (WIE0)	B	B	INT0	0	In	NA	D	D	D
1	Out	$\overline{OBF0}$	$\overline{DAK0}$ (WIE0)	B	B	INT0	0	Out	NA	D	D	D
1	Out	$\overline{OBF0}$	$\overline{DAK0}$ (WIE0)	B	B	INT0	1	In	NA	$\overline{STB1}$ (RIE1)	IBF1	INT1
1	Out	$\overline{OBF0}$	$\overline{DAK0}$ (WIE0)	B	B	INT0	1	Out	NA	$\overline{DAK1}$ (WIE1)	$\overline{OBF1}$	INT1
2	I/O	$\overline{OBF0}$	$\overline{DAK0}$ (WIE0)	IBF0	$\overline{STB0}$ (RIE0)	INT0	0	In	NA	D	D	D
2	I/O	$\overline{OBF0}$	$\overline{DAK0}$ (WIE0)	IBF0	$\overline{STB0}$ (RIE0)	INT0	0	Out	NA	D	D	D
2	I/O	$\overline{OBF0}$	$\overline{DAK0}$ (WIE0)	IBF0	$\overline{STB0}$ (RIE0)	INT0	1	In	NA	$\overline{STB1}$ (RIE1)	IBF1	INT1
2	I/O	$\overline{OBF0}$	$\overline{DAK0}$ (WIE0)	IBF0	$\overline{STB0}$ (RIE0)	INT0	1	Out	NA	$\overline{DAK1}$ (WIE1)	$\overline{OBF1}$	INT1

Note:

(1) In this chart, "NA" indicates that the bit cannot be used by this group.

(2) The symbol "B" indicates bits that can only be rewritten by the bit manipulation command.

(3) In this chart, "D" indicates that is used by the user.

(4) Symbols in parentheses are internal flags. They are not output to port 2 pins and they cannot be read by the host.

(5) In indicates Input, Out indicates Output, and I/O indicates Input/Output.

Description

The μPD71059 is a low-power CMOS programmable interrupt control unit for microcomputer systems. It can process eight interrupt request inputs, allocating a priority level to each one. It transfers the interrupt with the highest priority to the CPU, along with interrupt address information. By cascading up to eight slave μPD71059s to a master μPD71059, a system can process up to 64 interrupt requests. System scale, interrupt routine address, interrupt request priority and masking are all under complete program control.

Features

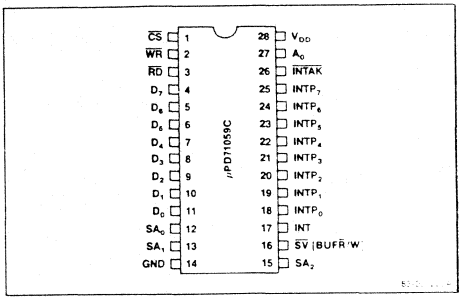
- ☐ μPD8085A compatible (CALL mode)
- ☐ μPD70108/70116 compatible (vector mode)
- ☐ Eight interrupt request inputs per chip
- ☐ Up to 64 interrupt requests inputs per system (extended mode)
- ☐ Edge- or level-triggered interrupt request inputs
- ☐ Each interrupt maskable
- ☐ Programmable priority level
- ☐ Polling operation
- ☐ Single +5 V ±10% power supply
- ☐ Industrial temperature range: −40 to +85 °C
- ☐ CMOS technology

Ordering Information

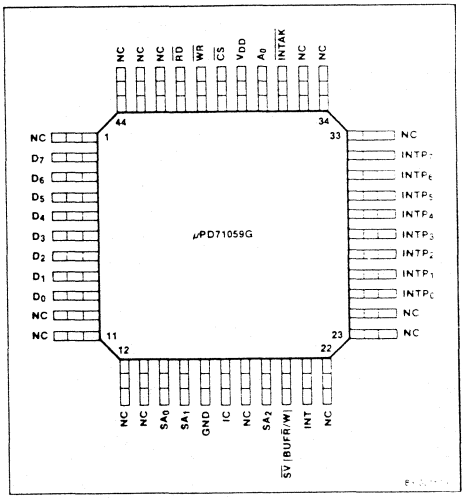
Order Code	Package Type
μPD71059C	28-pin plastic DIP
μPD71059G	44-pin plastic miniflat
μPD71059L	28-pin PLCC

Pin Configurations

28-Pin Plastic DIP



44-Pin Plastic Miniflat



Pin Identification

Plastic DIP

No.	Symbol	Function
1	$\overline{CS}$	Chip select input
2	$\overline{WR}$	Write strobe input
3	$\overline{RD}$	Read strobe input
4-11	D_7-D_0	Data bus I/O
12-13	SA_0, SA_1	Slave address I/O, bits 0, 1
14	GND	Ground potential
15	SA_2	Slave address I/O, bit 2
16	$\overline{SV}$ (BUF$\overline{R}$/W)	Slave (Buffer read write) I/O
17	INT	Interrupt output
18-25	$INTP_0$-$INTP_7$	Interrupt inputs
26	$\overline{INTAK}$	Interrupt acknowledge input
27	A_0	Address input
28	V_{DD}	Power supply

Plastic Flatpack

No.	Symbol	Function
1	NC	Not connected
2-9	D_7-D_0	Data bus I/O
10-13	NC	Not connected
14, 15	SA_0, SA_1	Slave address I/O, bits 0, 1
16	GND	Ground potential
17	IC	Internally connected
18	NC	Not connected
19	SA_2	Slave address I/O, bit 2
20	$\overline{SV}$ (BUF$\overline{R}$/W)	Slave (Buffer read write) I/O
21	INT	Interrupt output
22-24	NC	Not connected
25-32	$INTP_0$-$INTP_7$	Interrupt inputs
33-35	NC	Not connected
36	$\overline{INTAK}$	Interrupt acknowledge input
37	A_0	Address input
38	V_{DD}	Power supply
39	$\overline{CS}$	Chip select input
40	$\overline{WR}$	Write strobe input
41	$\overline{RD}$	Read strobe input
42-44	NC	Not connected

Pin Functions

D_7-D_0 [Data Bus]

The 8-bit 3-state bidirectional bus transfers data to and from the CPU through the system bus. The data bus becomes active when data is sent to the CPU in the $\overline{INTAK}$ sequence. Otherwise, the data bus is high impedance.

$\overline{CS}$ [Chip Select]

The CPU uses the μPD71059's $\overline{CS}$ input to select a μPD71059 to read from (IN instructions) or write to (OUT instructions). The $\overline{RD}$ and $\overline{WR}$ signals to the μPD71059 are enabled when $\overline{CS}$ is low. $\overline{CS}$ is not used for the INTAK sequence.

$\overline{RD}$ [Read Strobe]

The CPU sets the $\overline{RD}$ input to 0 when reading the internal registers IMR, IRR and ISR, and during polling operations to read polling data.

$\overline{WR}$ [Write Strobe]

The CPU sets the $\overline{WR}$ input to 0 when writing initializing words IW1-IW4 and command words IMW, PFCW and MCW.

A_0 [Address]

The A_0 input is used with $\overline{CS}$, $\overline{RD}$, and $\overline{WR}$ to read or write to the μPD71059. Normally, A_0 is connected to A_0 of the address bus. Table 1 shows the relationship between read/write operations and the control signals ($\overline{CS}$, $\overline{WR}$, $\overline{RD}$, and A_0).

$INTP_7$-$INTP_0$ [Interrupt Request from Peripheral]

$INTP_7$-$INTP_0$ are eight asynchronous interrupt request inputs. They can be set to be either edge-or level-triggered. These pins are pulled up by an internal resistance. Their power consumption is lower at high-level input than at low-level input.

INT [Interrupt]

INT is the interrupt request output from a μPD71059 to the CPU or master μPD71059. When an interrupt from a peripheral is input to an INTP pin and acknowledged, the μPD71059 asserts INT high to generate an interrupt request at the CPU or master μPD71059.

$\overline{INTAK}$ [Interrupt Acknowledge]

The $\overline{INTAK}$ input from the CPU acknowledges an interrupt from the μPD71059. After acknowledging the interrupt request, the CPU returns three low-level pulses (μPD8085) or two low-level pulses (μPD70108/70116). Synchronizing to these pulses, the μPD71059 sends a CALL instruction in three bytes, or an interrupt vector number in one byte through the data bus.

$\overline{SV}$ [BUF$\overline{R}$/W] [Slave, Buffer Read/Write]

This pin has two functions. When no external buffer is used in the data bus, it is the $\overline{SV}$ input. When $\overline{SV}$ is low, the μPD71059 acts as a slave. It operates as a master when $\overline{SV}$ is high. $\overline{SV}$ has no master/slave meaning when the μPD71059 is set to single mode.

As the BUF$\overline{R}$/W output, this pin can allow a bus transceiver to be controlled by the μPD71059, if one is required. When the μPD71059 changes its data bus to output, it sets BUF$\overline{R}$/W low. It sets BUF$\overline{R}$/W high when the data bus changes to input.

SA_2-SA_0 [Slave Address]

These pins are only used in systems with cascaded μPD71059s. The master μPD71059 uses these pins to address up to eight slave μPD71059s. These pins are output pins for masters, and input pins for slaves.

Note: In the single mode, SA_2-SA_0 are output pins, but the output data has no meaning.

V_{DD} [Power Supply]

This is the positive power supply.

GND [Ground]

This is the ground potential.

IC [Internally Connected]

This pin must be left unconnected.

Table 1. Read/Write Operations

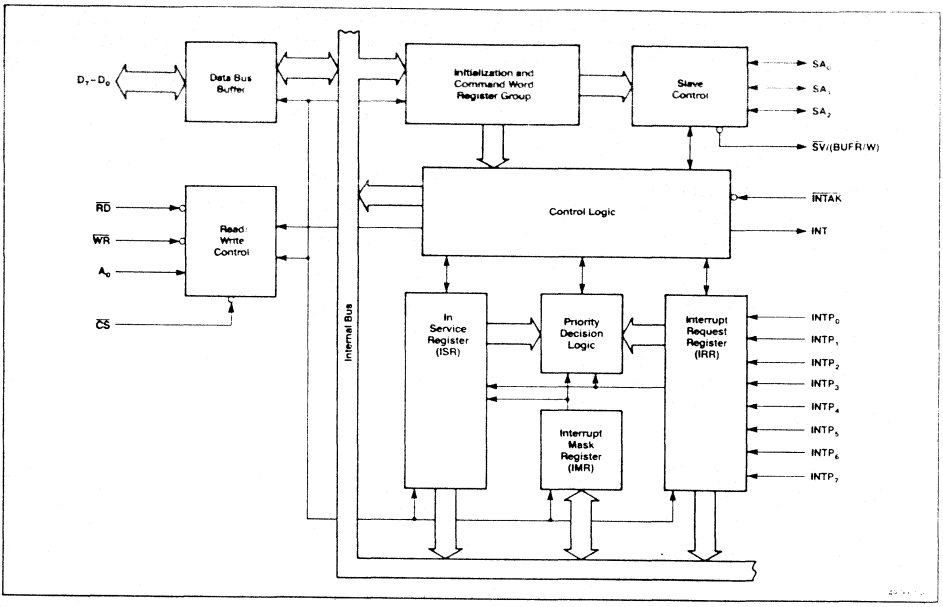
$\overline{CS}$	$\overline{RD}$	$\overline{WR}$	A_0	Other Conditions	μPD71059 Operation	CPU Operation
0	0	1	0	IRR set by MCW	IRR to Data bus	IRR read
				ISR set by MCW	ISR to Data bus	ISR read
				Polling phase (Note 1)	Polling data to Data bus	Polling
0	0	1	1		IMR to Data bus	IMR read
0	1	0	0	$D_4 = 1$	Data bus to IW1 register	IW1 write
				$D_4, D_3 = 0$	Data bus to PFCW register	PFCW write
				$D_4 = 0, D_3 = 1$	Data bus to MCW register	MCW write
0	1	0	1	(Note 2)	Data bus to IW2 register	IW2 write
					Data bus to IW3 register	IW3 write
					Data bus to IW4 register	IW4 write
				After initializing	Data bus to IMR	IMW write
0	1	1	x		Data bus high impedance	
1	x	x	x			
0	0	0	x		Illegal	

Note:

(1) In the polling phase, polling data is read instead of IRR and ISR.

(2) Refer to Control Words section for IW2-IW4 writing procedure.

Block Diagram



Block Diagram Functions

Data Bus Buffer

The data bus buffer is a buffer between D_7-D_0 and the μPD71059's internal bus.

Read/Write Control

The read/write control controls the CPU's reading and writing to and from the μPD71059 registers.

Initialization and Command Word Registers

These registers store initializing words IW1-IW4 and command words PFCW (priority and finish control word) and MCW (mode control word). The CPU cannot read these registers.

Interrupt Mask Register [IMR]

The interrupt mask register stores the interrupt mask word (IMW) command word. Each bit masks an interrupt. If bit n of this register is 1, the interrupt request $INTP_n$ is masked and cannot be accepted by the μPD71059. The CPU can read this register by performing an IN instruction with $A_0 = 1$.

Interrupt Request Register [IRR]

The interrupt request register shows which interrupt levels are currently being requested. If bit n of the IRR is 1, $INTP_n$ is requesting an interrupt. The CPU can read this register.

In-Service Register [ISR]

The in-service register shows all interrupt levels currently in service. If bit n of this register is 1, the interrupt routine corresponding to $INTP_n$ is currently being executed. The CPU can read this register.

Slave Control

Slave control is used in systems with cascaded μPD71059s. A master μPD71059 uses it to control slave μPD71059s, and a slave uses it to interface with the master μPD71059.

Control Logic

The control logic receives and generates the signals that control the sequence of events in an interrupt.

Priority Decision Logic

The priority decision logic determines which interrupt request from the IRR will be serviced next. The decision is made based upon the current interrupt mask, interrupt service status, mode status, and current priority.

Absolute Maximum Ratings

$T_A = 25°C$

Power supply voltage, V_{DD}	−0.5 to +7.0 V
Input voltage, V_I	−0.5 to V_{DD} + 0.3 V
Output voltage, V_O	−0.5 to V_{DD} + 0.3 V
Power dissipation, P_{DMAX}	500 mW
Operating temperature, T_{opt}	−40 to +85°C
Storage temperature, T_{stg}	−65 to +150°C

Comment: Exposing the device to stresses above those listed in the absolute maximum ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational section of this specification. Exposure to absolute maximum ratings for extended periods may affect device reliability.

Capacitance

$T_A = 25°C$; $V_{DD} = GND = 0$ V

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input capacitance	C_I			10	pF	f_c = 1 MHz
I/O capacitance	C_{IO}			20	pF	Unmeasured pins returned to 0 V

DC Characteristics

$T_A = -40°C$ to +85°C; $V_{DD} = 5$ V ±10%

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage high	V_{IH}	2.2		V_{DD} + 0.3	V	
Input voltage low	V_{IL}	−0.5		0.8	V	
Output voltage high	V_{OH}	0.7 (V_{DD})			V	$I_{OH} = -400\ \mu A$
Output voltage low	V_{OL}			0.4	V	I_{OL} = 2.5 mA
Input leakage current high	I_{LIH}			10	μA	$V_I = V_{DD}$
Input leakage current low	I_{LIL}			−10	μA	V_I = 0 V
Output leakage current high	I_{LOH}			10	μA	$V_O = V_{DD}$
Output leakage current low	I_{LOL}			−10	μA	V_O = 0 V
INTP input leakage current high	I_{LIPH}			10	μA	$V_I = V_{DD}$
INTP input leakage current low	I_{LIPL}			−300	μA	V_I = 0 V
Supply current (dynamic)	I_{DD1}		3.5	9	mA	
Supply current (power down mode)	I_{DD2}		2	50	μA	Input Pins $V_{IH} = V_{DD} - 0.1$ V V_{IL} = 0.1 V Output Pins Open (Note 1)

Note:

(1) In power down mode, INTP7 to INTP0, $\overline{INTAK}$ and $\overline{CS}$ must be at high level ($V_{IH} = V_{DD} - 0.1$ V).

AC Characteristics

T_A = −40 to +85°C, V_{DD} = 5 V ± 10%

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Read Timing						
A_0, $\overline{CS}$ set-up to $\overline{RD}$ ↓	t_{SAR}	0			ns	
A_0, $\overline{CS}$ hold from $\overline{RD}$ ↑	t_{HRA}	0			ns	
$\overline{RD}$ pulse width low	t_{RRL}	160			ns	
$\overline{RD}$ pulse width high	t_{RRH}	120			ns	
Data delay from $\overline{RD}$ ↓	t_{DRD}			120	ns	C_L = 150 pF
Data float from $\overline{RD}$ ↑	t_{FRD}	10		85	ns	C_L = 100 pF
Data delay from A_0, $\overline{CS}$	t_{DAD}			200	ns	C_L = 150 pF
BUFR/W delay from $\overline{RD}$ ↓	t_{DRBL}			100	ns	
BUFR/W delay from $\overline{RD}$ ↑	t_{DRBH}			150	ns	
Write Timing						
A_0, $\overline{CS}$ set-up to $\overline{WR}$ ↓	t_{SAW}	0			ns	
A_0, $\overline{CS}$ hold from $\overline{WR}$ ↑	t_{HWA}	0			ns	
$\overline{WR}$ pulse width low	t_{WWL}	120			ns	
$\overline{WR}$ pulse width high	t_{WWH}	120			ns	
Data set-up from $\overline{WR}$ ↑	t_{SDW}	120			ns	
Data hold from $\overline{WR}$ ↑	t_{HWD}	0			ns	

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Interrupt Timing						
INTP pulse width	t_{IPIPL}	100			ns	(Note 1)
SA set-up to second, third $\overline{INTAK}$ ↓	t_{SSIA}	40			ns	Slave
$\overline{INTAK}$ pulse width low	t_{IAIAL}	160			ns	
$\overline{INTAK}$ pulse width high	t_{IAIAH}	120			ns	$\overline{INTAK}$ Sequence
INT delay from INTP ↑	t_{DIPI}			300	ns	C_L = 150 pF
SA delay from first $\overline{INTAK}$ ↓	t_{DIAS}			360	ns	Master, C_L = 150 pF
Data delay from $\overline{INTAK}$ ↓	t_{DIAD}			120	ns	C_L = 150 pF
Data float from $\overline{INTAK}$ ↑	t_{FIAD}	10		85	ns	
Data delay from SA	t_{DSD}			200	ns	Slave, C_L = 150 pF
BUFR/W delay from $\overline{INTAK}$ ↓	t_{DIABL}			100	ns	C_L = 150 pF
BUFR/W delay from $\overline{INTAK}$ ↑	t_{DIABH}			150	ns	
Other Timing						
Command recovery time	t_{RV1}	120			ns	(Note 2)
$\overline{INTAK}$ recovery time	t_{RV2}	250			ns	(Note 3)
$\overline{INTAK}$/ command recovery time	t_{RV3}	250			ns	(Note 4)

Notes:

(1) The time to clear the input latch in edge-trigger mode.

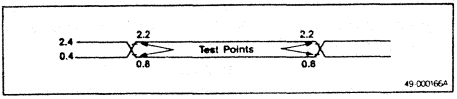
(2) The time to move from read to write operation.

(3) The time to move to the next $\overline{INTAK}$ operation.

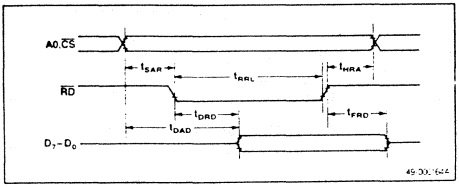
(4) The time to move $\overline{INTAK}$ to/from command (read/write).

Timing Waveforms

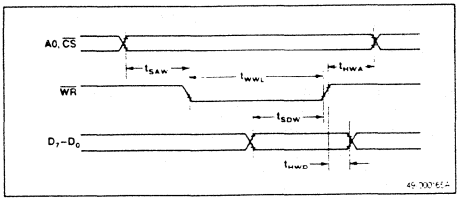
AC Test Input/Output Waveform



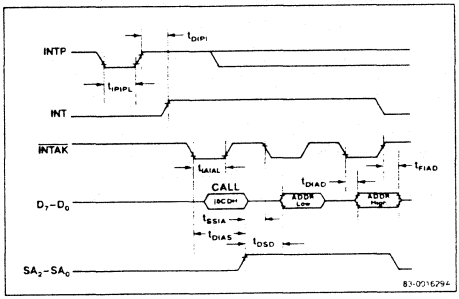
Read Cycle



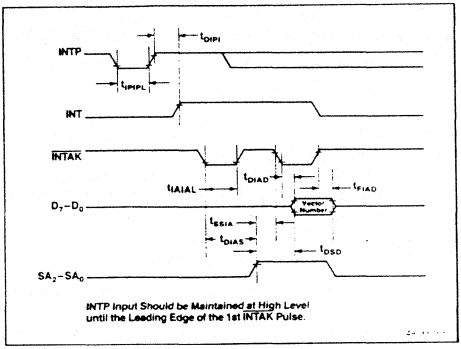
Write Cycle



INTAK Sequence (CALL Mode) μPD8085

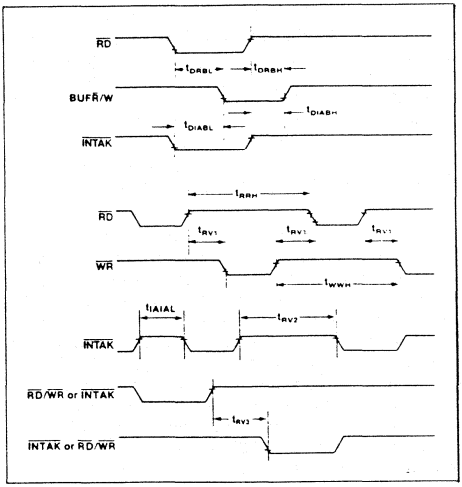


INTAK Sequence (Vector Mode) μPD70108/70116



INTP Input Should be Maintained at High Level until the Leading Edge of the 1st INTAK Pulse.

Other Timing



Interrupt Operation

Almost all microcomputer systems use interrupts to reduce software overhead when controlling peripherals. However, the number of interrupt pins on a CPU is limited. When the number of interrupt lines increases beyond that limit, external circuits like the μPD71059 become necessary.

The μPD71059 can process eight interrupt request according to an allocated priority order and transmit the signal with the highest priority to the CPU. It also supplies the CPU with information to ascertain the interrupt routine start address. Cascading μPD71059s by connecting up to eight "slave" μPD71059s to a single "master" μPD71059 permits expansion to up to a maximum of 64 interrupt request signals.

Interrupt system scale (master/slave), interrupt routine addresses, interrupt request priority, and interrupt request masking are all programmable, and can be set by the CPU.

Normal interrupt operation for a single μPD71059 is as follows. First, the initialization registers are set with a sequence of initialization words. When the μPD71059 detects an interrupt request from a peripheral to an INTP pin it sets the corresponding bit of the interrupt request register (IRR). The interrupt is checked against the interrupt mask register (IMR) and the interrupt service register (ISR). If the interrupt is not masked and there is no other interrupt with a higher priority in service or requesting service, it generates an INT signal to the CPU.

The CPU acknowledges the interrupt by bringing the $\overline{\text{INTAK}}$ line low. The μPD71059 then outputs interrupt CALL or vector data onto the data bus in response to $\overline{\text{INTAK}}$ pulses. During the last $\overline{\text{INTAK}}$ pulse, the μPD71059 sets the corresponding bit in its ISR to indicate that this interrupt is in service and to disable interrupts with lower priority. It resets the bit in the IRR at this point. When the CPU has finished processing the interrupt, it will inform the μPD71059 by sending a finish interrupt (FI) command. This resets the bit in the ISR and allows the μPD71059 to accept interrupts with lower priorities. If the μPD71059 is in the self-FI mode, the ISR bit is reset automatically and this step is not necessary.

Software Features

The μPD71059 has the following software features:

- Interrupt types: CALL/vector
- Interrupt masking: Normal/extended nesting
- End of interrupt: Self-FI/normal FI/specific FI
- Priority rotation: Normal nested/extended nested/exceptional nested
  Automatic priority rotation
  Rotate to specific priority
- Polled mode
- CPU-readable registers

Hardware Configurations

The μPD71059 has the following hardware configurations:

- Interrupt input: Edge/level sensitive
- Cascading μPD71059s: Single/extended (master/slave)
- Output driver control: Buffered/non-buffered

Mode Control

These features and configurations are selected and controlled by the four initialization words (IW1-IW4) and the three command words (IMW, PFCW, and MCW). The format of these words are shown in figures 2 and 3, respectively.

Control Words

There are two types of μPD71059 control words: initialization words and command words.

There are four initialization words: IW1-IW4. These words must be written to the μPD71059 at least once to initialize it. They must be written in sequence.

There are three types of command words: interrupt mask word (IMW), priority and finish control word (PFCW), and the mode control word (MCW). These words can be written freely after initialization.

Initialization Words

Initialization sequence. When data is written to a μPD71059 after setting $A_0 = 0$ and $D_4 = 1$, data is always accepted as IW1. This results in a default initialization as shown below. See figure 1.

(1) The edge-trigger circuit of the INTP input is reset. IRR is cleared in the edge-trigger mode.

(2) ISR and IMR are cleared.

(3) $INTP_7$ receives the lowest priority; $INTP_0$ receives the highest.

(4) The exceptional nesting mode is released. IRR is set as the register to be read.

(5) Register IW4 is cleared. The normal nesting mode, non-buffer mode, FI command mode, and CALL mode are set.

Initialization Words. The initialization words are written consecutively, and in order. The first two, IW1 and IW2, set the interrupt address or vector. IW3 specifies which interrupts are slaves for master systems, and defines the slave number of a slave system. Therefore, IW3 is only required in extended systems. The μPD71059 will only expect it if bit D_1 of IW1, SNGL = 0. IW4 is only written if bit D_0 of IW1, I4 = 1. See figure 2 for the format of the initialization words.

Command Words

The command words give various commands to a μPD71059 during its operation to change interrupt masks and priorities, to end interrupt processing, etc. See figure 3.

IMW [Interrupt Mask Word]. This word masks the IRR and disables the corresponding INTP interrupt requests. It also masks the ISR in the exceptional nesting mode. Bits M_7-M_0 correspond to the interrupt levels of $INTP_7$-$INTP_0$, respectively.

In the exceptional nesting mode, interrupts corresponding to the bits of IRR and ISR are masked if the M_n bit is set to 1.

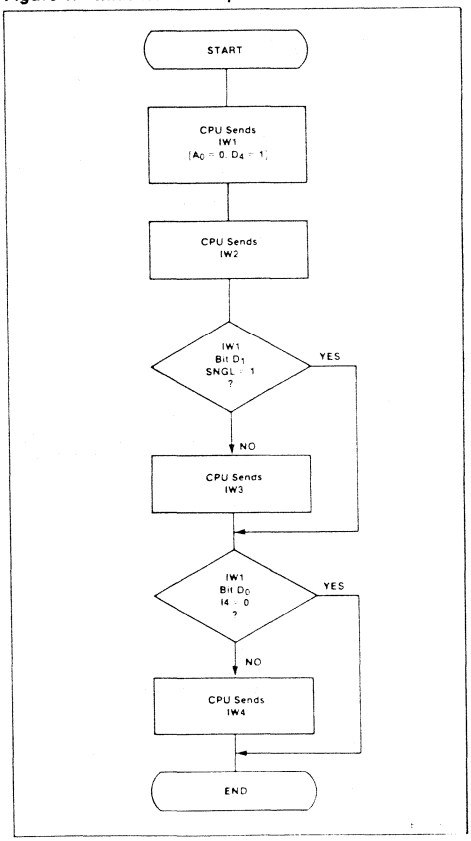
PFCW [Priority and Finish Control Word]. This word sets the FI (finish interrupt) command that defines the way that interrupts are ended, and the commands that change interrupt request priorities.

When RP (rotate priority) is set to 1, the priorities of the interrupt requests change (rotate). The priority order of the 8 INTP pins is as shown in figure 4. Setting a level as the lowest priority sets all the other levels correspondingly. For example, if $INTP_3$ is the lowest priority, $INTP_4$ will be the highest. ($INTP_7$ has the lowest priority after initialization).

SIL (specify interrupt level) is set to 1 to change the priority order or designate an interrupt level. It is used with the RP and FI bits (bits D_7 and D_5). When SIL = 1 and RP or FI = 1, the level identified by IL_2-IL_0 is designated as the lowest priority level. The other priorities will be set correspondingly. When used with FI = 1, it resets the ISR bit corresponding to the interrupt level IL_2-IL_0.

MCW [Mode Control Word]. This word is used to set the exceptional nesting mode, to poll the μPD71059, and to read the ISR and IRR registers.

Figure 1. Initialization Sequence



Bits SR and IS/$\overline{IR}$ are used to read the contents of the IRR and ISR registers. When SR = 0, no operation is performed. To read IRR or ISR, set A_0 = 0 and select the IRR or ISR register by writing to MCW. To select the IRR register, write MCW with SR = 1 and IS/$\overline{IR}$ = 0. To select the ISR, write MCW with SR = 1 and IS/$\overline{IR}$ = 1. The selection is retained, and MCW does not have to be rewritten to read the same register again. IRR and ISR are not masked by the IMR.

Figure 2. Initialization Word Formats (Sheet 1 of 2)

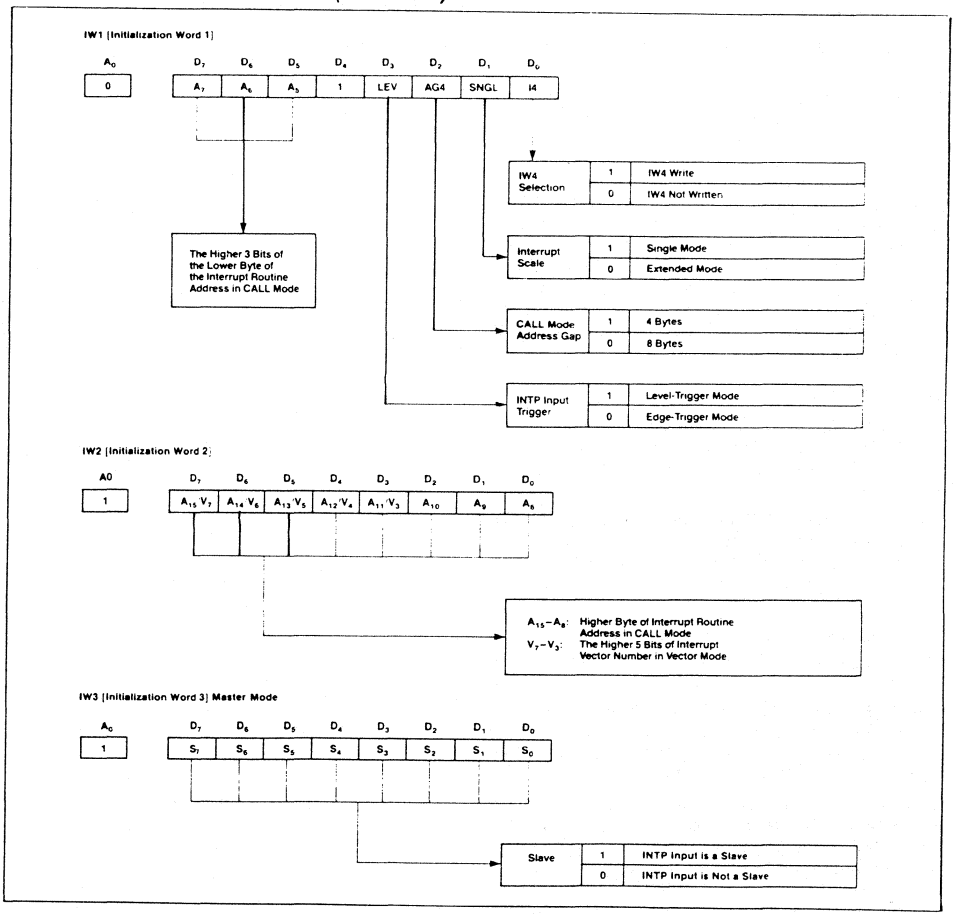


Figure 2. Initialization Word Formats (Sheet 2 of 2)

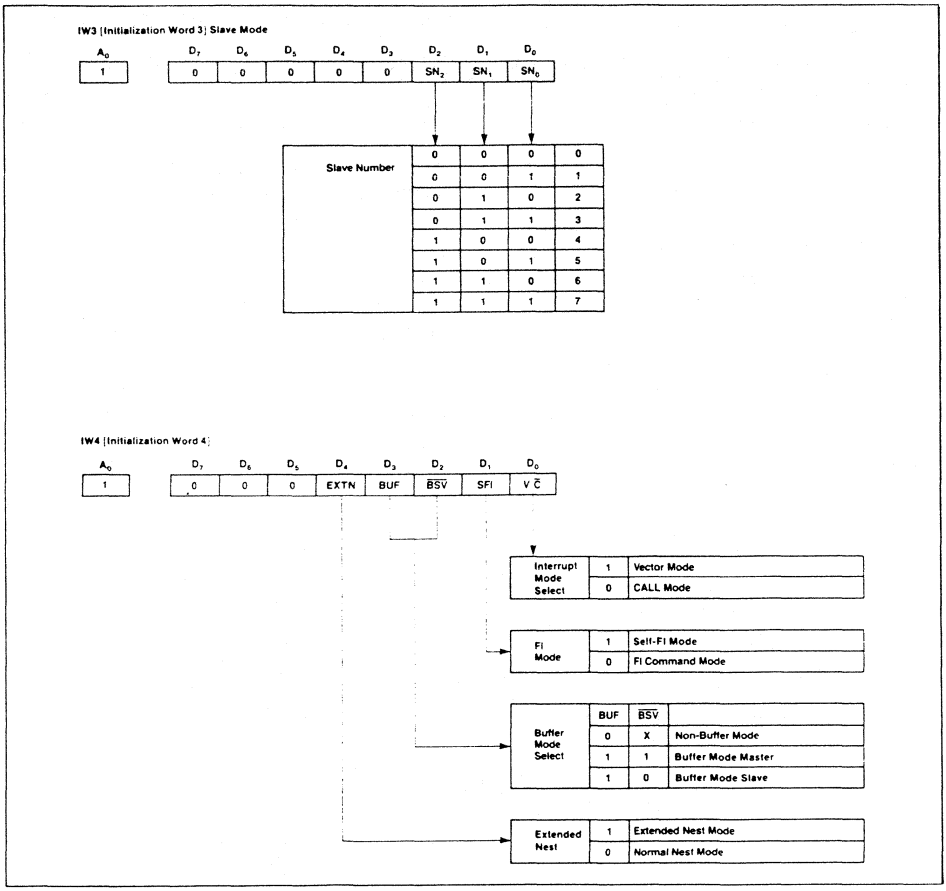


Figure 3. Command Word Format

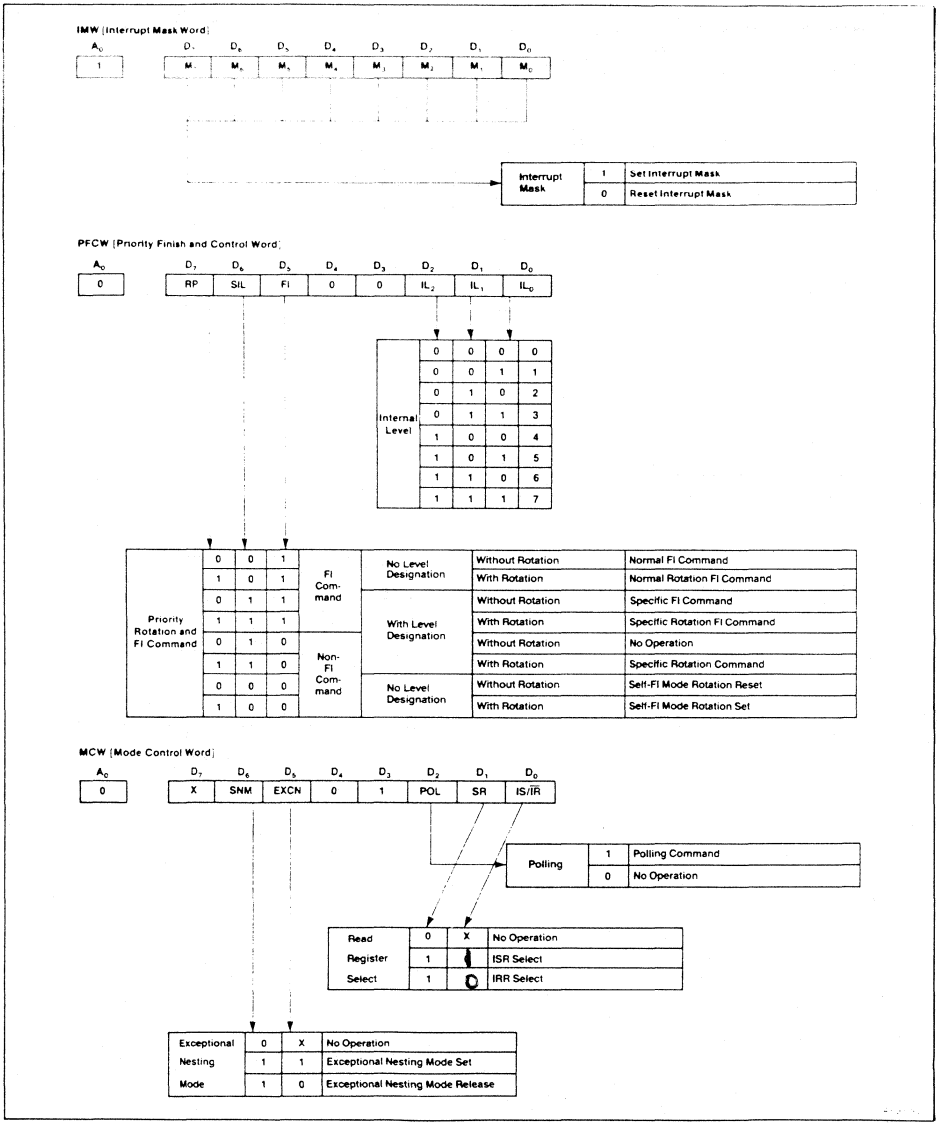
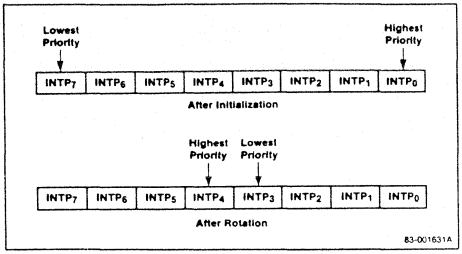


Figure 4. INTP Priority Order



CALL or Vector Modes

The μPD71059 passes interrupt routine address data to the CPU in two modes, depending on the CPU type. This mode is set by bit V/$\overline{C}$ in initialization word IW4. V/$\overline{C}$ is set to one to to select the vector mode for μPD70108/70116 CPUs, and reset to zero to select the CALL mode for μPD8085A CPUs.

CALL Mode [μPD8085A CPUs]

In this mode, when an interrupt is acknowledged by the CPU, the μPD71059 outputs three bytes of interrupt data to the data bus in its $\overline{INTAK}$ sequence. During the first $\overline{INTAK}$ pulse from the CPU, the μPD71059 outputs the CALL opcode 0CDH. During the next $\overline{INTAK}$ pulse, it outputs the lower byte of a two-byte interrupt routine address. During the third $\overline{INTAK}$ pulse, it outputs the upper byte of the address. The CPU interprets these three bytes as a CALL instruction and executes the CALL interrupt routine. See figure 5 and the $\overline{INTAK}$ sequence (CALL mode) μPD8085 diagram in the AC Timing Waveforms.

Interrupt routine addresses are set using words IW1 and IW2 during initialization. However, only the higher ten or eleven bits of the interrupt addresses are set, A_{15}-A_6 or A_{15}-A_5. The μPD71059 sets the remaining low bits (D_5-D_0 or D_4-D_0) to get the address of $INTP_n$'s interrupt routine. The addresses for $INTP_1$-$INTP_7$ are set in order of interrupt level. The space between interrupt addresses is determined by setting the AG4 bit (address gap 4 bytes) of IW1. When AG4 = 1, the interrupt routine starting addresses are 4 bytes apart. Therefore, the starting address for $INTP_n$ is the starting address for $INTP_0$ plus four times n. When AG4 = 0, starting addresses are eight bytes apart, so the starting address for $INTP_n$ is the starting address for $INTP_0$ plus eight times n. See figure 6.

Vector Mode [μPD70108/70116 CPUs]

In the vector mode, the μPD71059 outputs a one-byte interrupt vector number to the data bus in the $\overline{INTAK}$ sequence. The CPU uses that vector number to generate an interrupt routine address. See figure 7.

The higher five bits of the vector number, V_7-V_3, are set by IW2 during initialization. The μPD71059 sets the remaining three bits to the number of the interrupt input (0 for $INTP_0$, 1 for $INTP_1$, etc). See figure 8.

The CPU generates an interrupt vector by multiplying the vector number by four, and using the result as the address of a location in an interrupt vector table located at addresses 000H-3FFH. See figure 9.

System Scale Modes

The μPD71059 can operate in either single mode, with up to eight interrupt lines or extended mode, with more than one μPD71059 and more than eight interrupt lines. In extended mode a μPD71059 is in either master or slave mode.

Bit D_1, SNGL (single mode), of the first initialization word IW1 designates the scale of the interrupt system. SNGL = 1 designates that only one μPD71059 is being used (single mode system). SNGL = 0 designates an extended mode system with a master and slave μPD71059s. In the single mode (SNGL = 1), the SV input and IW4 buffer mode bits D_3 and D_2 do not indicate a master/slave relation for the μPD71059.

Single Mode

This mode is the normal mode of μPD71059 operation. It has been described in the Interrupt Operation description. See figure 10 for a system example.

Extended Mode

In this mode, up to 64 interrupt requests can be processed using a master (μPD71059 in master mode) connected to a maximum of eight slaves (μPD71059s in slave mode). See figure 11 for a system example.

Figure 5. CALL Mode Interrupt Sequence

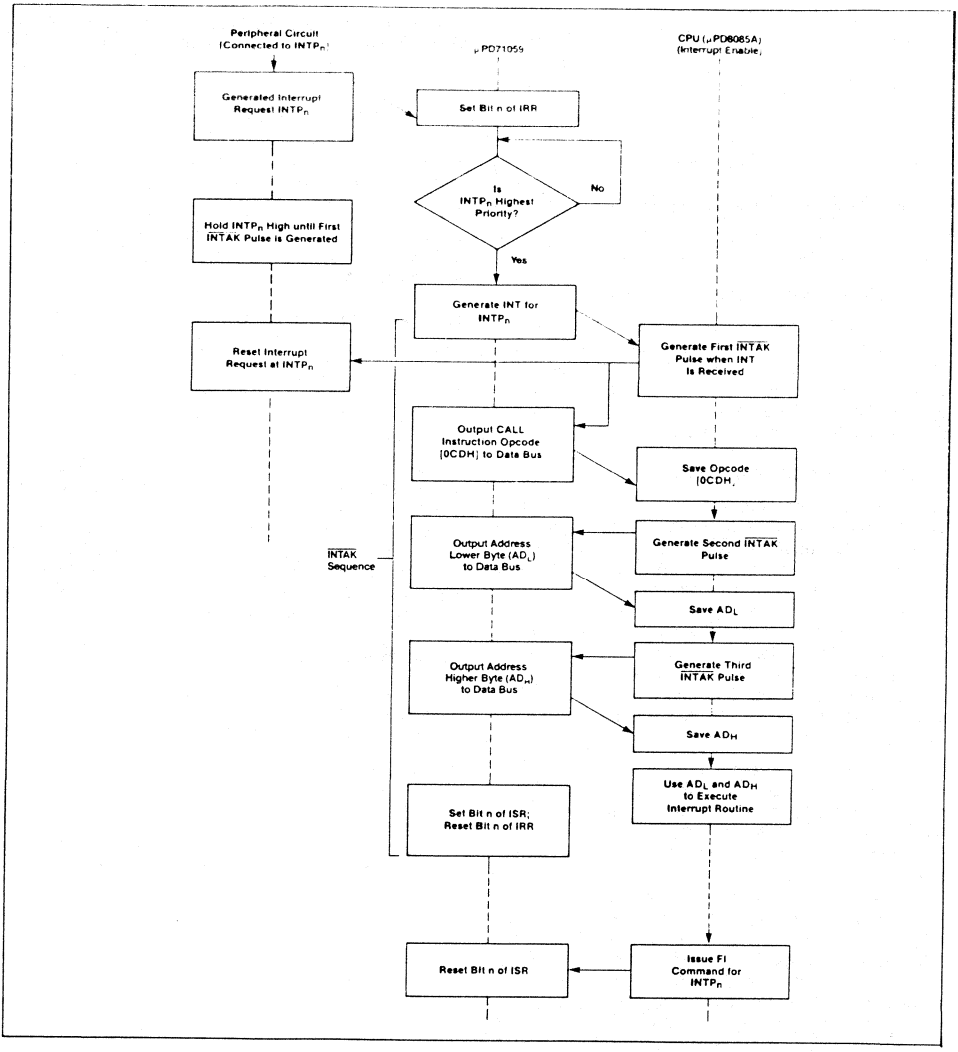
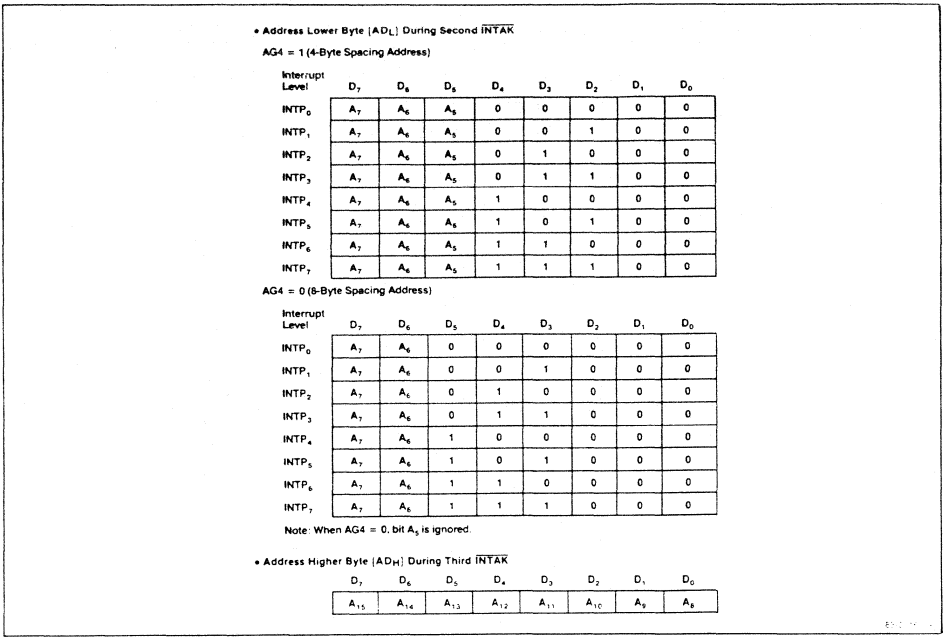


Figure 6. CALL Mode Interrupt Address Sequence



• Address Lower Byte (AD_L) During Second $\overline{INTAK}$

AG4 = 1 (4-Byte Spacing Address)

Interrupt Level	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
$INTP_0$	A_7	A_6	A_5	0	0	0	0	0
$INTP_1$	A_7	A_6	A_5	0	0	1	0	0
$INTP_2$	A_7	A_6	A_5	0	1	0	0	0
$INTP_3$	A_7	A_6	A_5	0	1	1	0	0
$INTP_4$	A_7	A_6	A_5	1	0	0	0	0
$INTP_5$	A_7	A_6	A_5	1	0	1	0	0
$INTP_6$	A_7	A_6	A_5	1	1	0	0	0
$INTP_7$	A_7	A_6	A_5	1	1	1	0	0

AG4 = 0 (8-Byte Spacing Address)

Interrupt Level	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
$INTP_0$	A_7	A_6	0	0	0	0	0	0
$INTP_1$	A_7	A_6	0	0	1	0	0	0
$INTP_2$	A_7	A_6	0	1	0	0	0	0
$INTP_3$	A_7	A_6	0	1	1	0	0	0
$INTP_4$	A_7	A_6	1	0	0	0	0	0
$INTP_5$	A_7	A_6	1	0	1	0	0	0
$INTP_6$	A_7	A_6	1	1	0	0	0	0
$INTP_7$	A_7	A_6	1	1	1	0	0	0

Note: When AG4 = 0, bit A_5 is ignored.

• Address Higher Byte (AD_H) During Third $\overline{INTAK}$

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
A_{15}	A_{14}	A_{13}	A_{12}	A_{11}	A_{10}	A_9	A_8

Figure 7. Vector Mode Interrupt Sequence

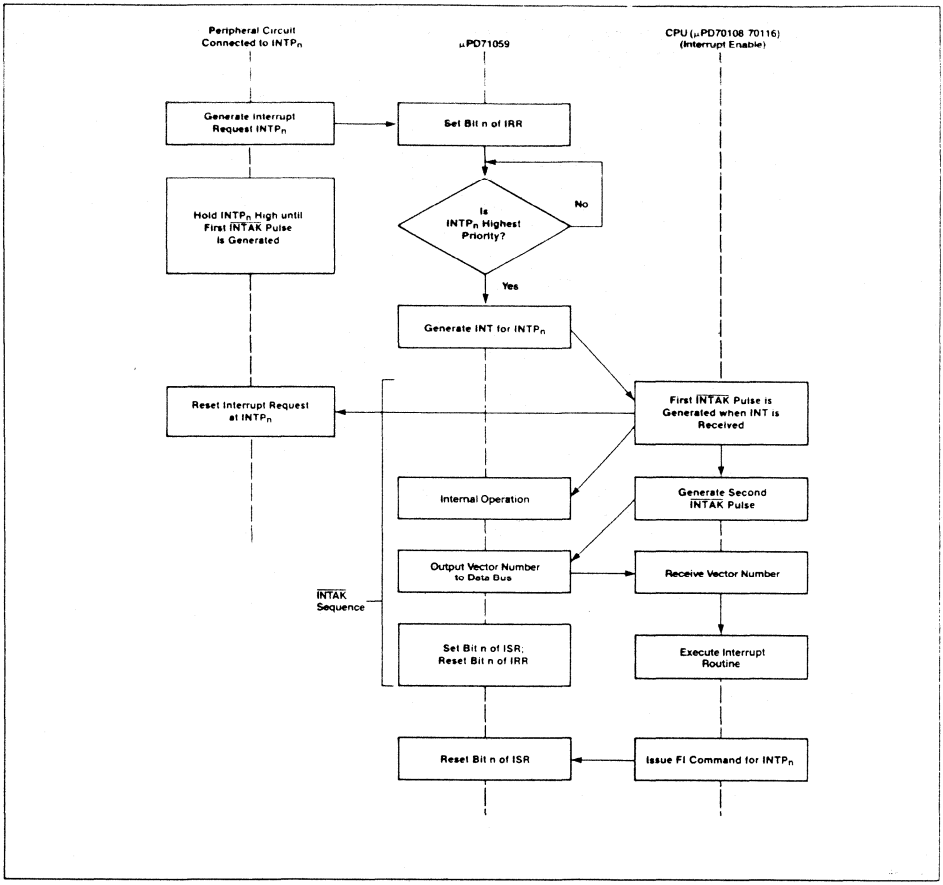


Figure 8. Vector Numbers Output In Vector Mode

Output During the Second $\overline{INTAK}$

Interrupt Levels	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
$INTP_0$	V_7	V_6	V_5	V_4	V_3	0	0	0
$INTP_1$	V_7	V_6	V_5	V_4	V_3	0	0	1
$INTP_2$	V_7	V_6	V_5	V_4	V_3	0	1	0
$INTP_3$	V_7	V_6	V_5	V_4	V_3	0	1	1
$INTP_4$	V_7	V_6	V_5	V_4	V_3	1	0	0
$INTP_5$	V_7	V_6	V_5	V_4	V_3	1	0	1
$INTP_6$	V_7	V_6	V_5	V_4	V_3	1	1	0
$INTP_7$	V_7	V_6	V_5	V_4	V_3	1	1	1

Figure 9. Interrupt Vectors for the μPD70108/70116

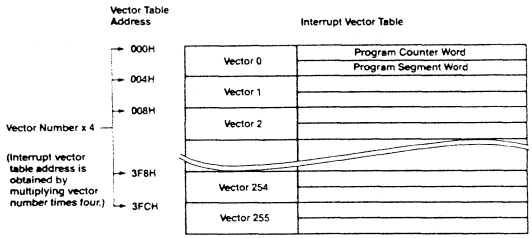


Figure 10. Single Mode System

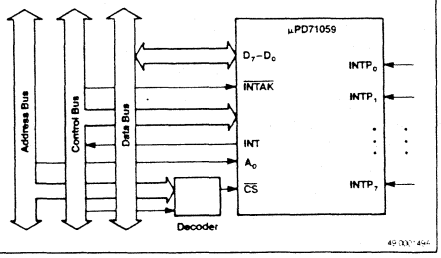
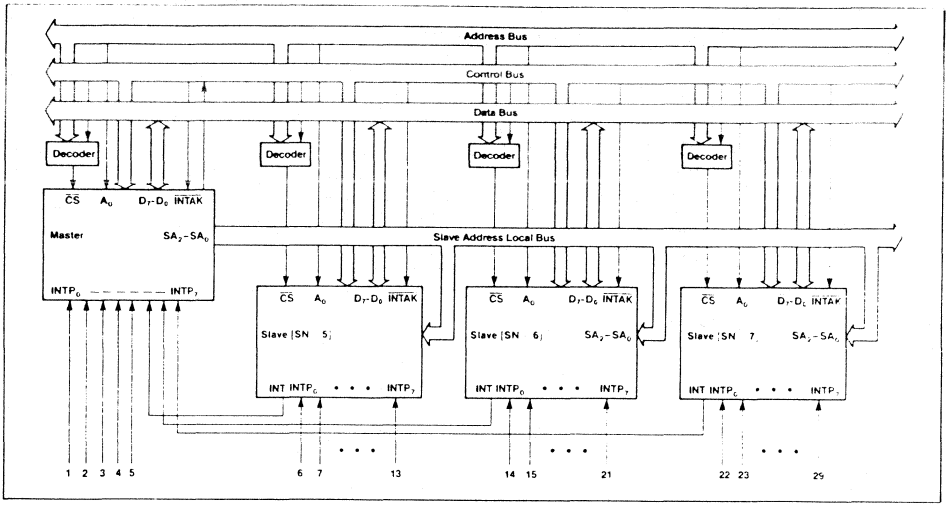


Figure 11. Extended System Example with Three Slaves



Master Mode

When a μPD71059 is a master in an extended mode system, S_7-S_0 of IW3 (master mode) define which of $INTP_7$-$INTP_0$ are inputs from slave μPD71059s or peripheral interrupts.

Consider an interrupt request from $INTP_n$. If $S_n = 0$, the interrupt is from a peripheral (for example, $INTP_0$ of the master μPD71059 in Figure 11), and the μPD71059 treats it the same way it would if it were in the single mode. SA_2-SA_0 outputs are low level and the master provides the interrupt address or vector number.

If $S_n = 1$, the interrupt is from a slave (for example, $INTP_7$ of the master). The master sends an interrupt to the CPU if the slave requesting the interrupt has priority. The master then outputs slave address n to pins SA_2-SA_0 on the first $\overline{INTAK}$ pulse by the CPU. It lets slave n perform the rest of the $\overline{INTAK}$ sequence.

Slave Mode

When a slave receives an interrupt request from a peripheral, and the slave has no interrupts with higher priority in service, it sends an interrupt request to the master through its INT output. When the interrupt is accepted by the CPU through the master, the master outputs the slave's address on pins SA_2-SA_0. Each slave compares the address on SA_2-SA_0 to its own address. The slave that sent the interrupt will find a match. It completes the $\overline{INTAK}$ sequence the same way as a single μPD71059 would.

The master outputs slave address 0 when it is processing a non-slave interrupt. Therefore, do not use 0 as a slave address if there are less than eight slaves connected to the master.

Figures 12 and 13 show the interrupt operating sequences for slaves in the extended mode.

Figure 12. Interrupt from Slave (CALL Mode)

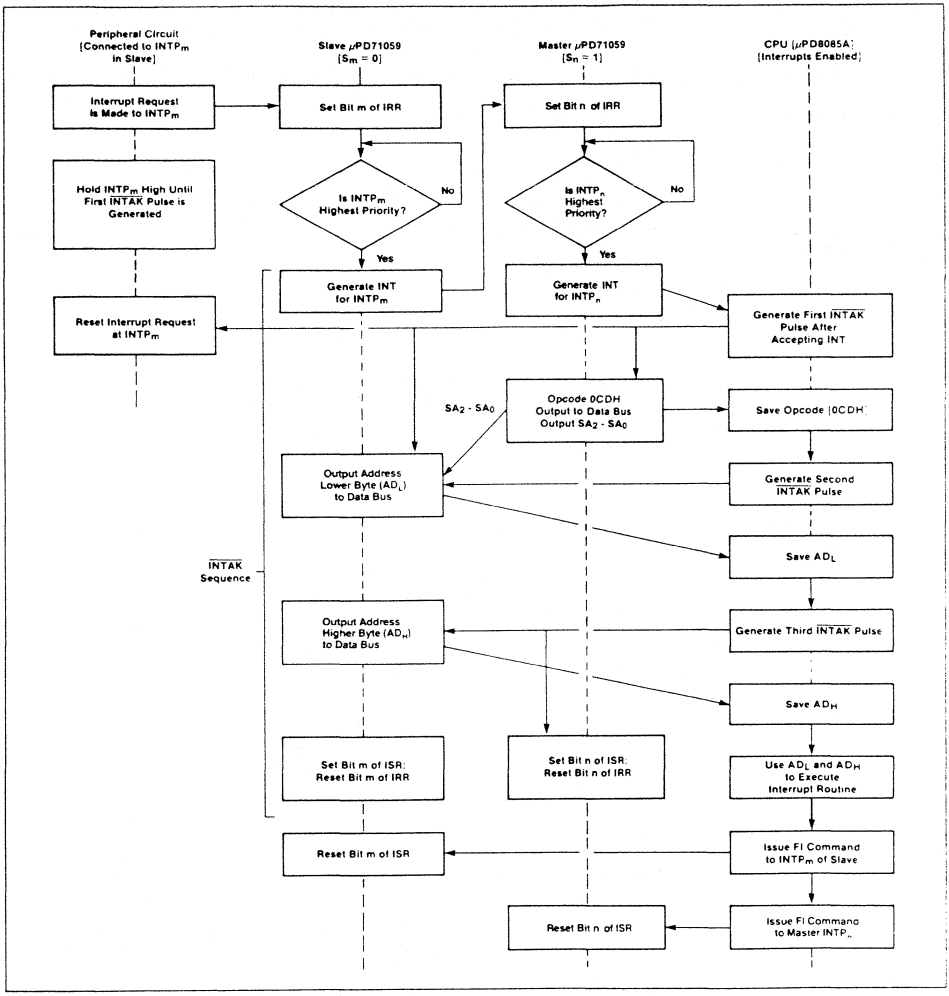
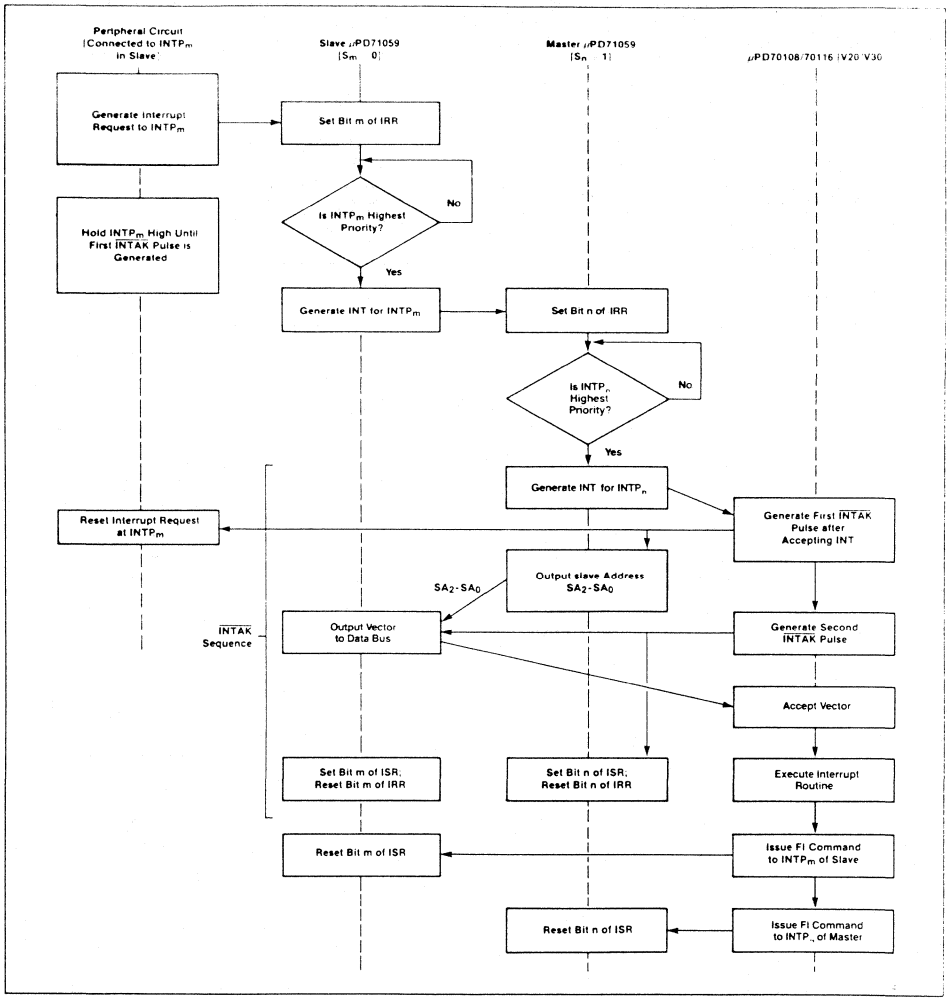


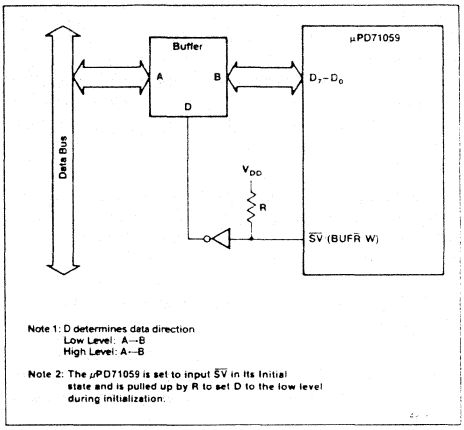
Figure 13. Interrupt from Slave (Vector Mode)



Buffer and Non-Buffer Modes

In a large system, a buffer may be needed by the μPD71059 to drive the data bus. A buffer mode is supplied, with a signal to specify the buffer direction. In the buffer mode, $\overline{SV}$ (BUF$\overline{R}$/W) is used to select the buffer direction and $\overline{SV}$ cannot be used to specify the master/slave mode. The master/slave selection must be set by IW4. IW4 bit D_3, BUF (buffer) and D_2, B$\overline{SV}$ (buffered slave) are used together to set the buffer mode and master/slave relation. When BUF = 0, the non-buffer mode is set and B$\overline{SV}$ has no meaning. When BUF = 1, the buffer mode is set. In buffer mode, the μPD71059 is a master when B$\overline{SV}$ = 1, a slave when BSV = 0. See figure 14.

Figure 14. Buffer Mode



Note 1: D determines data direction.
Low Level: A→B
High Level: A←B

Note 2: The μPD71059 is set to input $\overline{SV}$ in its initial state and is pulled up by R to set D to the low level during initialization.

Nesting Modes

The way a μPD71059 handles interrupts when there is already an interrupt in service depends on the nesting mode.

Normal Nesting Mode

This mode is set when IW4 is not written or when IW4 has EXTN = 0. It is the most common nesting mode. See figure 15.

When an interrupt is being executed in this mode (corresponding bit of ISR = 1), only interrupt requests with higher priority can be accepted.

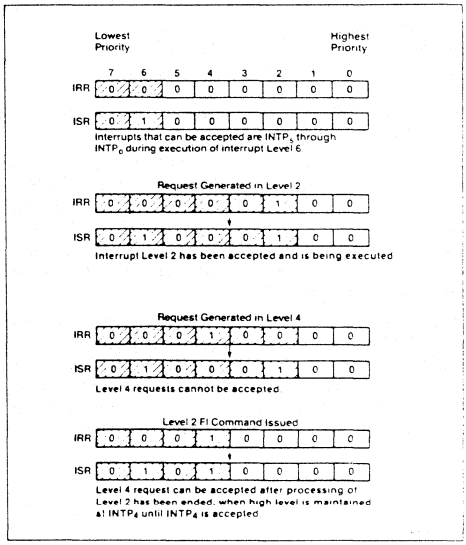
Extended Nesting Mode

This mode is only applicable to a master in the extended mode. A slave's eight interrupt priority levels become only one priority level when viewed by the master. Therefore, a request made by a slave with a higher priority than a previous request from the same slave will not be accepted. This cannot be called complete nesting since priority ranking within slaves loses its significance.

The extended nesting mode is set by setting bit D4 of IW4 in both the master and the slave. Interrupt requests of a higher level than the one currently being serviced can be accepted in the master from the same slave in the extended nesting mode.

Care should be exercised when issuing an FI (finish interrupt) command in the extended nesting mode. In an interrupt by a slave, the CPU first issues an FI command to the slave. Then, the CPU reads the slave's in-service register (ISR) to see if that slave still has interrupts in service. If there are no interrupts in service, (ISR = 00H) an FI command is issued to the master, as in the single mode when an interrupt is made by a peripheral.

Figure 15. Normal Nesting Mode



Exceptional Nesting Mode

A μPD71059 in the normal or extended nesting mode cannot accept interrupts of a lower priority than the interrupts in service. Sometimes, however, it is desirable that requests with lower priority be accepted while higher-priority interrupts are being serviced. Setting the exceptional nesting mode allows this. After releasing the exceptional mode, the previous mode is resumed.

The exceptional nesting mode is controlled by the SNM (set nesting mode) and EXCN (exceptional nesting mode) bits (D_6 and D_5) of MCW. They set and release the exceptional nesting mode. The mode doesn't change when SNM = 0. Exceptional nesting is set if SNM and EXCN = 1 and released when SNM = 1 and EXCN = 0.

Setting a bit in the IMW in the exceptional nesting mode, inhibits interrupts of that level and allows unmasked interrupts to all other levels, higher or lower priority.

The procedure for setting the exceptional nesting (EN) mode is as follows:

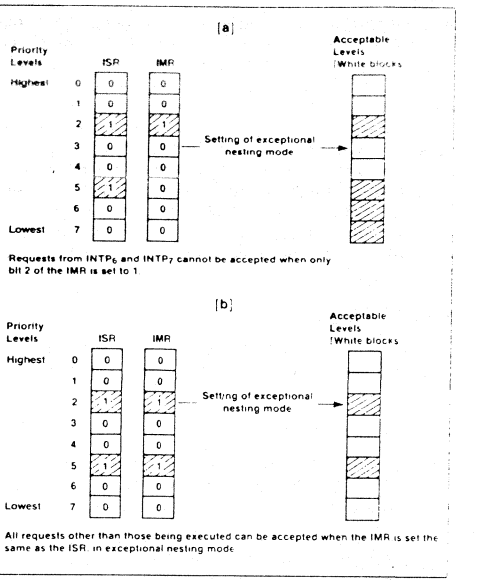
(1) Read the ISR.
(2) Write the ISR data to the IMR.
(3) Set the exceptional nesting mode.

In this way, all interrupt requests not currently in service will be enabled.

Figure 16 (a) shows what happens if IMR is not set to ISR. When the exceptional nesting is set, bit 2 of ISR will be ignored, and bit 5 will be serviced. Servicing bit 5 will mask the lower priority interrupts 6 and 7. When the ISR is set equal to the IMR as in (b), all interrupts except 2 and 5 can be serviced when the exceptional nesting mode is set.

Issuing an FI command to a level masked by the exceptional nesting mode requires caution. Since the ISR bit is masked, the normal FI command will not work. For this reason, a specific FI command specifying the ISR bit must be issued. After the exceptional mode is released, the normal FI command may be used.

Figure 16. Exceptional Nesting Mode



Finishing Interrupts (FI) and Changing the Priority Levels

The priority and finish control word (PFCW) issues FI commands and changes interrupt priorities.

Normal FI Command

	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
PFCW =	0	0	1	0	0	X	X	X

When a normal FI command is issued, the μPD71059 resets the ISR bit corresponding to the highest priority level selected from the interrupts in service. This operation assumes that the interrupt accepted last has ended.

When an interrupt routine changes the priority level or the exceptional nesting mode is set, this command will not operate correctly because the highest priority interrupt is not necessarily the last interrupt in service.

Specific FI Command

	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
PFCW =	0	1	1	0	0	IL_2	IL_1	IL_0

When the specific FI command is issued, the μPD71059 resets the ISR bit designated by bits IL_2-IL_0 of the PFCW. This command is used when the normal nesting mode isn't being used.

Self-FI Mode

When SFI of IW4 = 1, the μPD71059 is set to the self-FI mode. In this mode, the ISR bit corresponding to the interrupt is set and reset during the third $\overline{INTAK}$ pulse. Therefore, the CPU does not have to issue an FI command when the interrupt routine ends. In this mode, however, the ISR does not store the routine in service. Unless interrupts are disabled by the interrupt routine, newly generated interrupt requests are generated without priority limitation by the ISR. This can cause a stack overflow when frequent interrupt requests occur, or when the interrupt is level triggered.

Self-FI Rotation

Rotation of interrupt priorities can be added to the self-FI mode. In this case, the corresponding interrupt is set to the lowest priority level when a bit is reset in the ISR at the end of the $\overline{INTAK}$ sequence.

Self-FI Rotation Set:

	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
PFCW =	1	0	0	0	0	X	X	X

Self-FI Rotation Reset:

	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
PFCW =	0	0	0	0	0	X	X	X

Normal Rotation FI Command

	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
PFCW =	1	0	1	0	0	X	X	X

When the normal rotation FI command is issued, the μPD71059 resets the ISR bit corresponding to the highest priority level selected from the interrupts in service, then rotates the priority levels so that the interrupt just completed has the lowest priority.

Specific Rotation FI Command

	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
PFCW =	1	1	1	0	0	IL_2	IL_1	IL_0

When the specific rotation FI command is issued, the μPD71059 resets the ISR bit designated by bits IL_2-IL_0 of the PFCW and rotates the interrupt priorities so that the interrupt just reset becomes the lowest priority. This change in priority levels is different from the normal nesting mode, therefore, it is the user's responsibility to manage nesting.

Specific Rotation Command

	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
PFCW =	1	1	0	0	0	IL_2	IL_1	IL_0

When the specific rotation command is issued, the μPD71059 sets the interrupt priority specified by IL_2-IL_0 to the lowest priority. In this case also, the user must manage nesting.

Triggering Mode

Bit D_3 of the first initialization word, IW1, is LEV (level-trigger mode bit). LEV sets the trigger mode of the INTP inputs. The level-trigger mode is set when LEV = 1. The rising-edge-triggered mode is set when LEV = 0.

Edge-Trigger Mode

In the edge-trigger mode, an interrupt is detected by the rising edge of the signal on an INTP input. Although an IRR bit goes high when INTP is high, the IRR bit is not latched until the CPU returns an $\overline{INTAK}$ pulse. Therefore, the INTP input should be maintained high until $\overline{INTAK}$ is received. This filters out noise spikes on the INT lines. To send the next interrupt request, temporarily lower the INTP input, then raise it.

Level-Trigger Mode

In the level-trigger mode, an IRR bit is set by the INTP input being at a high level. As in the edge-trigger mode, the INTP must be maintained high until the $\overline{INTAK}$ is received. Interrupts are requested as long as the INTP input remains high. Care should be taken so as not to cause a stack overflow in the CPU. See figure 17.

Note: The μPD71059 operates as if the $INTP_7$ interrupt had occurred if the $\overline{INTAK}$ pulse is sent to the μPD71059 by the CPU when the μPD71059 INT output level is low. Bit 7 of ISR is not set. Accordingly, if it is expected that this will occur, the $INTP_7$ interrupt should be reserved for servicing incomplete interrupts. The FI should not be issued for incomplete interrupts. See figure 18.

Figure 17. INTP Input

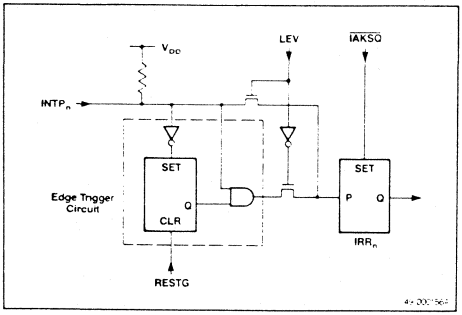
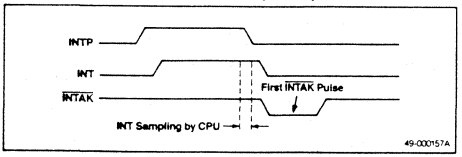


Figure 18. Incomplete Interrupt Request



Polling Operation

When polling, the CPU should disable its INT input. Next, it issues a polling command to the μPD71059 using MCW with POL = 1. This command sets the μPD71059 in polling mode until the CPU reads one of the μPD71059's registers.

When the CPU performs a read operation with $A_0 = 0$ in the polling mode, polling data as shown in figure 19 is read instead of ISR or IRR. The μPD71059 then ends the polling mode.

Figure 19. Polling Data

MCW =	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
	INT	0	0	0	0	PL_2	PL_1	PL_0

The INT bit has the same meaning as the INT pin. When it is set to 1, it means that the μPD71059 has accepted an INTP input.

The PL_2-PL_0 (permitted level) bits show which INTP input requested an interrupt when INT = 1.

If INT in the polling data is 1, the μPD71059 sets the ISR bit corresponding to the interrupt level shown by bits PL_2-PL_0 of the polling data and considers that interrupt as being executed. The CPU then processes the interrupt accordingly, based on the polling data read. An FI command should be issued when this processing ends.

Note: When a read is performed with A0 = 1 after the polling command is sent to the μPD71059, the IMR will be read instead of polling data. However, when the polling command is sent, the μPD71059 operates in the same manner when $A_0 = 0$ as it does when $A_0 = 1$. This means that although A_0 was set to 1, the μPD71059 will send the contents of the IMR, but it will also set an ISR bit just as it would if A0 had been set to zero. This may disturb the nesting. Therefore, performing a read operation with $A_0 = 1$ immediately after sending the polling command should be avoided.

Description

The μPD71071 is a high-speed, high-performance direct memory access (DMA) controller that provides high-speed data transfers between peripheral devices and memory. A programmable bus width allows bidirectional data transfer in both 8- and 16-bit systems. In addition, the μPD71071 uses CMOS technology to reduce power consumption.

The μPD71071 can perform a variety of transfer functions including byte/word, memory-to-memory, and transfers between memory and I/O. The μPD71071 also utilizes single, demand, and block mode transfers; release and bus hold modes; and normal and compressed timing.

Features

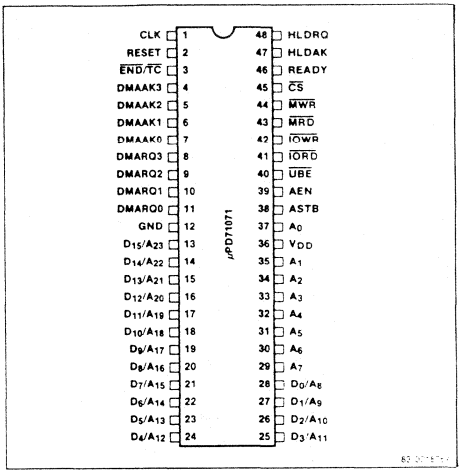
- ☐ Four independent DMA channels
- ☐ 16M-byte addressing
- ☐ 64K-byte/word transfer count
- ☐ 8- or 16-bit programmable data bus width
- ☐ Enable/disable of individual DMA requests
- ☐ Software DMA requests
- ☐ Enable/disable of autoinitialize
- ☐ Address increment/decrement
- ☐ Fixed/rotational DMA channel priority
- ☐ Terminal count output signal
- ☐ Forced transfer termination input
- ☐ Cascade capability
- ☐ Programmable DMA request and acknowledge signal polarities
- ☐ High performance: transfers to 5.33 Mbytes/s
- ☐ 8-MHz operation
- ☐ μPD70108/70116-compatible
- ☐ CMOS technology
- ☐ Low-power standby mode
- ☐ Single power supply, 5 V ±10%
- ☐ Industrial temperature range, −40 to +85 °C

Ordering Information

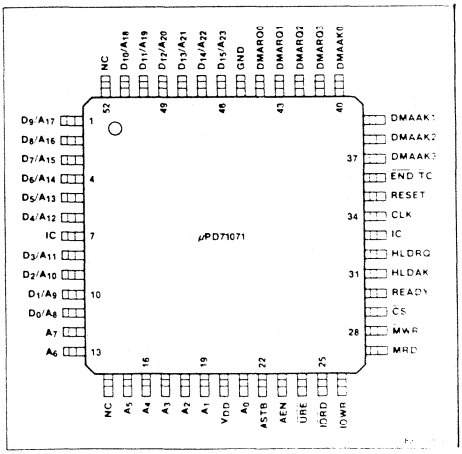
Part Number	Package Type	Maximum Frequency of Operation
μPD71071C	48-pin plastic DIP	8 MHz
μPD71071D	48-pin ceramic DIP	8 MHz
μPD71071G	52-pin plastic miniflat	8 MHz
μPD71071L	52-pin PLCC	8 MHz

Pin Configurations

48-Pin Plastic DIP, Ceramic DIP



52-Pin Plastic Miniflat



Pin Identification

Symbol	Function
A_{23}-A_8/ D_{15}-D_0	Bidirectional address/data bus
IC	Internally connected, leave open
A_7-A_4	Address bus output
NC	Not connected
A_3-A_0	Bidirectional address bus
V_{DD}	Power supply
ASTB	Address strobe output
AEN	Address enable output
$\overline{UBE}$	Upper byte enable input/output
$\overline{IORD}$	I/O read input/output
$\overline{IOWR}$	I/O write input/output
$\overline{MRD}$	Memory read output
$\overline{MWR}$	Memory write output
$\overline{CS}$	Chip select input
READY	Ready input
HLDAK	Hold acknowledge input
HLDRQ	Hold request output
CLK	Clock input
RESET	Reset input
$\overline{END}$/$\overline{TC}$	End DMA transfer input/terminal count output
DMAAK3-DMAAK0	DMA acknowledge output
DMARQ3-DMARQ0	DMA request input
GND	Ground

Pin Functions

CLK [Clock]

CLK controls the internal operation and data transfer speed of the μPD71071.

RESET [Reset]

RESET initializes the controller's internal registers and leaves the controller in the idle cycle (CPU controls the bus). Active high.

$\overline{END}$/$\overline{TC}$ [End/Terminal Count]

This is a bidirectional pin. The $\overline{END}$ input is used to terminate the current DMA transfer. $\overline{TC}$ indicates the designated cycles of the DMA count transfer have finished. $\overline{END}$/$\overline{TC}$ is open drain and requires an external pull-up resistor. Active low.

DMAAK3-DMAAK0 [DMA Acknowledge]

DMAAK3-DMAAK0 indicates to peripheral devices that DMA service has been granted. DMAAK3-DMAAK0 respond respectively to DMA channels 3-0 and the polarities are user programmable.

DMARQ3-DMARQ0 [DMA Request]

DMARQ3-DMARQ0 accept DMA service requests from peripheral devices. DMARQ3-DMARQ0 respond respectively to DMA channels 3-0 and the polarities are user programmable. DMARQ must remain asserted until DMAAK is asserted.

GND [Ground]

GND connects to the power supply ground terminal.

A_{23}-A_8/D_{15}-D_0 [Address/Data Bus]

A_{23}-A_8/D_{15}-D_0 function as a 16-bit, multiplexed address data bus when the μPD71071 is in the 16-bit data mode. In the 8-bit data mode, A_{23}-A_{16} (pins 13-20) become address bits only and A_{15}-A_8/D_7-D_0 (pins 21-28) remain an 8-bit multiplexed address/data bus. A_{23}-A_8/D_{15}-D_0 are three-state.

A_7-A_4, A_3-A_0 [Address Bus]

A_7-A_4, A_3-A_0 function as the lower eight bits of the address bus. A_7-A_4 output memory addresses during the DMA cycle and become high impedance in the idle cycle. A_3-A_0 function as the lower four bits of the address bus. In the idle cycle, A_3-A_0 become address inputs to select internal registers for the CPU to read or write. In the DMA cycle, A_3-A_0 output memory addresses.

V_{DD} [Power Supply]

V_{DD} connects to the +5-V power supply.

ASTB [Address Strobe]

ASTB latches address A_{23}-A_8 (16-bit mode)/A_{15}-A_8 (8-bit mode) from the address/data bus into an external address latch at the falling edge of ASTB during a DMA cycle. Active high.

AEN [Address Enable]

AEN enables the output of an external latch that holds DMA addresses. AEN becomes high during the DMA cycle.

$\overline{UBE}$ [Upper Byte Enable]

$\overline{UBE}$ indicates the upper byte of the data bus is valid during 16-bit mode. In the idle cycle during data transfer, the μPD71071 acknowledges data on D_{15}-D_8 when $\overline{UBE}$ is asserted. During a DMA cycle, UBE goes low to signify the presence of valid data on D_{15}-D_8. $\overline{UBE}$ has no meaning in 8-bit mode and becomes high impedance in the idle cycle and high level in the DMA cycle. Three-state, active low.

$\overline{IORD}$ [I/O Read]

In the idle cycle, $\overline{IORD}$ inputs a read signal from the CPU. In the DMA cycle, $\overline{IORD}$ outputs a read signal to an I/O device. Three-state, active low.

$\overline{IOWR}$ [I/O Write]

In the idle cycle, $\overline{IOWR}$ inputs a write signal from the CPU. In the DMA cycle, $\overline{IOWR}$ outputs a write signal to an I/O device. Three-state, active low.

$\overline{MRD}$ [Memory Read]

During the DMA cycle, $\overline{MRD}$ outputs a read signal to memory. $\overline{MRD}$ is high impedance during the idle cycle. Three-state, active low.

$\overline{MWR}$ [Memory Write]

During the DMA cycle, $\overline{MWR}$ outputs a write signal to memory. $\overline{MWR}$ is high impedance during the idle cycle. Three-state, active low.

$\overline{CS}$ [Chip Select]

During the idle cycle, $\overline{CS}$ selects the μPD71071 as an I/O device. Active low.

READY [Ready]

During a DMA operation, READY indicates that a data transfer for one cycle has been completed and may be terminated. To meet the requirements of low-speed I/O devices or memory, READY may be negated to insert wait states to extend the bus cycle until READY is again asserted.

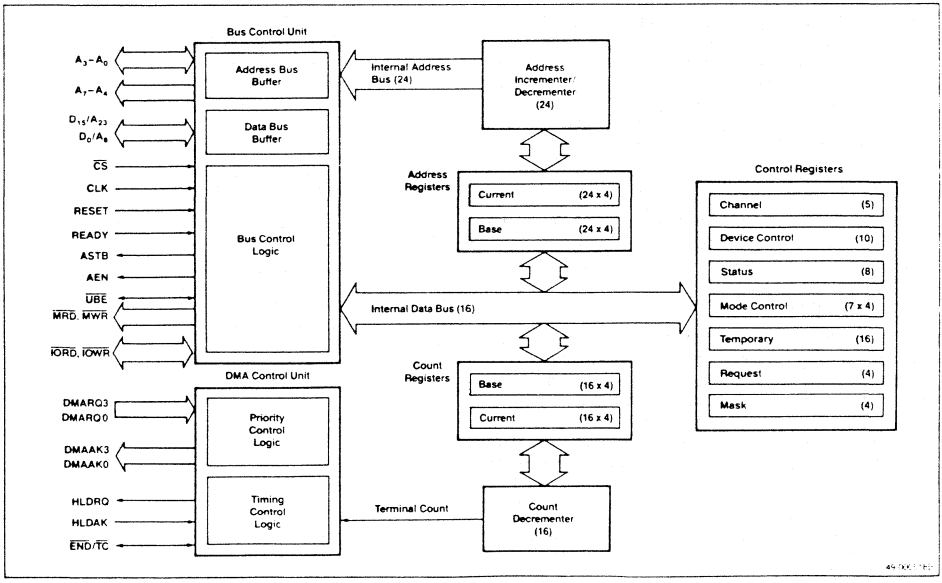
HLDAK [Hold Acknowledge]

When active, HLDAK indicates that the CPU has granted the μPD71071 the use of the system bus. Active high.

HLDRQ [Hold Request]

HLDRQ outputs a bus hold request to the CPU. Active high.

Block Diagram



Block Diagram Description

The μPD71071 has the following functional units.

- Bus control unit
- DMA control unit
- Address registers
- Address incrementer/decrementer
- Count registers
- Count decrementer
- Control registers

Bus Control Unit

The bus control unit consists of the address and data buffers, and bus control logic. The bus control unit generates and receives signals that control addresses and data on the internal address and data buses.

DMA Control Unit

The DMA control unit contains the priority and timing control logic. The priority control logic determines the priority level of DMA requests and arbitrates the use of the bus in accordance with this priority level. The DMA control unit also provides internal timing and controls DMA operations.

Address Registers

Each of the four DMA channels has one 24-bit base address register and one 24-bit current address register. The base address register holds a value determined by the CPU and transfers this value to the current address register during autoinitialization (address and count are automatically initialized). The channel's current address register is incremented/decremented for each transfer and always contains the address of the data to be transferred next.

Address Incrementer/Decrementer

The address incrementer/decrementer updates the contents of the current address register whenever a DMA transfer completes.

Count Registers

Each of the four DMA channels has one 16-bit base count register and one 16-bit current count register. The base count register holds a value written by the CPU and transfers the value to the current count register during autoinitialization. A channel's current count register is decremented for each transfer and generates a terminal count when the count register is decremented to FFFFH.

Note: The number of DMA transfer cycles is actually the value of the current count register + 1. Therefore, when programming the count register, specify the number of DMA transfers minus one.

Count Decrementer

The count decrementer decrements the contents of the current count register by one when each DMA transfer cycle ends.

Control Registers

The μPD71071 contains the following control registers.

- Channel
- Device
- Status
- Mode
- Temporary
- Request
- Mask

These registers control bus mode, pin active levels, DMA operation mode, mask bits, and other μPD71071 operating functions.

Absolute Maximum Ratings

Power supply voltage, V_{DD}	−0.5 to +7.0 V
Input voltage, V_I	−0.5 to V_{DD} + 0.3 V
Output voltage, V_O	−0.5 to V_{DD} + 0.3 V
Operating temperature, T_{OPT}	−40 to +85°C
Storage temperature, T_{STG} (D/G)	−65 to +150°C
Storage temperature, T_{STG} (C)	−40 to +125°C

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

T_A = 25°C

Parameter	Symbol	Limits Typ	Limits Max	Unit	Test Conditions
Output capacitance	C_O	4	8	pF	f_c = 1.0 MHz Unmeasured pins returned to 0 V
Input capacitance	C_I	8	15	pF	
I/O capacitance	C_{IO}	10	18	pF	

DC Characteristics

$T_A = -40$ to $+85°C$, $V_{DD} = 5\ V \pm 10\%$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input high voltage	V_{IH}	3.3		$V_{DD}+0.3$	V	CLK input pin
		2.2		$V_{DD}+0.3$	V	Other inputs
Input low voltage	V_{IL}	−0.5		0.8	V	
Output high voltage	V_{OH}	0.7 V_{DD}			V	$I_{OH} = -400\ \mu A$
Output low voltage	V_{OL}			0.4	V	$I_{OL} = 2.5$ mA; 2.7 mA (TC)
Input leakage current	I_{LI}			±10	μA	$0\ V \le V_I \le V_{DD}$
Output leakage current	I_{LO}			±10	μA	$0\ V \le V_O \le V_{DD}$
Supply current (dynamic)	I_{DD1}		15	30	mA	
Supply current (static)	I_{DD2}		10		μA	Inputs stable, outputs open

AC Characteristics

$T_A = -40$ to $+85°C$, $V_{DD} = 5\ V \pm 10\%$

Parameter	Symbol	Limits Min	Max	Unit	Test Conditions
DMA Mode					
Clock cycle	t_{CYK}	125		ns	
Clock pulse width high	t_{KKH}	44		ns	
Clock pulse width low	t_{KKL}	55		ns	
Clock rise time	t_{KR}		10	ns	1.5 V → 3.0 V
Clock fall time	t_{KF}		10	ns	3.0 V → 1.5 V
Input rise time	t_{IR}		20	ns	
Input fall time	t_{IF}		12	ns	
Output rise time	t_{OR}		20	ns	
Output fall time	t_{OF}		12	ns	
DMARQ setup time to CLK high	t_{SDQ}	35		ns	S1, S0, S3, SW, S4w
HLDRQ high delay from CLK low	t_{DHQH}		100	ns	S1, S4w
HLDRQ low delay from CLK low	t_{DHQL}		100	ns	S1, S0, S4w
HLDRQ low level period	t_{HQHQL}	$2t_{CYK}-50$		ns	S4w

Parameter	Symbol	Limits Min	Max	Unit	Test Conditions
HLDAK high setup time to CLK low	t_{SHA}	35		ns	S0, S4, S4w
AEN high delay from CLK low	t_{DAEH}		90	ns	S1, S2
AEN low delay time from CLK low	t_{DAEL}		90	ns	S1, S4w
ASTB high delay time from CLK low	t_{DSTH}		70	ns	S1
ASTB low delay time from CLK high	t_{DSTL}		70	ns	S1
ASTB high level period	t_{STSTH}	$t_{KKL}-15$		ns	
ADR/$\overline{UBE}$/$\overline{RD}$/WR (1) active delay from CLK low	t_{DA}		100	ns	S1, S2
ADR/$\overline{UBE}$/$\overline{RD}$/WR float time from CLK low	t_{FA}		70	ns	S1, S4w
ADR setup time to ASTB low	t_{SAST}	$t_{KKL}-50$		ns	
ADR hold time from ASTB low	t_{HSTA}	$t_{KKH}-20$		ns	
ADR/$\overline{UBE}$ off delay time from CLK low	t_{DAF}	0	70	ns	S1, S2
$\overline{RD}$ low delay time from ADR float	t_{DAR}	−10		ns	
Input data delay time from MRD low	t_{DMRID}		$2t_{CYK}-100$	ns	S12
Input data hold time from MRD high	t_{HMRID}	0		ns	S14
Output data delay time from CLK low	t_{DOD}	10	100	ns	S22
Output data hold time from CLK high	t_{HOD}	10		ns	S24
Output data hold time from $\overline{MWR}$ high	t_{HMWOD}	$t_{KKL}-50$		ns	

AC Characteristics (cont)

Parameter	Symbol	Limits Min	Max	Unit	Test Conditions
DMA Mode (cont)					
$\overline{RD}$ low delay time from CLK low	t_{DKLR}		70	ns	S2 normal timing
$\overline{RD}$ low delay time from CLK high	t_{DKHR}		70	ns	S2 compressed timing
$\overline{RD}$ low level period	t_{RRL1}	$2t_{CYK} - 50$		ns	Normal timing
	t_{RRL2}	$t_{CYK} + t_{KKH} - 50$		ns	Compressed timing
$\overline{RD}$ high delay time from CLK low	t_{DRH}	15	100	ns	S4
ADR delay time from RD high	t_{DRA}	$t_{CYK} - 40$		ns	
$\overline{WR}$ low delay time from CLK low	t_{DWL1}	10	70	ns	S3 normal write
$\overline{WR}$ low delay time from CLK low	t_{DWL2}	10	70	ns	S2 extended write, normal timing
$\overline{WR}$ low delay time from CLK high	t_{DWL3}	10	70	ns	S2 extended write, compressed timing
$\overline{WR}$ low level period	t_{WWL1}	$t_{CYK} - 50$		ns	Normal write
	t_{WWL2}	$2t_{CYK} - 50$		ns	Extended write, normal timing
	t_{WWL3}	$t_{CYK} + t_{KKH} - 50$		ns	Extended write, compressed timing
$\overline{WR}$ high delay from CLK low	t_{DWH}	10	80	ns	S4
$\overline{RD}$, $\overline{WR}$ low delay from DMAAK active	t_{DDARW}	0		ns	S1, S2
$\overline{RD}$ high delay time from WR high	t_{DWHRH}	5		ns	
DMAAK delay time from CLK high	t_{DKHDA}	10	70	ns	S1 I/O memory timing
DMAAK delay time from CLK low	t_{DKLDA}	10	115	ns	S1 cascade mode
DMAAK inactive delay time from CLK high	t_{DDAI1}	10	70	ns	S4
DMAAK inactive delay time from HLDAK low	t_{DDAI2}	5	$t_{KKL} + 80$	ns	S4 cascade mode, HLDAK low in S4
	t_{DDAI3}	$t_{KKL} + 80$	$4t_{CYK} - 80$	ns	S4 cascade mode, HLDAK low except in S4
DMAAK active level period	t_{DADA}	$2t_{CYK}$		ns	Cascade mode
$\overline{TC}$ low delay time from CLK high	t_{DTCL}		100	ns	S3
$\overline{TC}$ off delay time from CLK high	t_{DTCF}		40	ns	S4
$\overline{TC}$ high delay time from CLK high	t_{DTCH}		$t_{KKH} + t_{CYK} - 10$	ns	0.1 to 2.2 V, 2
$\overline{TC}$ low level period	t_{TCTCL}	$t_{CYK} - 15$		ns	
$\overline{END}$ low setup time to CLK high	t_{SED}	35		ns	S2
$\overline{END}$ low level period	t_{EDEDL}	100		ns	
READY setup time to CLK high	t_{SRY}	35		ns	S3, SW
READY hold time from CLK high	t_{HRY}	20		ns	S3, SW

Note:

(1) $\overline{RD}$/$\overline{WR}$ refers to $\overline{IORD}$ or $\overline{MRD}$ and $\overline{IOWR}$ or $\overline{MWR}$, respectively.

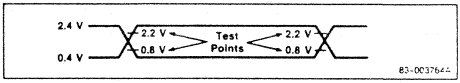
(2) For $\overline{END}$/$\overline{TC}$, output load capacitance = 75 pF maximum. To meet the t_{DTCH} parameter use a 2.2-kΩ pull-up resistor with a load capacitance of 75 pF. For other than $\overline{END}$/$\overline{TC}$, output load capacitance = 100 pF maximum.

AC Characteristics (cont)

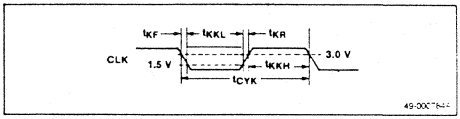
Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Programming Mode and RESET					
$\overline{IOWR}$ low level period	t_{IWIWL}	100		ns	
$\overline{CS}$ low setup time to $\overline{IOWR}$ high	t_{SCSIW}	100		ns	
CS hold time from $\overline{IOWR}$ high	t_{HIWCS}	0		ns	
ADR/$\overline{UBE}$ setup time to $\overline{IOWR}$ high	t_{SAIW}	100		ns	
ADR/$\overline{UBE}$ hold time from $\overline{IOWR}$ high	t_{HIWA}	0		ns	
Input data setup time to $\overline{IOWR}$ high	t_{SIDIW}	100		ns	
Input data hold time from $\overline{IOWR}$ high	t_{HIWID}	0		ns	
$\overline{IORD}$ low level period	t_{IRIRL}	150		ns	
ADR/$\overline{CS}$ setup time to $\overline{IORD}$ low	t_{SAIR}	35		ns	
ADR/$\overline{CS}$ hold time from $\overline{IORD}$ high	t_{HIRA}	0		ns	
Output data delay time from $\overline{IORD}$ low	t_{DIROD}		120	ns	
Output data float time from $\overline{IORD}$ high	t_{FIROD}		100	ns	
RESET high level period	t_{RESET}	$2t_{CYK}$		ns	
V_{DD} setup time to RESET low	t_{SVDD}	500		ns	
$\overline{IOWR}$/$\overline{IORD}$ wait time from RESET low	t_{SYIWR}	$2t_{CYK}$		ns	RESET low to first read/write
$\overline{IOWR}$/$\overline{IORD}$ recovery time	t_{RVIWR}	200		ns	

Timing Waveforms

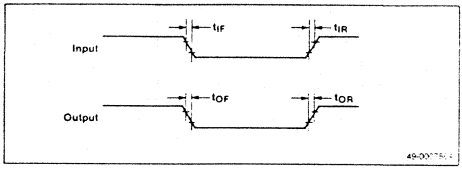
Timing Measurement Points



Clock Timing

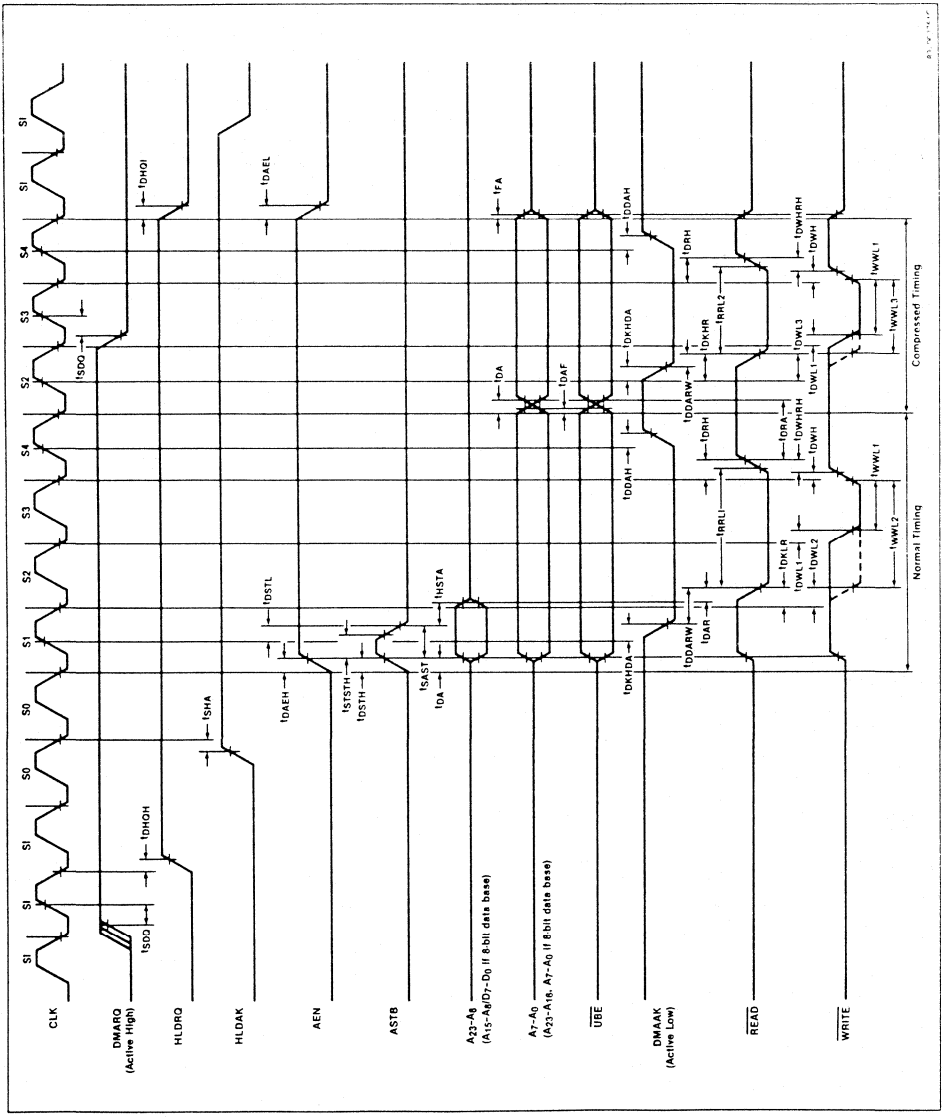


Input/Output Edge Timing



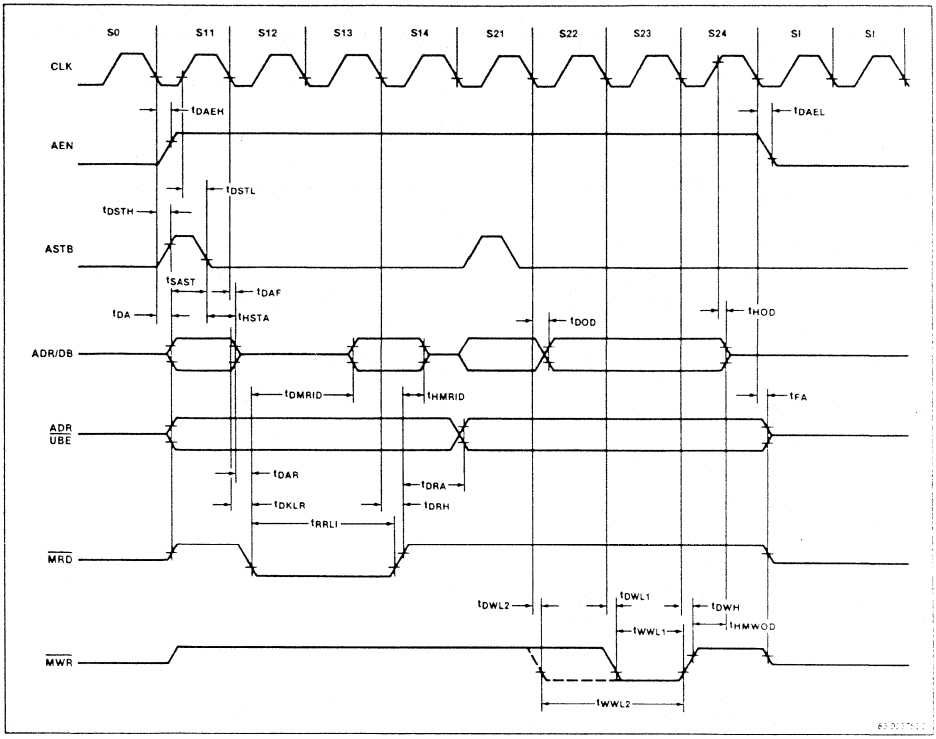
Timing Waveforms (cont)

Directional I/O-Memory Transfer Timing

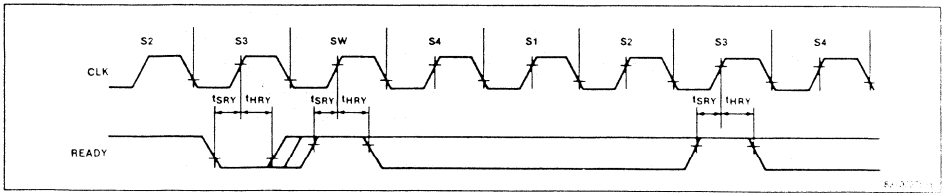


Timing Waveforms (cont)

Memory-to-Memory Transfer Timing

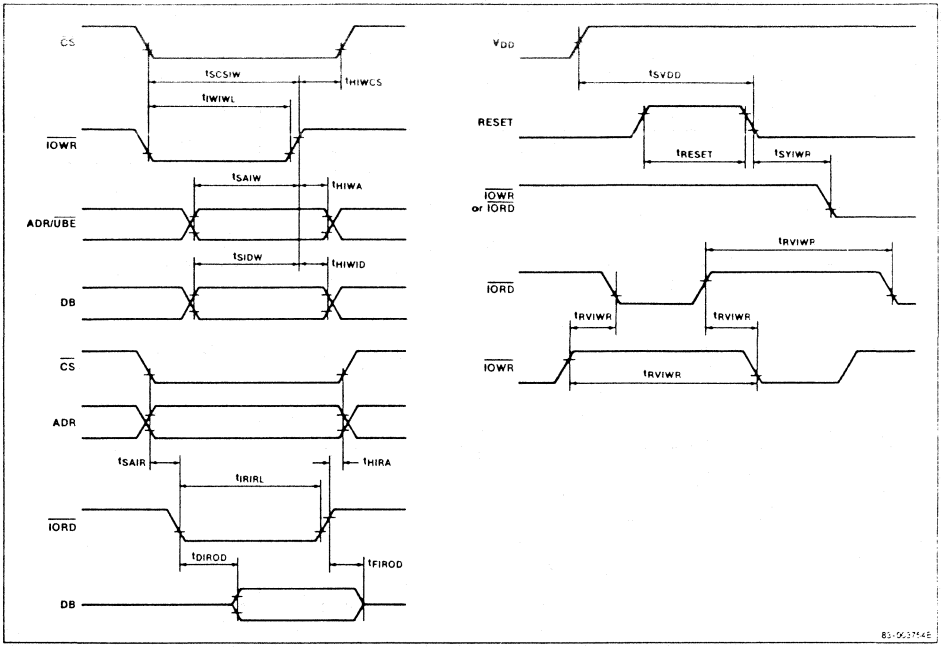


Ready Timing

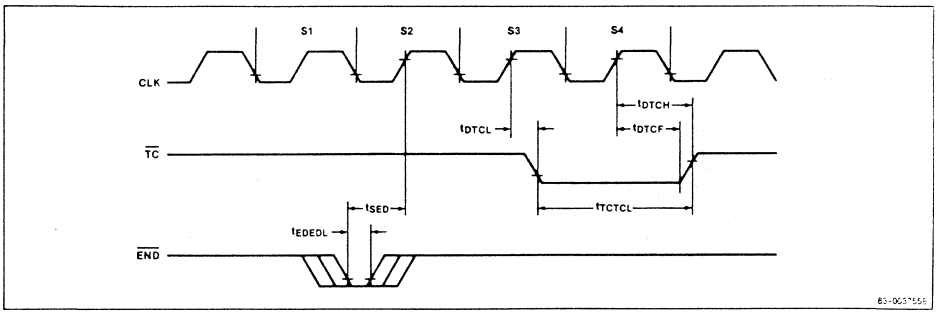


Timing Waveforms (cont)

Programming Mode and RESET Timing

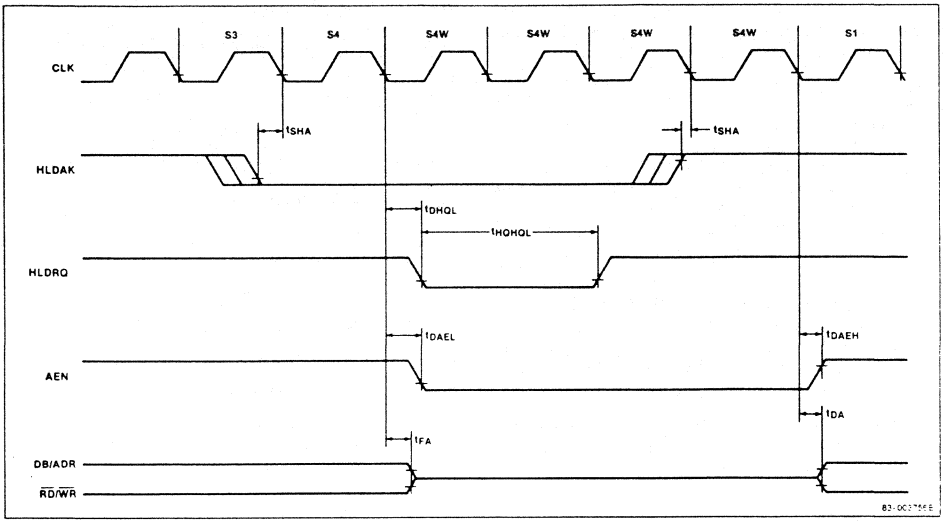


END/TC Timing

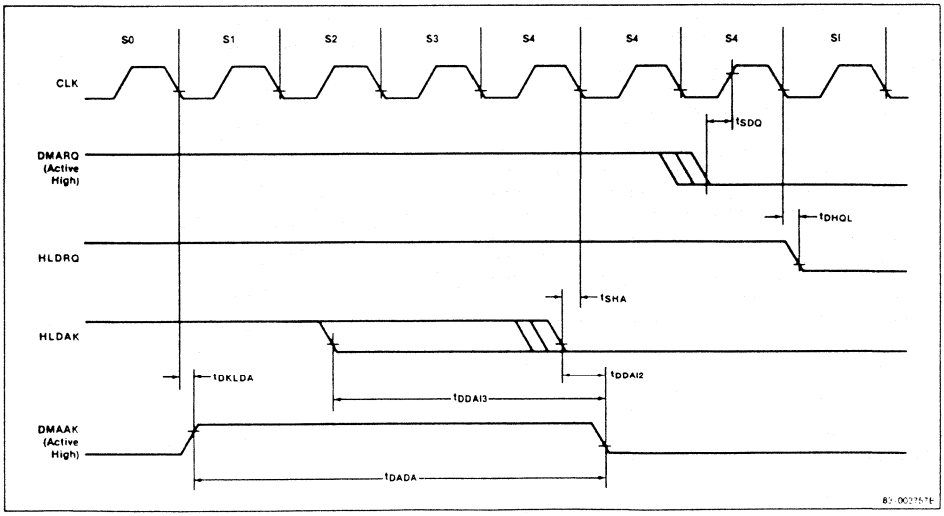


Timing Waveforms (cont)

Bus Wait Timing



Cascade Timing



Functional Description

DMA Operation

The μPD71071 functions in three cycles: idle, DMA, and standby. In an idle or standby cycle, the CPU uses the bus, while in a DMA cycle, the μPD71071 uses it.

Idle Cycle. In an idle cycle, there are no DMA cycles active, but there may be one or more active DMA requests; however, the CPU has not released the bus. The μPD71071 will sample the four DMARQ input pins at every clock. If one or more inputs are active, the corresponding DMA request bits (RQ) are set in the status register and the μPD71071 sends a bus hold request to the CPU. The μPD71071 continues to sample DMA requests until it obtains the bus.

After the CPU returns a HLDAK signal and the μPD71071 obtains the bus, the μPD71071 stops DMA sampling and selects the DMA channel with the highest priority from the valid DMA request signals. Programming of the μPD71071 is done when the μPD71071 is in the idle cycle or the standby mode.

DMA Cycle. In a DMA cycle, the μPD71071 controls the bus and performs DMA transfer operations based on programmed information. Figure 1 outlines the sequential flow of a DMA operation.

Standby Mode. The μPD71071 can also be used in standby mode. It is in standby mode and consumes the static supply current (I_{DD2}) when the clock is turned off and no I/O read or write operations are being performed. All internal registers will retain their contents.

The μPD71071 can be programmed (using $\overline{IOWR}$) and read (using $\overline{IORD}$) with the clock off. The μPD71071 only uses the clock for the DMA data transfer cycles. The clock may be turned off without altering the internal registers when the μPD71071 is in the idle cycle. If the clock is turned off during a DMA transfer, the μPD71071 will not operate correctly. When the clock is off, the DMARQ inputs will not be recognized. The DMARQ inputs could be externally logically ORed and cause an interrupt to the CPU. The CPU could then turn on the clock, thus activating the μPD71071. If the previously programmed mode of operation is still valid, the μPD71071 does not have to be reprogrammed.

Data Bus Width

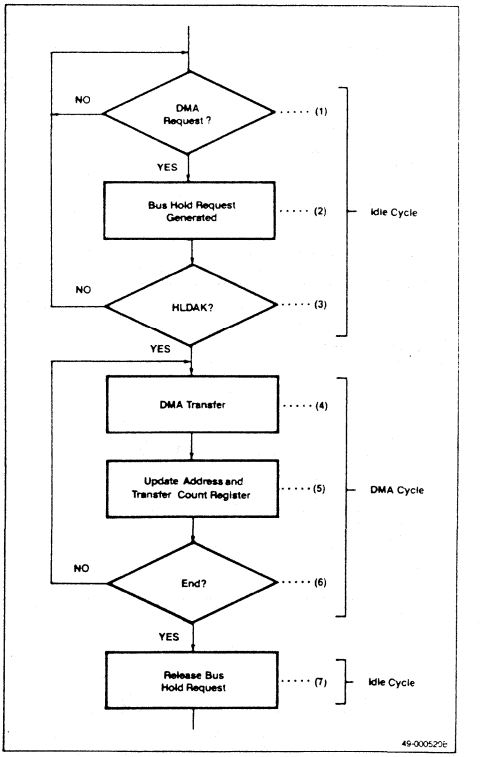
In order to allow an easy interface with an 8- or 16-bit CPU, the data bus width of the μPD71071 is user programmable for 8 or 16 bits. A 16-bit data bus allows 16-bit memory-to-memory DMA transfers and also provides a one-I/O bus cycle access to the 16-bit internal registers.

Table 1 shows the relationship of the data bus width, A_0, $\overline{UBE}$, and the internal registers.

Table 1. Data Bus Width

Bus Width	A_0	$\overline{UBE}$	Internal Read/Write Registers
8 bits	X	X	D_7-D_0 ⟷ 8-bit internal register
16 bits	0	1	D_7-D_0 ⟷ 8-bit internal register
	1	0	D_{15}-D_8 ⟷ 8-bit internal register
	0	0	D_{15}-D_0 ⟷ 16-bit internal register

Figure 1. DMA Operation Flow



Terminal Count

The μPD71071 ends DMA service when it generates a terminal count ($\overline{TC}$) or when the $\overline{END}$ input becomes active. A terminal count is produced when a borrow is generated by the current count register and a low-level pulse is output to the $\overline{TC}$ pin. Figure 2 shows that the current count register is tested after each DMA operation.

If autoinitialize is not set when DMA service ends, the mask register bit applicable to the channel where service ended is set, and the DMARQ input of that channel is masked.

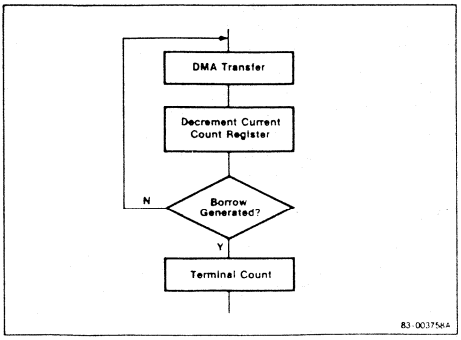
DMA Transfer Type

The type of transfer the μPD71071 performs depends on the following conditions.

- Memory-to-memory transfer enable
- Direction of memory-to-I/O transfer (each channel)
- Transfer mode (each channel)
- Bus mode

Memory-to-Memory Transfer Enable. The μPD71071 can perform memory-to-I/O transfers (one transfer cycle in one bus cycle) and memory-to-memory transfers (one transfer in two bus cycles). To select memory-to-memory transfer, set bit 0 of the device control register to 1. The DMA channels used in memory-to-memory transfers are fixed, with channel 0 as the source channel and channel 1 as the destination channel. Channels 2 and 3 cannot be used in memory-to-memory transfers. The contents of the count registers and word/byte transfer modes of channels 0 and 1 should be the same when performing memory-to-memory transfer.

Figure 2. Generation of Terminal Count ($\overline{TC}$)



For memory-to-memory byte transfer in 16-bit data bus mode, a read data from upper data bus is to be written to upper data bus, while a read data from lower data bus is to be written to lower data bus. Therefore, start addresses for source and destination must be the even-even or odd-odd. For word transfer, only even-even addresses are to be set for source and destination. (See Byte/Word Transfer paragraphs below.) When DMARQ0 (channel 0) becomes active, the transfer is initiated.

During memory-to-memory bus cycles in the 16-bit mode, data read from the DMAC's upper (lower) data bus is written to the upper (lower) data bus of the destination device. Thus, for word transfers, only even source and destination addresses should be used.

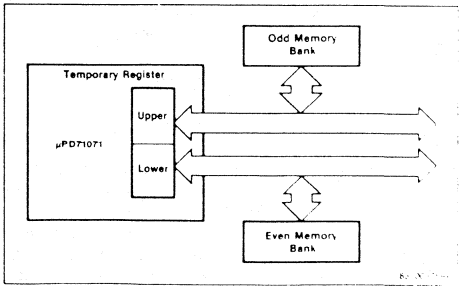
The DMA request input pin or a software DMA request to channel 0 may initiate memory-to-memory transfers. The μPD71071 performs the following operations until a channel 1 terminal count or $\overline{END}$ input is present:

- During the first bus cycle, the memory data pointed to by the current address register of channel 0 is read into the temporary register of the μPD71071 and the address and count of channel 0 are updated.
- During the second bus cycle, the temporary register data is written to the memory location shown by the current address register of channel 1, and the address and count of channel 1 are updated.

Note: If DMARQ1 (channel 1) becomes active, the μPD71071 will perform memory-to-I/O transfer even though memory-to-memory transfer is selected. Since this may cause erroneous memory-to-memory transfers, mask out channel 1 (DMARQ1) by setting bit 1 of the mask register to 1 before starting memory-to-memory transfers.

During memory-to-memory transfers, the addresses on the source side (channel 0) can be fixed by setting bit 1 of the device control register to 1. In this manner, a

Figure 3. Memory-to-Memory Transfer in 16-Bit Data Bus Mode



range of memory can be initialized with the same value since the contents of the source address never change. During memory-to-memory transfer, the DMAAK signal and channel 0's terminal count ($\overline{TC}$) pulse are not output. (See figure 3.)

Direction of Memory-to-I/O Transfers. All DMA transfers use memory as a reference point. Therefore, a DMA read reads a memory location and writes to an I/O port. A DMA write reads an I/O port and writes the data to a memory location. In memory-to-I/O transfer, use the mode control register to set one of the transfer directions in table 2 for each channel and activate the appropriate control signals.

Table 2. Transfer Direction

Transfer Direction	Activated Signals
Memory → I/O (DMA read)	$\overline{IOWR}$, $\overline{MRD}$
I/O → memory (DMA write)	$\overline{IORD}$, $\overline{MWR}$
Verify (Outputs addresses only. Does not perform a transfer.)	—

Transfer Modes. In memory-to-I/O transfer, the mode control register selects the single, demand, or block mode of DMA transfer for each channel. The conditions for the termination of each transfer characterize each transfer mode. Memory-to-memory transfers have no relationship to single, demand, or block mode. Memory-to-memory transfers are a separate and distinct type of transfer mode. Table 3 shows the various transfer modes and termination conditions.

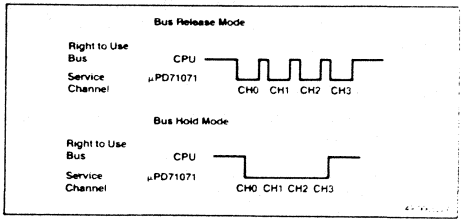
Table 3. Transfer Termination

Transfer Mode	End of Transfer Conditions
Single	After each byte/word
Demand	$\overline{END}$ input Generation of terminal count When DMA request of the channel in service becomes inactive When DMA request of a channel in higher priority becomes active (bus hold mode)
Block	$\overline{END}$ input Generation of terminal count
Memory-to-memory	$\overline{END}$ input Generation of terminal count

Bus Modes. The device control register selects either the bus release or bus hold mode. The bus mode determines when the μPD71071 returns the system bus to the CPU. The μPD71071 can be in either the release or hold modes for the single, demand, or block mode transfers. Therefore, there are six possible mode combinations.

Figure 4 shows that in bus release mode, only one channel can receive service after obtaining the bus. When DMA service ends (end of transfer conditions depend on the transfer mode), the channel returns the bus to the CPU (regardless of the state of other DMA requests) and the μPD71071 enters the idle cycle. When the μPD71071 regains use of the bus, a new DMA operation begins.

Figure 4. Bus Modes



In bus hold mode, several channels can receive service without releasing the bus after obtaining it. If there is another valid DMA request when a channel's DMA service is finished, the new DMA service can begin after the previous service without returning the bus to the CPU. End of transfer conditions depend on the transfer mode. A channel cannot terminate (end count) a transfer mode and immediately start on its next set of transfers. There must be another DMA channel service interleaved or the μPD71071 will put in an idle cycle. The following shows an example of the possible sequences for Channel 2.

CHAN2 → CHANn (n = 0,1,3) → CHAN2
or,
CHAN2 → idle → CHAN2

The operation of single, demand, and block mode transfers depends on whether the μPD71071 is in bus release or bus hold mode. In bus release mode, only one type of bus mode (single, demand, or block) is used each time the μPD71071 has the bus. In bus hold mode, multiple types of transfers are possible. Channel 0 might operate in the demand mode, and channel 1, which could get the bus immediately after channel 0, could operate in block mode.

Single Mode Transfer

In bus release mode, when a channel completes the transfer of a single byte or word, the μPD71071 enters the idle cycle regardless of the state of the DMA request inputs. In this manner, other devices will be able to access the bus on alternate bus cycles.

In bus hold mode, when a channel completes the transfer of a single byte or word, the μPD71071 terminates the channel's service even if it is still asserting a DMA request signal. The μPD71071 will then service the highest priority channel requesting the bus. If there are no requests from any other channel, the μPD71071 releases the bus and enters the idle cycle.

Demand Mode Transfer

In bus release mode, the currently active channel continues its data transfer as long as the DMA request of that channel is active, even though other DMA channels are issuing higher priority requests. When the DMA request of the serviced channel becomes inactive, the μPD71071 releases the bus and enters the idle state, even if the DMA request lines of other channels are active.

In bus hold mode, when the active channel completes a single transfer, the μPD71071 checks DMA request lines (other request lines when $\overline{END}$ or TC, all request lines including the last serviced channel when there is no $\overline{END}$ or TC). If there are active requests, the μPD71071 starts servicing the highest priority channel requesting service. If there is no request, the μPD71071 releases the bus and enters the idle state.

Block Mode Transfer

In bus release mode, the current channel continues data transfer until a terminal count or the external $\overline{END}$ signal becomes active. During this time, the μPD71071 ignores all other DMA requests. After completion of the block transfer, the μPD71071 releases the bus and enters the idle cycle even if DMA requests from other channels are active.

In bus hold mode, the current channel transfers data until a terminal count or the external $\overline{END}$ signal becomes active. When the service is complete, the μPD71071 checks all DMA requests without releasing the bus. If there is an active request, the μPD71071 immediately begins servicing the request. The μPD71071 releases the bus after it honors all DMA requests or a higher priority bus master requests the bus.

Figure 5 shows the operation flow for the six possible transfer and bus mode operations in DMA transfer.

Byte/Word Transfer

If the initialize command selects a 16-bit data bus width, the mode control register can specify DMA transfer in byte or word units for each channel. Table 4 shows the update of the address and count registers during byte/word transfer.

Table 4. Address and Count Registers

Register	Byte Transfer	Word Transfer
Address	± 1	± 2
Count	−1	−1

During word transfers, two bytes starting at an even address are handled as one word. If word transfer is selected and the initial value of the set address is odd, the μPD71071 will always decrement that address by 1, thus making the address even for the data transfer. For this reason, it is best to select even addresses when transferring words, to avoid destroying data. A_0 and $\overline{UBE}$ control byte and word transfers.

Table 5 shows the relationship between the data bus width, A_0 and $\overline{UBE}$ signals, and data bus status.

Table 5. Data Bus Status

Data Bus Width	A_0	$\overline{UBE}$	Data Bus Status
8 bits	X	1 (1)	D_7-D_0 valid byte
16 bits	0	1	D_7-D_0 valid byte
	1	0	D_{15}-D_8 valid byte
	0	0	D_{15}-D_0 valid word

Note:

(1) Always 1 for an 8-bit bus.

Compressed Timing

In transfers between I/O and memory, a DMA transfer cycle is normally executed in four clocks. However, when the device control register selects compressed timing, one DMA cycle can be executed in a three-clock bus cycle. Compressed timing may be used in the release or hold modes when doing block transfers between I/O and memory. In the demand mode, only use compressed timing in the bus release mode. Compressed timing mode increases data transfer rates by 33%.

The μPD71071 is able to omit one clock period during compressed timing by not updating the upper 16 bits of the latched address. In block mode and demand bus release mode, addresses are output sequentially and the upper 16 bits of addresses latched in external latches need not be updated except after a carry or borrow from A_7 to A_8. For this reason, during compressed timing, the S1 state (output of upper 16 bits of an address for external latching) is omitted in the bus cycles except during the first bus cycle when the upper 16 bits of an address are changed. Figure 6 shows one word waveforms for normal and compressed timing

Figure 5. Transfer and Bus Modes Operations

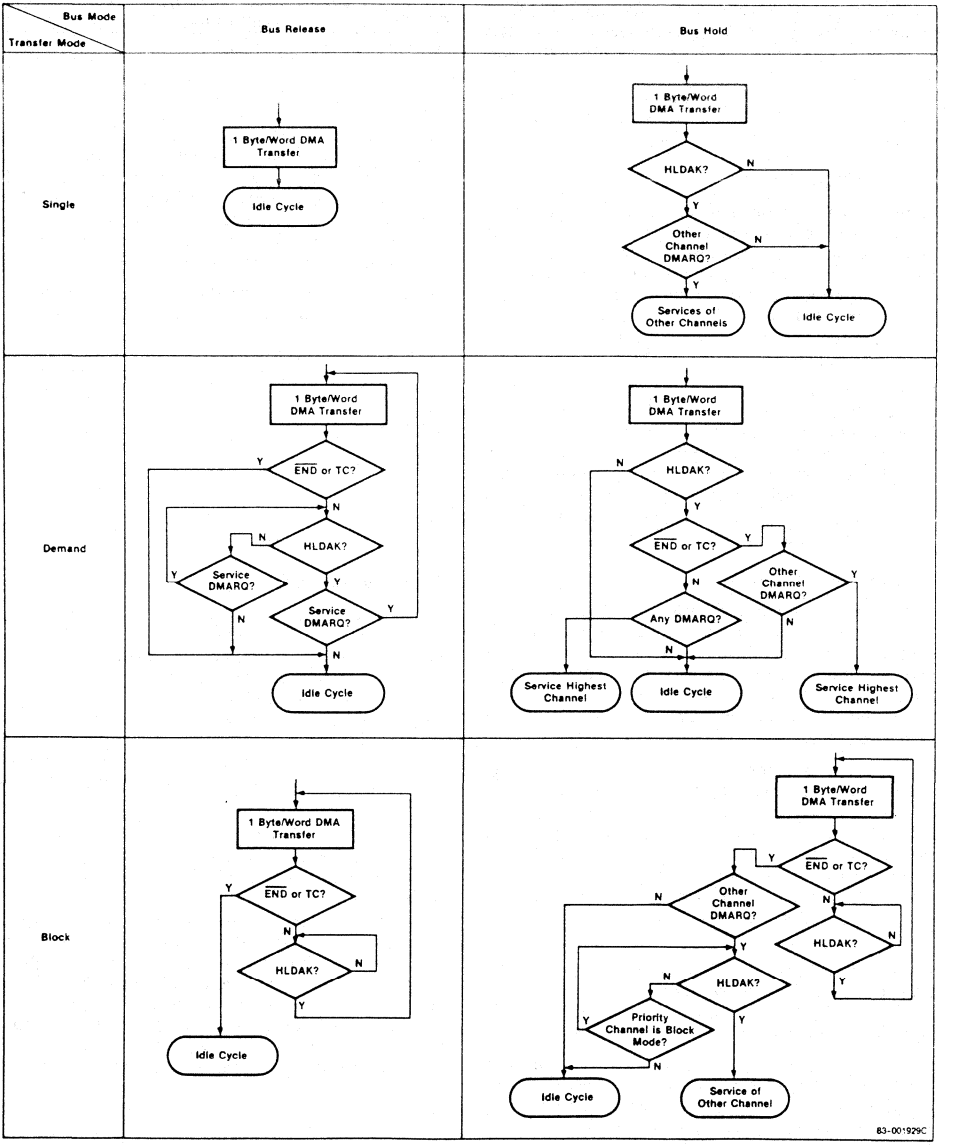
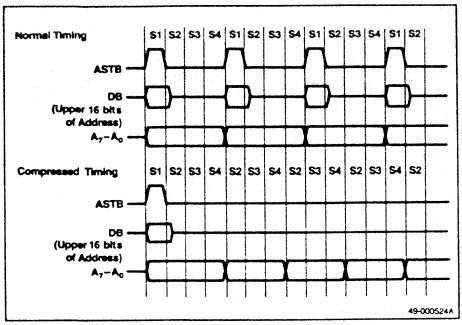


Figure 6. Normal and Compressed Timing Waveforms



Software DMA Requests

The μPD71071 can accept software DMA requests in addition to DMA requests from the four DMARQ pins. Setting the appropriate bit in the request register generates a software DMA request. The mask register does not mask software DMA requests. Software DMA requests operate differently depending on which bus or transfer mode is used.

Bus Mode. When bus release mode is set, the highest priority channel among software DMA requests and DMARQ pins is serviced, and all bits of the request register are cleared when the service is over. Therefore, there is a chance that other software DMA requests will be cancelled.

When bus hold mode is set, only the corresponding bit of the request register is cleared after a DMA service is over. Therefore, all software DMA requests will be serviced in the sequence of their priority level.

Software DMA requests for cascade channels (see Cascade Connection) must be performed in bus hold mode. When a cascade channel is serviced, the master μPD71071 operational mode is changed to bus release mode temporarily and all bits of the request register are cleared when the cascade channel service is over. To avoid this, it is necessary to mask any cascade channels before issuing a software DMA request. After confirming that all DMA software services are complete and all bits of the request register are cleared, the cascade channel masks can be cleared.

Transfer Mode. When single or demand mode is set, the applicable request bits are cleared and software DMA service ends with the transfer of one byte/word. When block mode or memory-to-memory modes are set, service continues until $\overline{END}$ is input or a terminal count is generated. Applicable request bits are cleared when service ends.

Autoinitialize

When the mode control register is set to autoinitialize a channel, the μPD71071 automatically initializes the address and count registers when $\overline{END}$ is input or a terminal count is generated. The contents of the base address and base count registers are transferred to the current address and current count registers, respectively. The applicable bit of the mask register is unaffected. The applicable bit of the mask register is set for channels not programmed for autoinitialize.

The autoinitialize function is useful for the following types of transfers.

Repetitive Input/Output of Memory Area. Figure 7 shows an example of DMA transfer between a CRT controller and memory. After setting the value in the base and current registers, autoinitialize allows repetitive DMA transfer between the CRT controller and the video memory area without CPU involvement.

Continuous Transfer of Several Memory Areas. The CPU can indirectly write to the address or count registers by writing to the base registers. New values can be written to the base registers. In the autoinitialize mode, the value in the base register will be transferred to the address/count registers when termination is reached in the address/count registers. Because of this, the autoinitialize function can perform continuous transfer of several contiguous or noncontiguous memory areas during single or demand bus release modes in the following manner.

During the transfer of data in area 1 (the first area being transferred), the CPU can write address and count information about area 2 (the second area to be transferred). Generation of a terminal count for area 1 results in the transfer of information of area 2 to the address and count registers. This will cause area 2 to be transferred. Figure 8 illustrates this procedure.

Channel Priority

Each of the μPD71071's four channels has its own priority. When there are DMA requests from several channels simultaneously, the channel with the highest priority will be serviced. The device control register selects one of two channel priority methods: fixed and rotational priority. In fixed priority, the priority (starting with the highest) is channel 0, 1, 2, and 3, respectively. In rotational priority, priority order is rotated so that the channel that has just been given service receives the lowest priority and the next highest channel number is given the highest priority. This method prevents exclusive servicing of some channel(s). Figure 9 shows the two priority order methods.

Figure 7. Autoinitialize Application 1

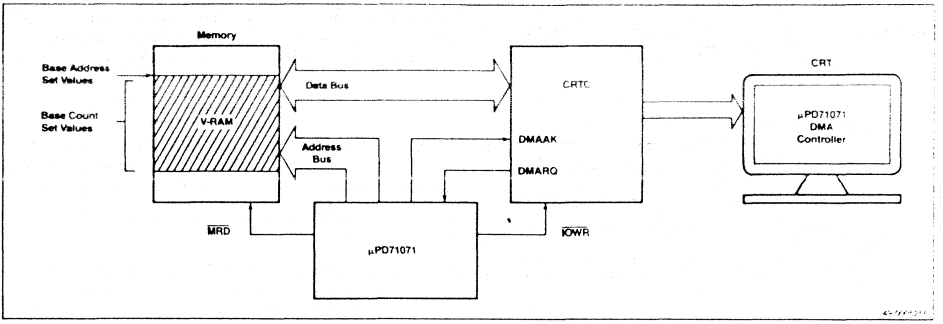


Figure 8. Autoinitialize Application 2

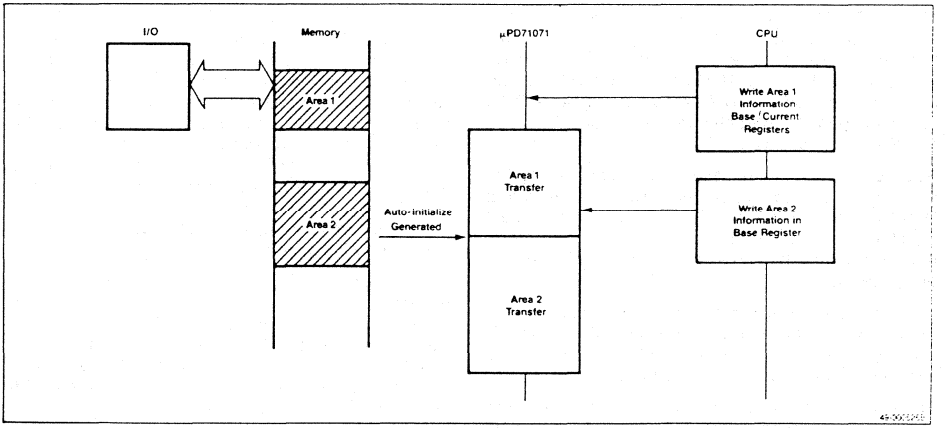
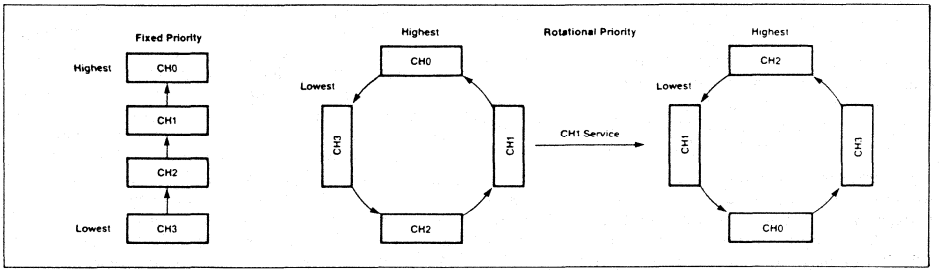


Figure 9. Priority Order



Cascade Connection

The μPD71071 can be cascaded to expand the system DMA channel capacity. To connect a μPD71071 for cascading (figure 10), perform the following operations.

(1) Connect pins HLDRQ and HLDAK of the second-stage (slave) μPD71071 to pins DMARQ and DMAAK of any channel of the first-stage (master) μPD71071.

(2) To select the cascade mode of a particular channel of a master μPD71071, set bits 7 and 6 of that channel's mode control register to 11.

When a channel is set to the cascade mode in a master μPD71071, DMARQ, DMAAK, HLDRQ, HLDAK, and RESET are the only valid signals in the master μPD71071. The other signals are disabled. The master cascade channel only intermediates hold request/hold acknowledge between the slave and CPU.

The master μPD71071 always operates in the bus release mode when a cascade channel is in service (even when the bus hold mode is set). Other DMA requests are ignored while a cascade channel is in service. When the slave μPD71071 ends DMA service and moves into an idle cycle, the master also moves to an idle cycle and releases the bus. At this time, all bits of the master's request register are cleared. The master operates its non-cascaded channels normally.

Bus Wait Operation

In systems using a μPD70208/70216 (V40/V50) as the CPU, the refresh control unit in the CPU changes the HLDAK signal to inactive (even during a DMA cycle) and uses the bus. Here, the μPD71071 automatically performs a bus wait operation. This system has a bus master (V40/V50) whose priority level is higher than that of the μPD71071.

The μPD71071 executes the bus wait operation when the HLDAK signal becomes inactive in an operating mode where transfer is executed continuously in block mode, during demand bus release mode, or during memory-to-memory transfer.

When HLDAK becomes inactive during service in other operating modes, the operation returns to the idle cycle and transfers control of the bus to the higher bus master.

Figure 11 shows that when the HLDAK signal becomes inactive during a continuous transfer, the μPD71071 is set up in an S4w state (bus wait). Operation moves to the idle cycle if DMARQ is inactive in the demand mode. The HLDRQ signal is made inactive for a period of about two clocks and the bus is released. The S4w state is repeated until the HLDAK signal again becomes active and the interrupted service is immediately restarted.

Figure 10. Cascade Connection Example

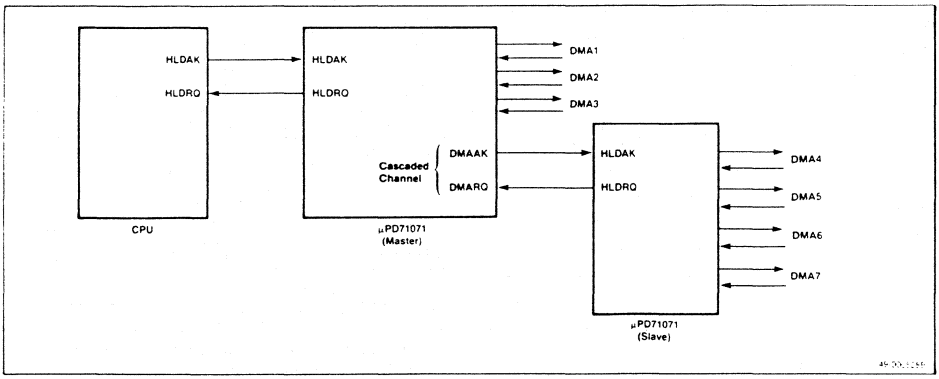
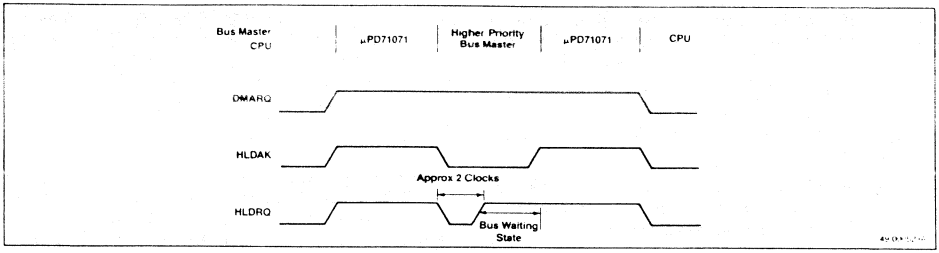


Figure 11. Bus Wait Operation



Programming the μPD71071

To prepare a channel for DMA transfer, you must select the following characteristics.

- Starting address for the transfer
- Number of byte/word transfers
- DMA operating modes
- Data bus widths
- Active levels of the DMARQ and DMAAK signals

When reading from or writing to a μPD71071 internal register, address lines A_3-A_0 select the register, $\overline{IORD}$ or $\overline{IOWR}$ select the data transfer direction, and $\overline{CS}$ enables the transfer. Table 6 shows the register and command configurations.

Table 6. Register Configuration

Register	Bit size
Channel	5
Base address	24 (4)
Current address	24 (4)
Base count	16 (4)
Current count	16 (4)
Mode control	7 (4)
Device control	10
Status	8
Request	4
Mask	4
Temporary	16

Note:

When using a 16-bit CPU and selecting a 16-bit data bus, the word IN/OUT instruction can be used to read/write information two bytes at a time. However, commands in table 7 suffixed with B must be issued with the byte IN/OUT instruction.

Initialize

Use the initialize command as a software initialize to the μPD71071 or to set the width of the data bus. When using a 16-bit CPU, set the data bus width to 16 bits first. Figure 12 shows the initialize command format.

Bit 0. When the RES bit is set, the internal state of the μPD71071 is initialized and will be the same as when a hardware reset is used (except for data bus width selection). A software reset leaves bit 16B intact whereas a hardware reset selects the 8-bit data bus. After initialization, the registers are as in table 8 and the RES bit is cleared automatically.

Table 8. Register Initialization

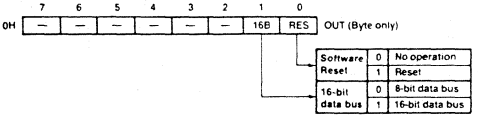
Register	Initialization Operation
Initialize	Clears bit 0 only
Address	No change
Count	No change
Channel	Selects channel 0, current and base
Mode control	Clears all bits
Device control	Clears all bits
Status	Clears bits 3-0 only
Request	Clears all bits
Mask	Sets all bits (masks all channels)
Temporary	Clears all bits

Bit 1. The 16B bit determines the data bus width. When using the μPD71071 in a 16-bit system, set this bit immediately after a hardware reset since a hardware reset always initializes it to the 8-bit data bus mode.

Table 7. Command Configuration

Address	R/W	Command Name	MSB Format LSB							
0H	W(B)	Initialize	—	—	—	—	—	—	16B	RES
1H	R(B)	Channel Register Read	—	—	—	BASE	SEL3	SEL2	SEL1	SEL0
	W(B)	Channel Register Write	—	—	—	—	—	BASE	SELCH	
2H	R/W	Count Register Read/Write	C7	C6	C5	C4	C3	C2	C1	C0
3H	R/W		C15	C14	C13	C12	C11	C10	C9	C8
4H	R/W	Address Register Read/Write	A7	A6	A5	A4	A3	A2	A1	A0
5H	R/W		A15	A14	A13	A12	A11	A10	A9	A8
6H	R/W(B)		A23	A22	A21	A20	A19	A18	A17	A16
8H	R/W	Device Control Reg. Read/Write	AKL	RQL	EXW	ROT	CMP	DDMA	AHLD	MTM
9H	R/W		—	—	—	—	—	—	WEV	BHLD
0AH	R/W(B)	Mode Control Reg. Read/Write	TMODE		ADIR	AUTI	TDIR		—	W/B
0BH	R(B)	Status Register Read	RQ3	RQ2	RQ1	RQ0	TC3	TC2	TC1	TC0
0CH	R	Temporary Reg. (lower) Read	T7	T6	T5	T4	T3	T2	T1	T0
0DH	R	Temporary Reg. (higher) Read	T15	T14	T13	T12	T11	T10	T9	T8
0EH	R/W(B)	Request Reg. Read/Write	—	—	—	—	SRQ3	SRQ2	SRQ1	SRQ0
0FH	R/W(B)	Mask Reg. Read/Write	—	—	—	—	M3	M2	M1	M0

Figure 12. Initialize Command Format



Channel Register

This command reads and writes the channel register that selects one of four DMA channels for programming the address, count, and mode control registers. Figure 13 shows the channel register read/write format.

Channel Register Read

SEL3-SEL0. These mutually exclusive bits show which of the four channels is currently selected for programming.

BASE. Base = 0. The current register may be read. During a write, the base and current registers will be written to simultaneously.

Base = 1. Only the base registers may be read or written to.

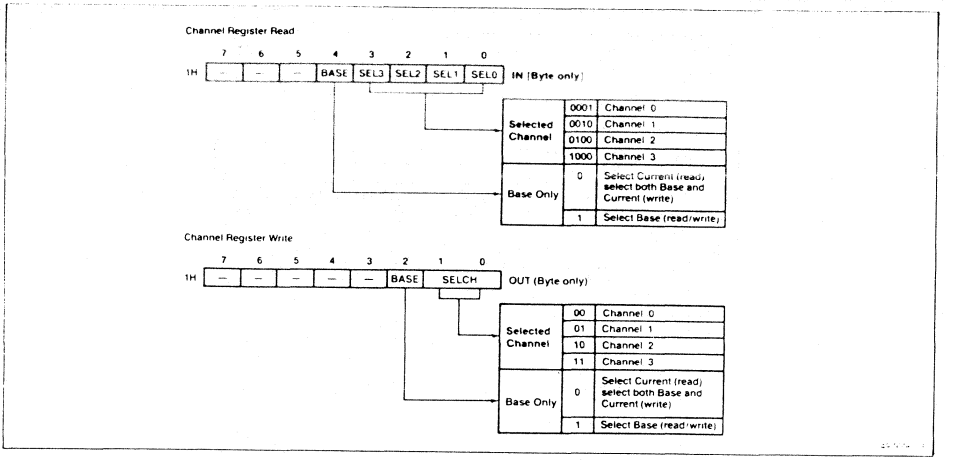
Channel Register Write

SELCH. This bit selects the channel to be programmed.

BASE. Base = 0. The current register may be read. During a write, the base and current registers will be written to simultaneously.

Base = 1. Only the base registers may be read or written to.

Figure 13. Channel Register Format



Count Register Read/Write

When the 16-bit bus mode is selected, the IN/OUT instruction can directly transfer 16-bit data. The channel register selects one of the count registers. When bit 2 of the channel register write is cleared, a write to the count register updates both the base and current count registers with the new data. If bit 2 of the channel register write is set, a write to the count register only affects the base count register.

The base count registers hold the initial count value until a new count is specified. If autoinitialize is enabled, this value is transferred to the current count register when an $\overline{END}$ or $\overline{TC}$ is generated. For each DMA transfer, the current count register is decremented by one. Figure 14 shows the count register read/write format.

Address Register Read/Write

When a 16-bit data bus width is selected, the IN/OUT instruction can directly transfer the lower two bytes (4H and 5H) of the register. You must use the byte IN/OUT instruction with the upper byte (6H) of the register. The channel register selects one of the address registers. When bit 2 of the channel register is cleared, a write to the address register updates both the base and current address registers with the new data. If bit 2 of the channel register is set, a write to the address register only affects the base address register.

The base register holds the starting address value until a new setting is made and this value is transferred to the current address register during autoinitialization. For each DMA transfer, the current address register is updated ±2 during word transfer and ±1 during byte transfer. Figure 15 shows the address register read/write format.

Device Control Register Read/Write

The device control command reads from and writes to the device control register. When using a 16-bit data bus, use the word IN/OUT instruction to read and write 16-bit data. Figure 16 shows the device control register read/write format.

Figure 14. Count Register Read/Write Format

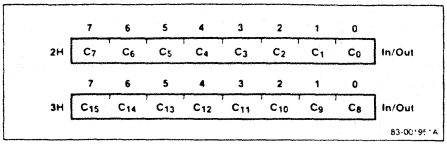


Figure 15. Address Register Read/Write Format

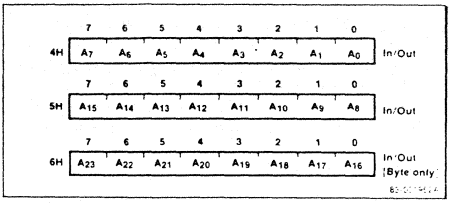
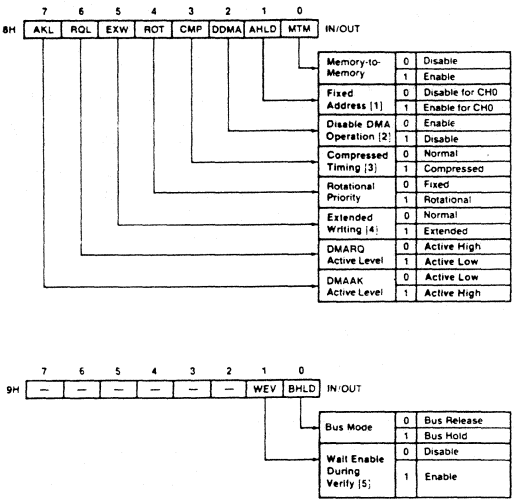


Figure 16. Device Control Register Read/Write Format



Note:

[1] This bit is only used when MTM = 1, (memory-to-memory transfers).

[2] Disables HLDRQ to the CPU to prevent incorrect DMA operation while the μPD71071's registers are being initialized or modified.

[3] When 1, causes the μPD71071 to use compressed timing in the demand bus release mode or in the block mode.

[4] When EXW is 0, the write signal becomes active (normal write) during S3 and SW. When 1, the write signal becomes active during S2, S3, and SW. See figures 27-29.

[5] This bit enables or disables the wait state generated by the READY signal during a verify transfer.

Mode Control Register Read/Write

This command reads from and writes to the mode control register to specify the operating mode for each channel. The channel register selects the mode control register to be programmed. This command must be issued by the byte IN/OUT instruction. Figure 17 shows the mode control register read/write format.

Status Register Read

This command reads the status register for the individual DMA channels. The register has DMA request states and terminal count or $\overline{END}$ information. This command must be issued by the byte IN instruction. Figure 18 shows the status register read format.

Temporary Register Read

When a 16-bit data bus is selected, the IN instruction will read 16-bit data with this command. The last data transferred in memory-to-memory transfer is stored in the temporary register. Figure 19 shows the temporary register read format.

Request Register Read/Write

This command reads from and writes to the request register to generate DMA requests by software for the four corresponding DMA channels. This command may be issued by the byte IN/OUT instruction. Figure 20 shows the reguest register read/write format.

Mask Register Read/Write

This command reads from and writes to the mask register to mask or unmask external DMA requests for the corresponding four DMA channels (DMARQ3-DMARQ0). This command may be issued by the byte IN/OUT instruction. Figure 21 shows the mask register read/write format.

DMA Transfer Modes

Figures 22-27 show state transition diagrams for the different modes of DMA transfer.

Figure 23 shows the state of a master μPD71071 when an input from a slave μPD71071 (cascaded μPD71071) is using the system bus.

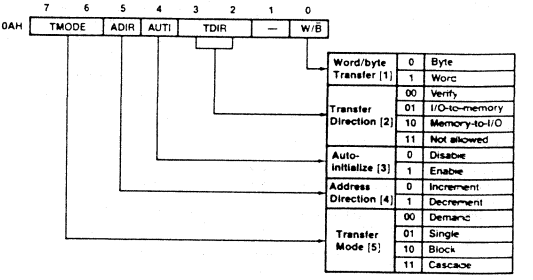
Transfer Timing

Figures 28-30 show μPD71071 timing waveforms.

Examples of System Configuration

Figures 31-32 show system configuration examples using the 8-bit μPD70108 CPU and the 16-bit μPD70116 CPU. The μPD71082 externally latches addresses and data.

Figure 17. Mode Control Register Read/Write Format



Note:

[1] This bit selects byte or word transfer for DMA transfers. This bit is used only in 16-bit data bus mode.

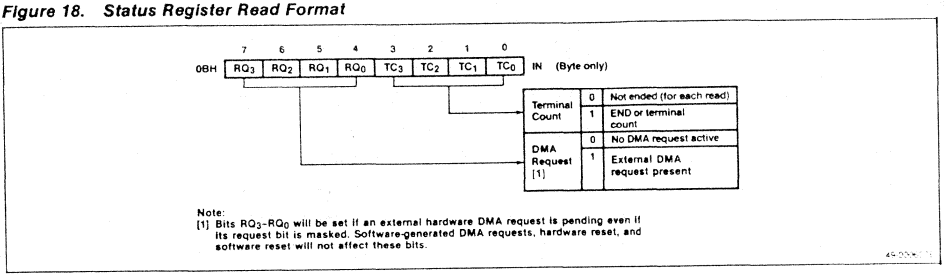
[2] These bits select the DMA transfer direction between memory and I/O. These bits are meaningless during memory-to-memory transfer.

[3] Channel 0 and 1 must have the same AUTI bit value when performing memory-to-memory transfer.

[4] This bit decides the update direction of the Current Address Register. When ADIR is 0, the register increments by 1 for a byte transfer and by 2 for a word transfer. When ADIR is 1, the register decrements by 1 for a byte transfer and by 2 for a word transfer.

[5] These bits select the transfer mode during DMA transfer between memory and I/O and are meaningless during memory-to-memory transfer.

Figure 18. Status Register Read Format



Note:
[1] Bits RQ_3-RQ_0 will be set if an external hardware DMA request is pending even if its request bit is masked. Software-generated DMA requests, hardware reset, and software reset will not affect these bits.

Figure 19. Temporary Register Read Format

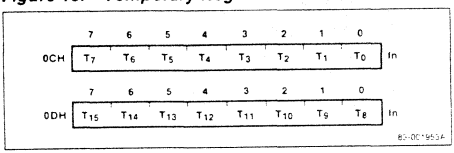
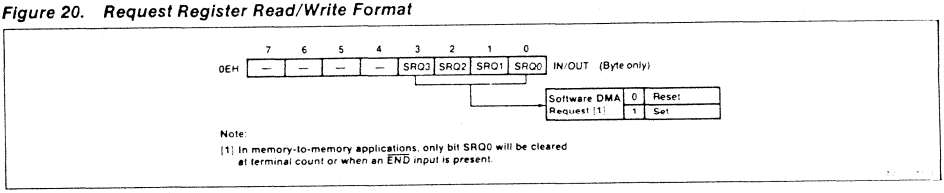
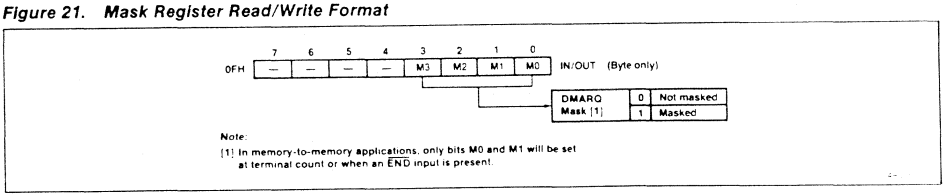


Figure 20. Request Register Read/Write Format



Note:
[1] In memory-to-memory applications, only bit SRQ0 will be cleared at terminal count or when an $\overline{END}$ input is present.

Figure 21. Mask Register Read/Write Format



Note:
[1] In memory-to-memory applications, only bits M0 and M1 will be set at terminal count or when an $\overline{END}$ input is present.

Figure 22. Idle Cycle

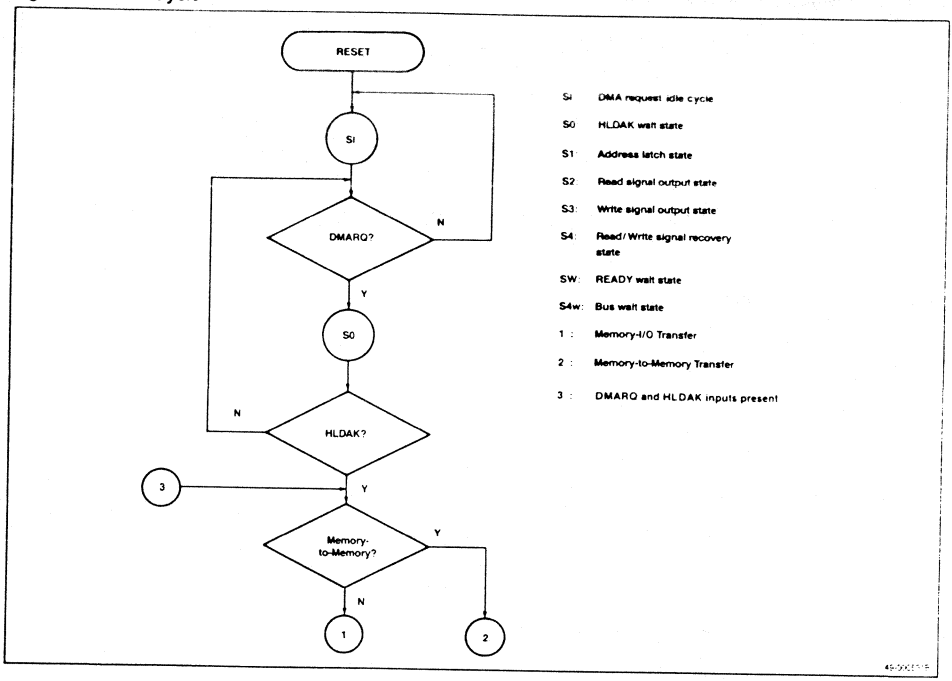


Figure 23. DMA Cycle, Cascade Mode

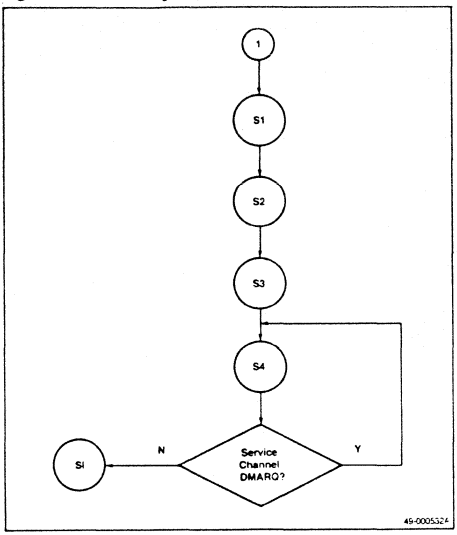


Figure 24. DMA Cycle, Single Mode

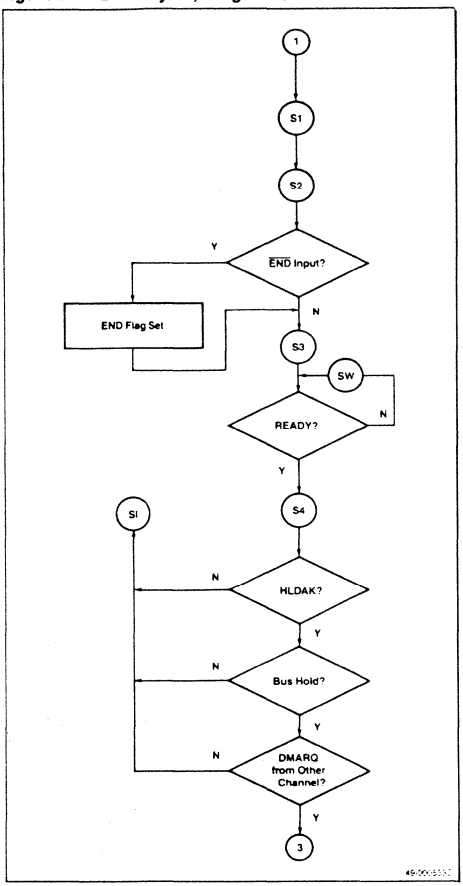
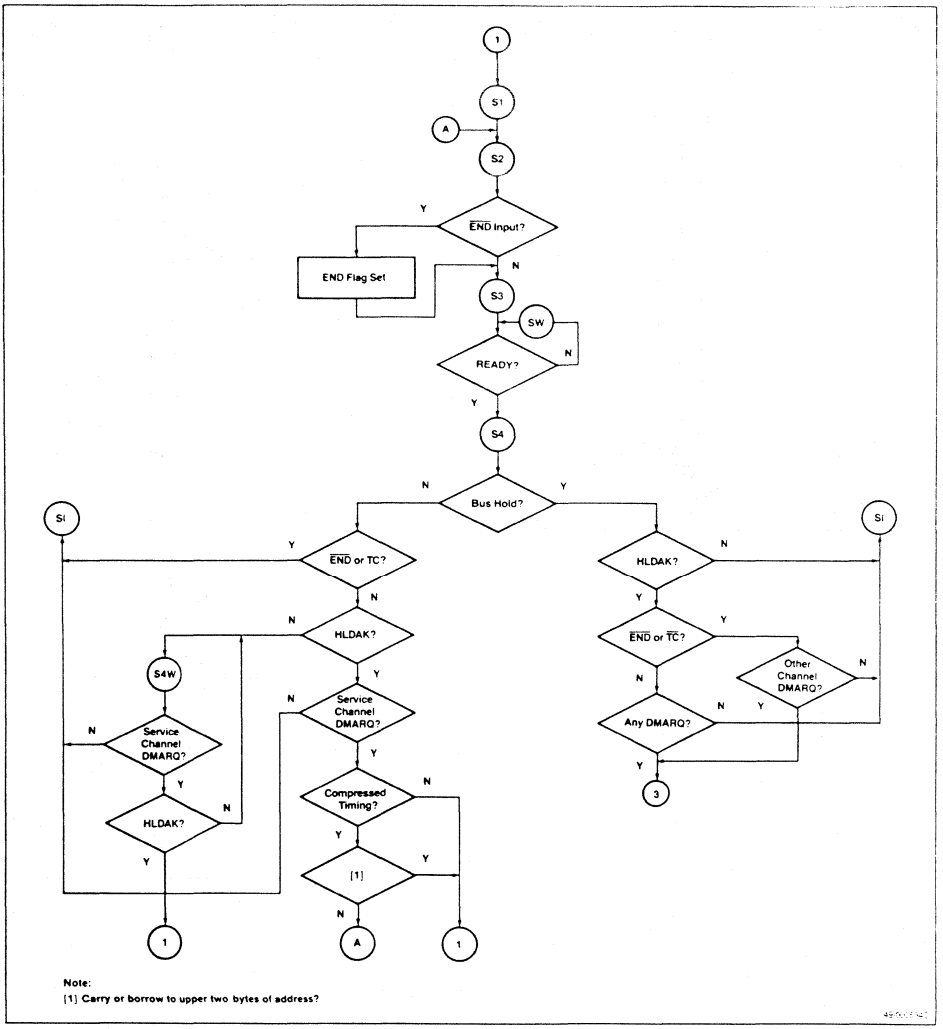


Figure 25. DMA Cycle, Demand Mode



Note:
[1] Carry or borrow to upper two bytes of address?

Figure 26. DMA Cycle, Block Mode

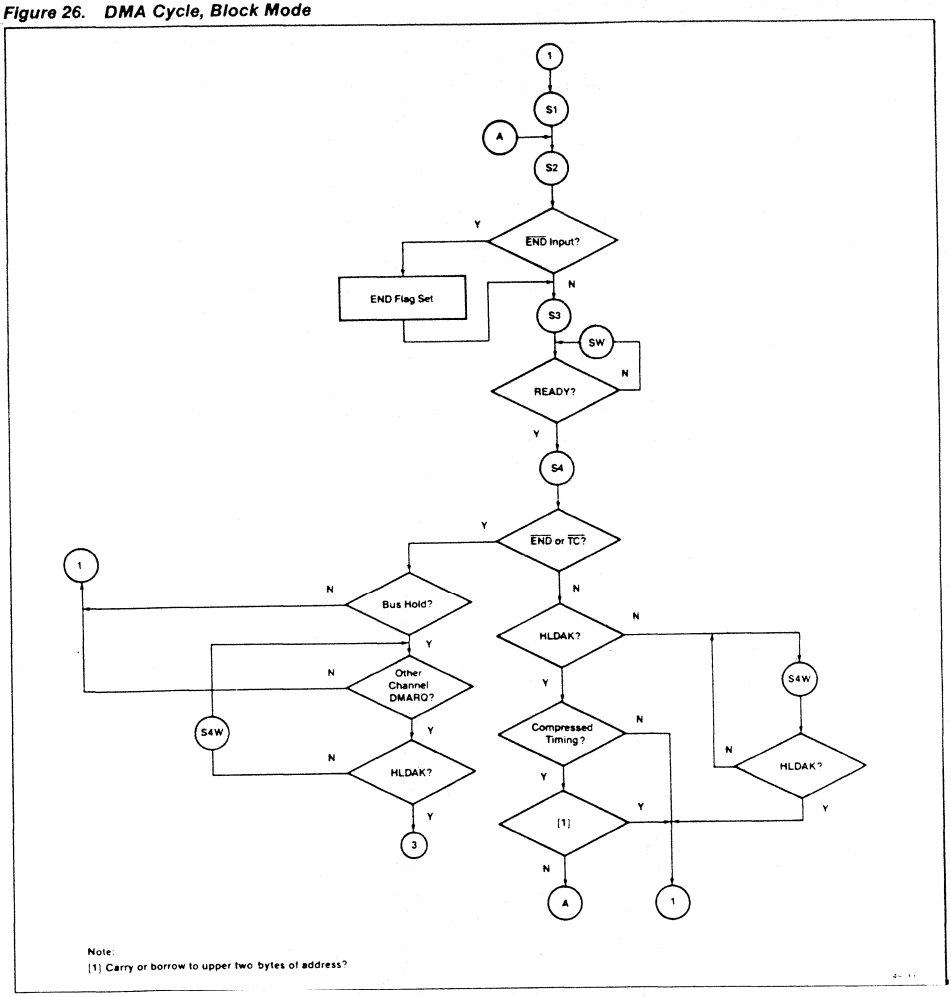


Figure 27. DMA Cycle, Memory-to-Memory Transfer

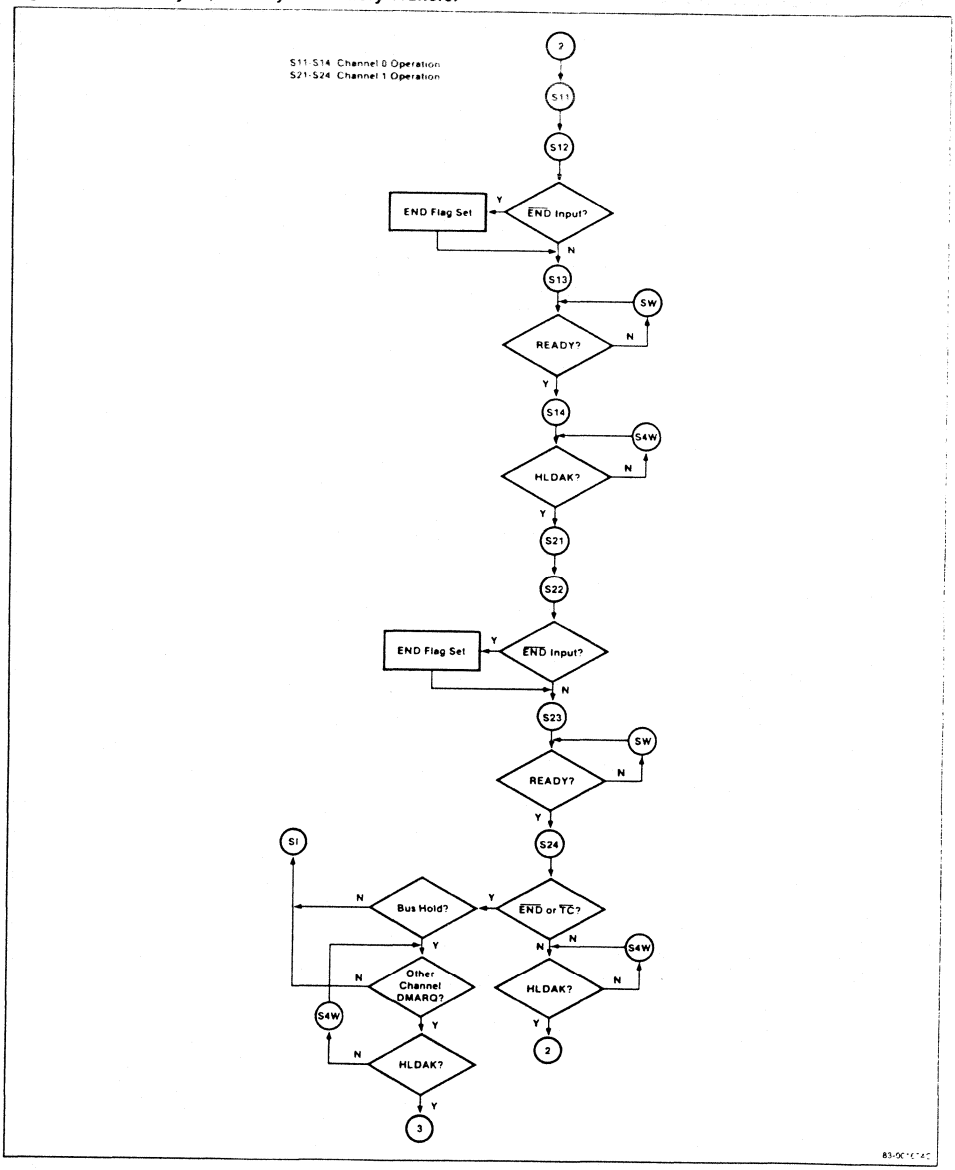
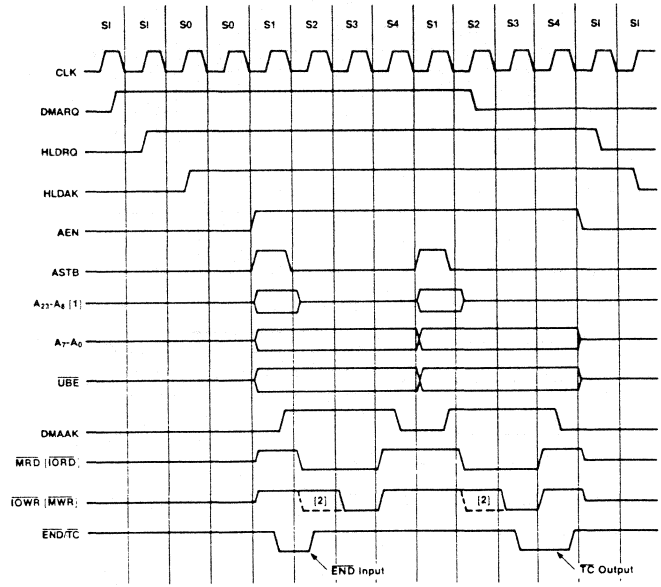


Figure 28. Memory-I/O Transfer, Normal Timing

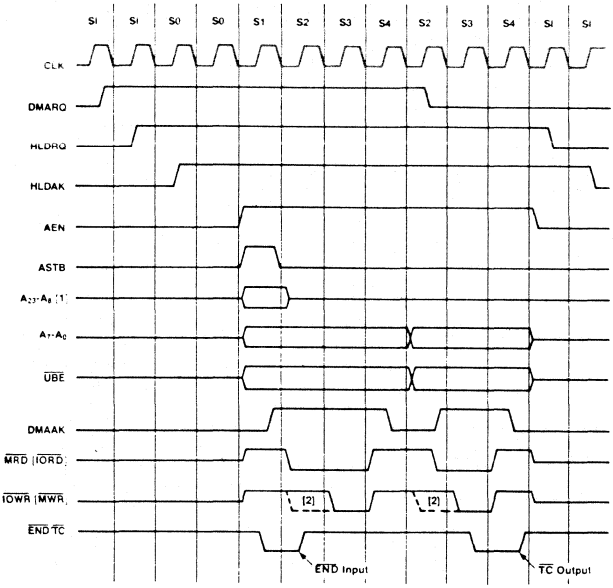


Note:

[1] When an 8-bit data bus is selected, D_{15}-D_8 are not used. Therefore, A_{23}-A_{16} are not multiplexed address/data signals and will have the same timing as A_7-A_0.

[2] The broken lines of the write signal are for extended write timing.

Figure 29. Memory-I/O Transfer, Compressed Timing

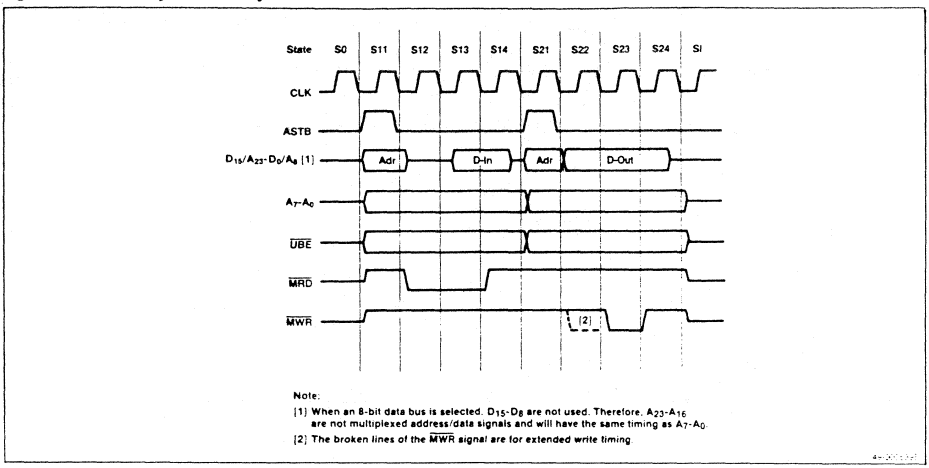


Note

[1] When an 8-bit data bus is selected. D_{15}-D_8 are not used. Therefore, A_{23}-A_{16} are not multiplexed address/data signals and will have the same timing as A_7-A_0.

[2] The broken lines of the write signal are for extended write timing.

Figure 30. Memory-to-Memory Transfer



Note:
[1] When an 8-bit data bus is selected. D_{15}-D_8 are not used. Therefore, A_{23}-A_{16} are not multiplexed address/data signals and will have the same timing as A_7-A_0.
[2] The broken lines of the $\overline{MWR}$ signal are for extended write timing.

Figure 31. END/TC Input/Output

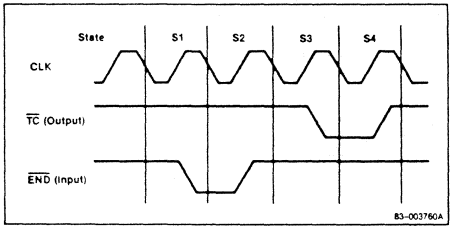


Figure 32. System Configuration with μPD70108

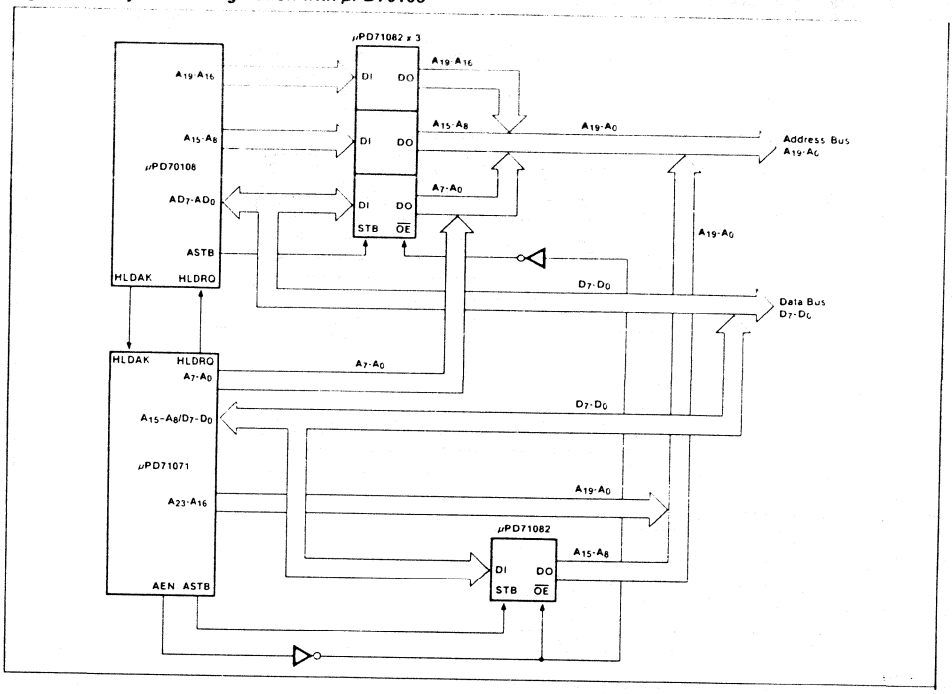
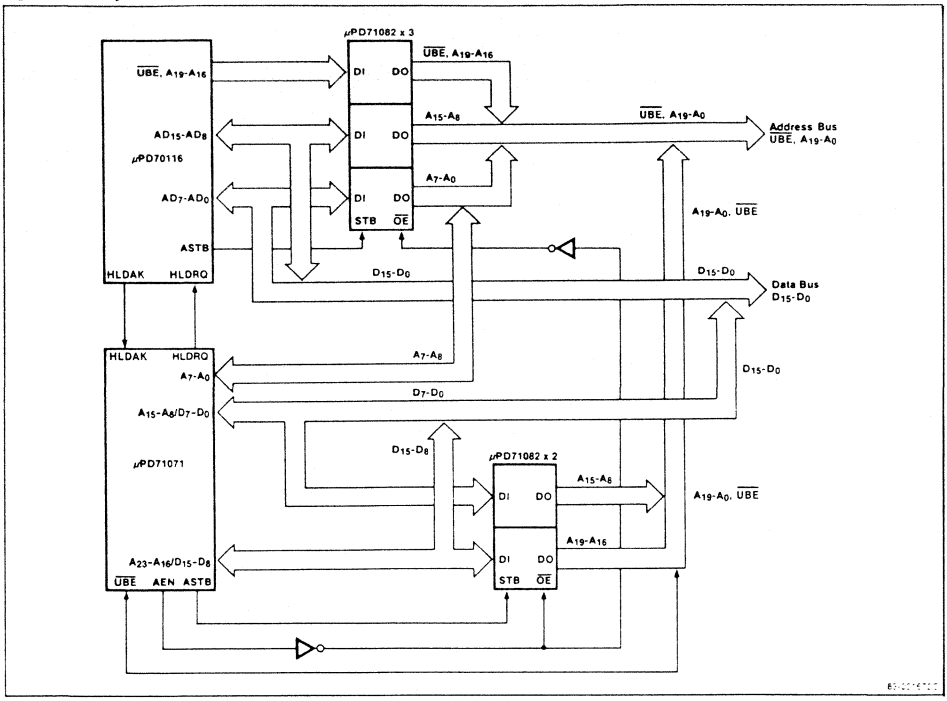


Figure 33. System Configuration with μPD70116



Description

μPD71082 and μPD71083 are CMOS 8-bit transparent latches with three-state output buffers. They are used as bus buffers or bus multiplexers in microprocessor systems. Their high-drive capability makes them suitable for data latch, buffer, or I/O port applications.

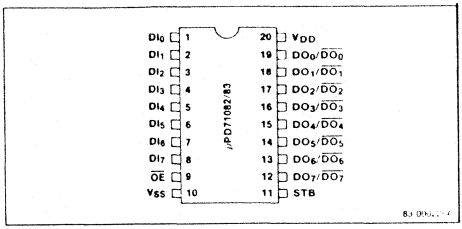
Features

- ☐ CMOS technology
- ☐ 8-bit parallel data register
- ☐ Three-state output buffer
- ☐ High drive capability output buffer (I_{OL} = 12 mA)
- ☐ μPD8085A, 8048, 8086, 8088, 70108, and 70116 CPU system compatible
- ☐ μPD71082 — non-inverted output; μPD71083 — inverted output
- ☐ Single +5 V ±10% power supply
- ☐ 20-pin plastic DIP (300 mil)
- ☐ Transparent operation
- ☐ Industrial temperature range: −40 to +85 °C

Pin Identification

No.	Symbol	Function
1	DI_0	Data input, bit 0
2	DI_1	Data input, bit 1
3	DI_2	Data input, bit 2
4	DI_3	Data input, bit 3
5	DI_4	Data input, bit 4
6	DI_5	Data input, bit 5
7	DI_6	Data input, bit 6
8	DI_7	Data input, bit 7
9	$\overline{OE}$	Output enable input
10	V_{SS}	Ground
11	STB	Strobe input
12	$DO_7/\overline{DO_7}$	Data output, bit 7
13	$DO_6/\overline{DO_6}$	Data output, bit 6
14	$DO_5/\overline{DO_5}$	Data output, bit 5
15	$DO_4/\overline{DO_4}$	Data output, bit 4
16	$DO_3/\overline{DO_3}$	Data output, bit 3
17	$DO_2/\overline{DO_2}$	Data output, bit 2
18	$DO_1/\overline{DO_1}$	Data output, bit 1
19	$DO_0/\overline{DO_0}$	Data output, bit 0
20	V_{DD}	+5 V Power supply

Pin Configuration



Ordering Information

Part Number	Package Type	Output
μPD71082C	20-pin plastic DIP	Non-inverted
μPD71083C	20-pin plastic DIP	Inverted
μPD71082G	20-pin plastic SO	
μPD71083G	20-pin plastic SO	

Pin Functions

DI_7-DI_0 [Data Input]

DI_7-DI_0 are data input lines to the 8-bit data latch. Data on DI lines passes through the latch while STB is high. The data is latched to DO/$\overline{DO}$ with the trailing edge of STB (high to low).

DO_7-DO_0/$\overline{DO_7}$-$\overline{DO_0}$ [Data Output]

DO_7-DO_0/$\overline{DO_7}$-$\overline{DO_0}$ are the three-state data output lines from the 8-bit data latch. When $\overline{OE}$ is high, these lines go into the high-impedance state. When $\overline{OE}$ is low, data from the latch is output, either non-inverted (μPD71082) or inverted (μPD71083).

STB [Strobe]

STB is the input strobe signal for the 8-bit latch. When STB is high, data on the DI lines passes through the 8-bit latch. Data is latched on the trailing edge of STB (high to low). When STB is low, latched data does not change.

$\overline{OE}$ [Output Enable]

$\overline{OE}$ input is the output enable signal for the DO/$\overline{DO}$ lines. When $\overline{OE}$ is high, DO/$\overline{DO}$ lines are high impedance. When $\overline{OE}$ is low, data from the 8-bit latch is output to DO_7-DO_0/$\overline{DO_7}$-$\overline{DO_0}$. See table 1.

Block Diagram

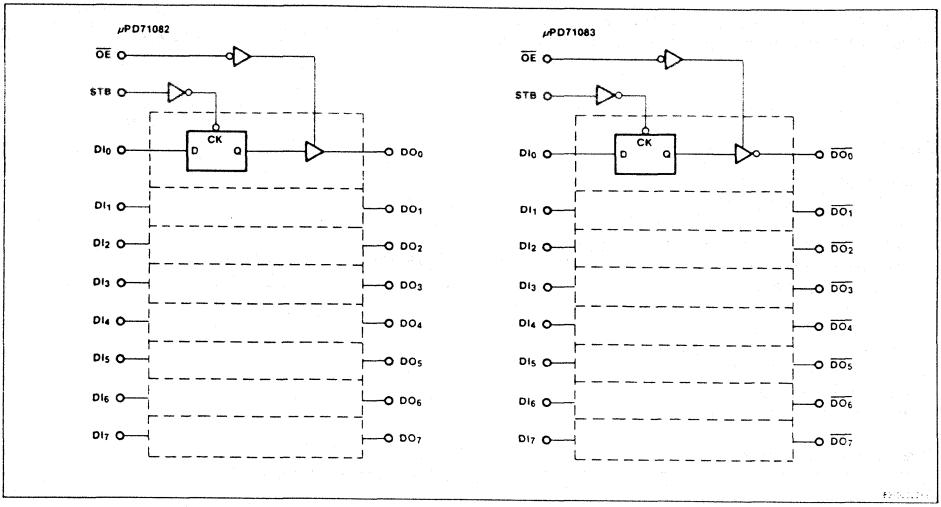


Table 1. Latch Operation

STB	OE	DO_7-DO_0/$\overline{DO_7}$-$\overline{DO_0}$	8-Bit Data Latch
Low	Low	Latched data from 8-bit data latch is enabled	DI line data has been latched with trailing edge of STB (high to low)
	High	High impedance	
High	Low	Data on DI_7-DI_0	DI passes through to DO/$\overline{DO}$
	High	High impedance	

Functional Description

The μPD71082 and μPD71083 are 8-bit data latches strobed by the STB signal. They have high-drive capability output buffers controlled by the $\overline{OE}$ signal. Data on the DI lines is latched by the trailing edge of STB (high to low). When STB is high, data passes through the latch. When $\overline{OE}$ is high, DO lines are high impedance. When $\overline{OE}$ is low, the contents of the latches are output on DO_7-DO_0. The DO lines are isolated from $\overline{OE}$ switching noise.

Absolute Maximum Ratings

T_A = 25 °C, V_{SS} = 0 V

Power supply voltage, V_{DD}	−0.5 to +7.0 V
Input voltage, V_I	−1.0 to V_{DD} + 1 V
Output voltage, V_O	−0.5 to V_{DD} + 0.5 V
Power dissipation, P_{DMAX}	500 mW
Operating temperature, T_{opt}	−40 °C to +85 °C
Storage temperature, T_{stg}	−65 °C to +150 °C

Comment: Exposing the device to stresses above those listed in the absolute maximum ratings could cause permanent damage. Exposure to absolute maximum ratings for extended periods may affect device reliability.

Capacitance

T_A = 25 °C, V_{DD} = +5 V

Parameter	Symbol	Limits Min	Limits Max	Units	Test Conditions
Input capacitance	C_{in}		12	pF	f = 1 MHz

DC Characteristics

T_A = −40 to +85°C, V_{DD} = 5 V ± 10%

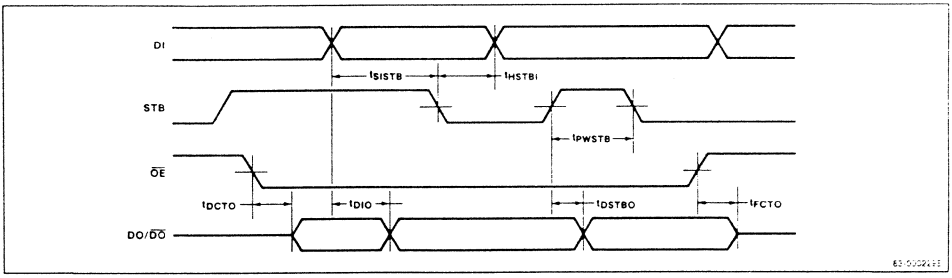
Parameter	Symbol	Limits Min	Limits Max	Units	Test Conditions
Input voltage high	V_{IH}	2.2		V	
Input voltage low	V_{IL}		0.8	V	
Output voltage high	V_{OH}	V_{DD} − 0.8		V	I_{OH} = −4 mA
Output voltage low	V_{OL}		0.45	V	I_{OL} = 12 mA
Input current	I_I	−1.0	1.0	μA	$V_I = V_{DD}, V_{SS}$
Leakage current, high impedance	I_{OFF}	−10	10	μA	$\overline{OE} = V_{DD}$
Power supply current (static)	I_{DD}		80	μA	$V_I = V_{DD}, V_{SS}$
Power supply current (dynamic)	I_{DDdyn}		20	mA	F_{in} = 10 MHz C = 200 pF

AC Characteristics

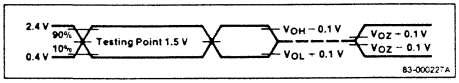
T_A = −40 to +85°C, V_{DD} = 5 V ± 10%

Parameter	Symbol	Limits Min	Limits Max	Units	Test Conditions
Input to output delay	t_{DIO}	5	40	ns	Load circuit a
STB to output delay	t_{DSTBO}	10	60	ns	Load circuit a
Data float time from $\overline{OE}$ high	t_{FCTO}	5	30	ns	Load circuit b
Data output delay from $\overline{OE}$ low	t_{DCTO}	10	40	ns	Load circuit b
Input to STB setup time	t_{SISTB}	0		ns	Load circuit a
Input to STB hold time	t_{HSTBI}	25		ns	Load circuit a
STB high pulse width	t_{PWSTB}	20		ns	Load circuit a
Signal rise time	t_{LH}		20	ns	0.8 V to 2.0 V
Signal fall time	t_{HL}		12	ns	2.0 V to 0.8 V

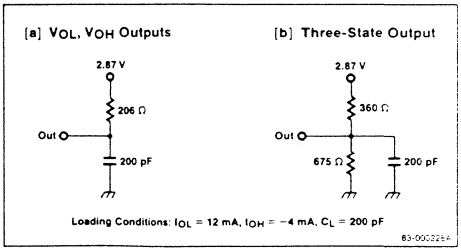
Timing Waveforms



AC Testing



Loading Circuits for AC Testing



Description

The μPD71084 is a clock pulse generator/driver for microprocessors and their peripherals using NEC's high-speed CMOS technology.

Features

- ☐ CMOS technology
- ☐ Clock pulse generator/driver for μPD70108/70116 or other CMOS or NMOS CPUs and their peripherals
- ☐ Frequency source can be crystal or external clock input
- ☐ Reset signal with Schmitt-trigger circuit for CPU or peripherals
- ☐ Bus ready signal with two-bus system synchronization
- ☐ Clock synchronization with other μPD71084s
- ☐ Single +5 V ±10% power supply
- ☐ Industrial temperature range: −40 to +85°C

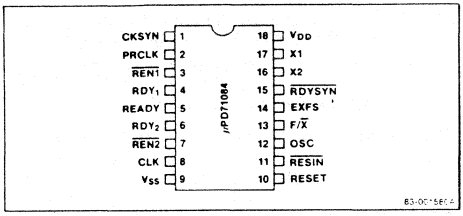
Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD71084C	18-pin plastic DIP	25 MHz
μPD71084G	20-pin plastic SO	25 MHz

Pin Identification

No.	Symbol	Function
1	CKSYN	Clock synchronization input
2	PRCLK	Peripheral clock output
3	$\overline{REN1}$	Bus ready enable input 1
4	RDY_1	Bus ready input 1
5	READY	Ready output
6	RDY_2	Bus ready input 2
7	$\overline{REN2}$	Bus ready enable input 2
8	CLK	Processor clock output
9	V_{SS}	Ground potential
10	RESET	Reset output
11	$\overline{RESIN}$	Reset input
12	OSC	Oscillator output
13	F/$\overline{X}$	External frequency source/crystal select
14	EXFS	External frequency source input
15	$\overline{RDYSYN}$	Ready synchronization select input
16	X2	Crystal input
17	X1	Crystal input
18	V_{DD}	+5 V Power supply

Pin Configuration



Pin Functions

X1, X2 [Crystal]

When the F/$\overline{X}$ input is low, a crystal connected to X1 and X2 will be the frequency source to generate clocks for a CPU and its peripherals. The crystal frequency should be three times the frequency of CLK.

EXFS [External Frequency]

EXFS is the external frequency input in the external TTL frequency source mode (F/$\overline{X}$ high). A TTL-level clock signal three times the frequency of CLK's output should be used for the source.

F/$\overline{X}$ [Frequency/Crystal Select]

F/$\overline{X}$ input selects whether an external TTL-level input or an external crystal input is the frequency source of the CLK output. When F/$\overline{X}$ is low, CLK is generated from the crystal connected to X1 and X2. When F/$\overline{X}$ is high, CLK is generated from an external TTL-level frequency input on the EXFS pin. At the same time, the internal oscillator circuit will stop and the OSC output will be high.

CLK [Processor Clock]

CLK output supplies the CPU and its local bus peripherals. CLK is a 33% duty cycle clock of one-third the frequency of the frequency source. The CLK output is +0.4 V higher than the other outputs.

PRCLK [Peripheral Clock]

PRCLK output supplies a 50% duty cycle clock at one-half the frequency of CLK to drive peripheral devices.

OSC [Oscillator]

OSC outputs a signal at the same frequency as the crystal input. When EXFS is selected, the OSC output is powered down, and its output will be high.

CKSYN [Clock Synchronization]

CKSYN input synchronizes one μPD71084 to other μPD71084s. A high level at CKSYN resets the internal counter, and a low level enables it to count.

$\overline{\text{RESIN}}$ [Reset]

This Schmitt-trigger input generates the RESET output. It is used as a power-on reset.

RESET [Reset]

This output is a reset signal for the CPU. Reset timing is provided by the $\overline{\text{RESIN}}$ input to a Schmitt-trigger input gate and a flip-flop which will synchronize the reset timing to the falling edge of CLK. Power-on reset can be provided by a simple RC circuit on the $\overline{\text{RESIN}}$ input.

RDY_1, RDY_2 [Bus Ready]

A peripheral device drives the RDY_1 or RDY_2 inputs to signal that the data on the system bus has been received or is ready to be sent. $\overline{\text{REN1}}$ and $\overline{\text{REN2}}$ enable the RDY_1 and RDY_2 signals.

$\overline{\text{REN1}}$, $\overline{\text{REN2}}$ [Address Enable]

$\overline{\text{REN1}}$ and $\overline{\text{REN2}}$ inputs qualify their respective RDY inputs.

$\overline{\text{RDYSYN}}$ [Ready Synchronization Select]

$\overline{\text{RDYSYN}}$ input selects the mode of READY signal synchronization. A low-level signal makes the synchronization a two-step process. Two-step synchronization is used when RDY_1 or RDY_2 are not synchronized to the microprocessor clock and therefore cannot be guaranteed to meet the READY setup time. A high-level signal makes synchronization a one-step process. One-step synchronization is used when RDY_1 and RDY_2 are synchronized to the processor clock. See Block Diagram.

READY [Ready]

The READY output signal to the processor is synchronized by the RDY inputs to the processor CLK. READY is cleared after RDY goes low and the guaranteed hold time of the processor has been met.

Crystal

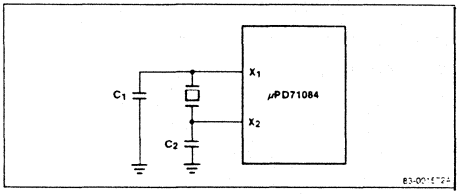
The oscillator circuit of the μPD71084 works with a parallel-resonant, fundamental mode, "AT cut" crystal connected to pins X1 and X2.

Figure 1 shows the recommended circuit configuration. Capacitors C1 and C2 are required for frequency stability. The values of C1 and C2 (C1 = C2) can be calculated from the load capacitance (C_L) specified by the crystal manufacturer.

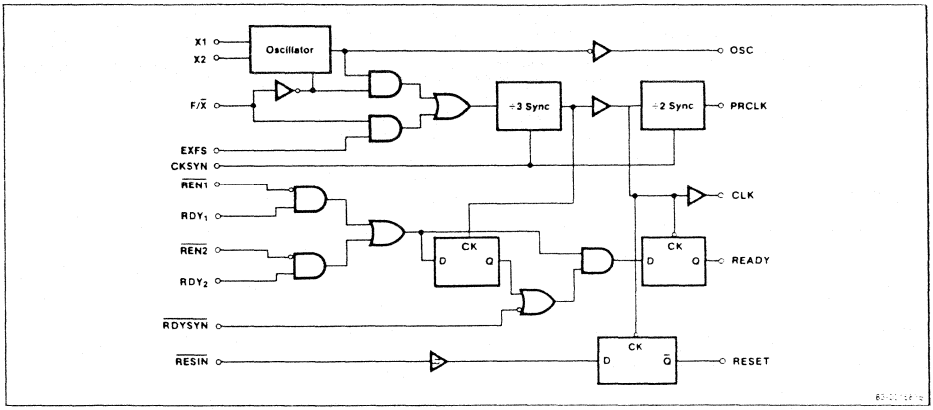
$$C_L = \frac{C1 \times C2}{C1 + C2} + C_S$$

Where C_S is any stray capacitance in parallel with the crystal, such as the μPD71084 input capacitance C_{in}.

Figure 1. Crystal Configuration Circuit



Block Diagram



Absolute Maximum Ratings

(T_A = 25°C, V_{SS} = 0 V)

Power supply voltage, V_{DD}	−0.5 to +7.0 V
Input voltage, V_I	−1.0 to V_{DD} + 1.0 V
Output voltage, V_O	−0.5 to V_{DD} + 0.5 V
Power dissipation, P_{DMAX}	500 mW
Operating temperature, T_{opt}	−40 to +85°C
Storage temperature, T_{stg}	−60 to +125°C

Comment: Exposing the device to stresses above those listed in the absolute maximum ratings could cause permanent damage. Exposure to absolute maximum ratings for extended periods may affect device reliability.

Capacitance

(T_A = 25°C, V_{DD} = +5 V)

Parameter	Symbol	Limits Min	Limits Max	Units	Test Conditions
Input capacitance	C_{in}		12	pF	F = 1 MHz

DC Characteristics

(T_A = −40 to +85°C, V_{DD} = 5 V ± 10%)

Parameter	Symbol	Limits Min	Limits Max	Units	Test Conditions
Input voltage high	V_{IH}	2.2		V	
Input voltage low	V_{IL}		0.8	V	
Input voltage high	V_{IH}	2.6		V	RESIN
Output voltage high	V_{OH}	V_{DD} − 0.4		V	I_{OH} = −4 mA CLK
Output voltage high	V_{OH}	V_{DD} − 0.8		V	I_{OH} = −4 mA
Output voltage low	V_{OL}		0.45	V	I_{OL} = 4 mA
Input current	I_I	−1.0	1.0	μA	
Input current	I_I	−400	1.0	μA	RDYSYN
RESIN input hysteresis	V	0.25		V	
Power supply current (static)	I_{DD}		200	μA	
Power supply current (dynamic)	I_{DDdyn}		30	mA	F_{in} = 24 MHz

AC Characteristics

(T_A = −40 to +85 °C, V_{DD} = 5 V ± 10%)

Parameter	Symbol	Limits Min	Max	Units	Test Conditions
EXFS high	t_{EHEL}	16		ns	At 2.2 V
EXFS low	t_{ELEH}	16		ns	At 0.8 V
EXFS period	t_{ELEL}	40		ns	
XTAL frequency		12	25	MHz	
$RDY_{1,2}$ setup to CLK	t_{R_1VCL}, t_{R_1VCH}	35		ns	
$RDY_{1,2}$ hold to CLK	t_{CLR_1X}	0		ns	
$\overline{RDYSYN}$ setup to CLK	t_{RSYVCL}	50		ns	
$\overline{RDYSYN}$ hold to CLK	t_{CLRSYX}	0		ns	
$\overline{REN}1, 2$ setup to $RDY_{1,2}$	$t_{A_1R_1V}$	15		ns	
$\overline{REN}1, 2$ hold to CLK	t_{CLA_1X}	0		ns	
CKSYN setup to EXFS	t_{YHEH}	20		ns	
CKSYN hold to EXFS	t_{EHYL}	20		ns	
CKSYN width	t_{YHYL}	$2t_{ELEL}$		ns	
$\overline{RESIN}$ setup to CLK	t_{I_1HCL}	65		ns	

AC Characteristics (cont)

(T_A = −40 to +85 °C, V_{DD} = 5 V ± 10%)

Parameter	Symbol	Limits Min	Max	Units	Test Conditions
$\overline{RESIN}$ hold to CLK	t_{CLI_1H}	20		ns	
CLK cycle period	t_{CLCL}	125		ns	
CLK high	t_{CHCL}	41		ns	3 V, f_{OSC} ≤ 24 MHz (Note 1)
		$1/3t_{CLCL}+2$		ns	1.5 V, f_{OSC} ≤ 24 MHz (Note 2)
CLK low	t_{CLCH}	68		ns	1.5 V, f_{OSC} ≤ 24 MHz (Note 1)
		$2/3t_{CLCL}-15$		ns	1.5 V, f_{OSC} ≤ 24 MHz (Note 2)
CLK rise and fall time	t_{CLH}, t_{CHL}		10	ns	1.5 V to 3.5 V 3.5 V to 1.5 V
PRCLK high	t_{PHPL}	$t_{CLCL}-20$		ns	
PRCLK low	t_{PLPH}	$t_{CLCL}-20$		ns	
READY inactive to CLK	t_{RYLCL}		8	ns	
READY active to CLK	t_{RYHCH}		8	ns	
CLK to RESET delay	t_{CLIL}		40	ns	
CLK to PRCLK delay	t_{CLPH}		22	ns	
CLK to PRCLK delay	t_{CLPL}		22	ns	
OSC to CLK ↑ delay	t_{OLCH}	−5	22	ns	
OSC to CLK ↓ delay	t_{OLCL}	2	35	ns	
Signal rise time (except CLK)	t_{LH}		20	ns	0.8 V to 2.0 V
Signal fall time (except CLK)	t_{HL}		12	ns	2.0 V to 0.8 V

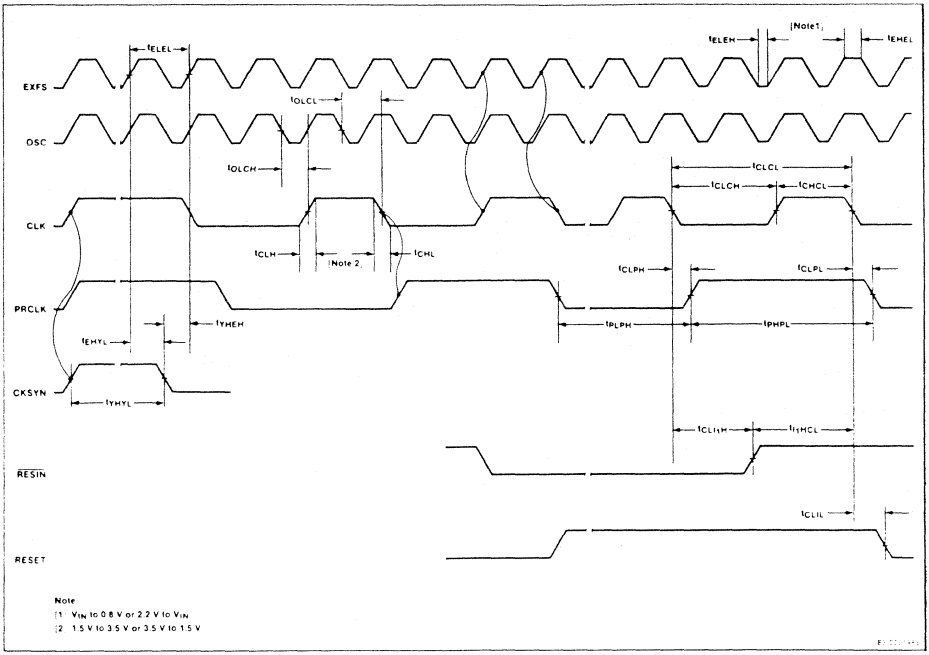
Note:

(1) Test points are specified in accordance with V-Series CMOS peripherals.

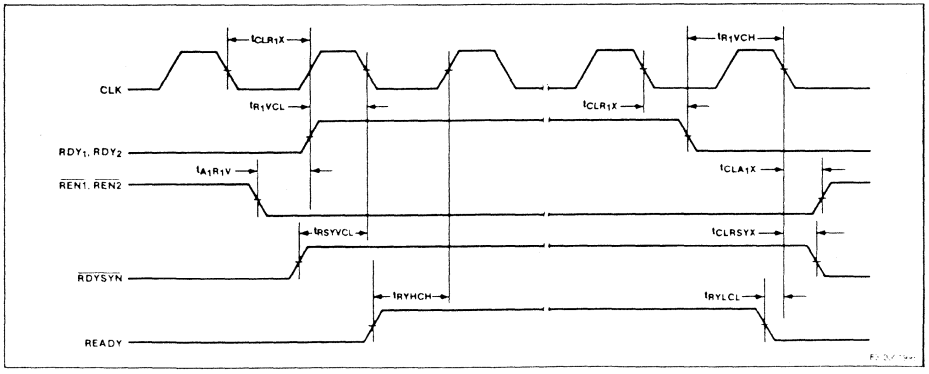
(2) Test points are specified in accordance with the μPD8284.

Timing Waveforms

CLK, RESET Signals

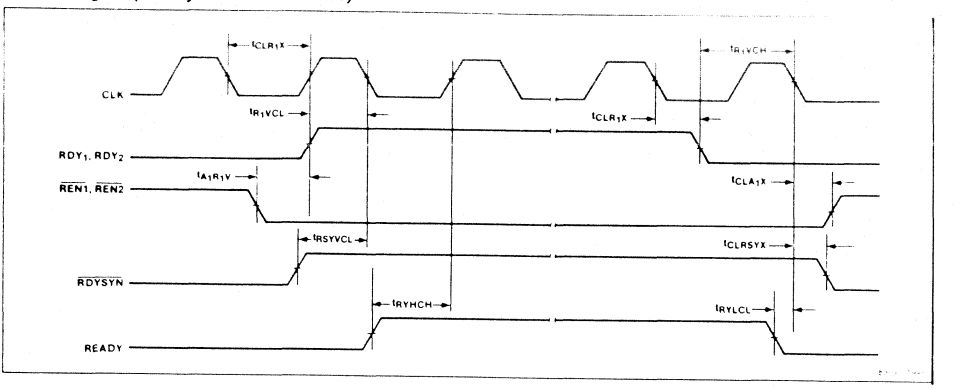


READY Signal (In an Asynchronous Device)

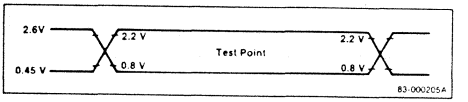


Timing Waveforms (cont)

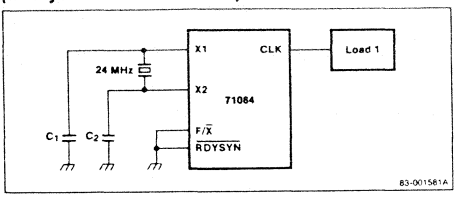
READY Signal (In a Synchronous Device)



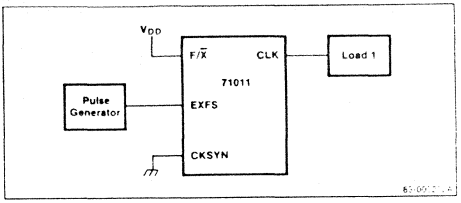
Input/Output Waveform for AC Test



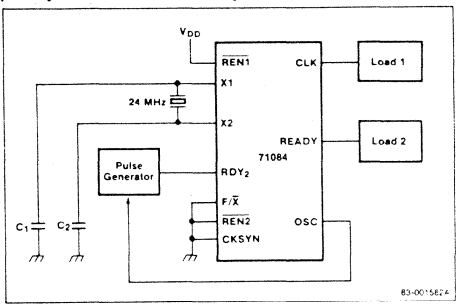
Test Circuit for CLK High or Low Time (in Crystal Oscillation Mode)



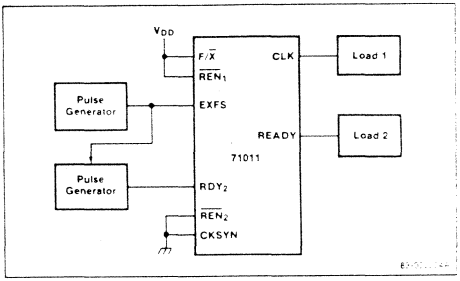
Test Circuit for CLK High or Low Time (in EXFS Oscillation Mode)



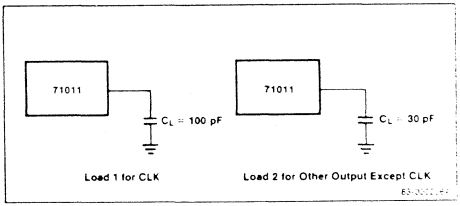
Test Circuit for CLK to READY (in Crystal Oscillation Mode)



Test Circuit for CLK to READY (in EXFS Oscillation Mode)



Loading Circuits



Description

μPD71086 and μPD71087 are 8-bit, bidirectional bus buffer/drivers with three-state outputs. The μPD71086 provides a non-inverted system bus. The μPD71087 provides an inverted system bus. These devices are used to expand CPU bus drive capability. The input/output lines are isolated from $\overline{OE}$ and BUF$\overline{R}$/W switching noise.

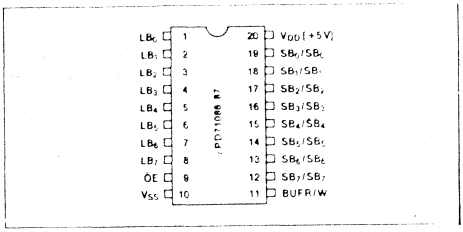
Features

- ☐ CMOS technology
- ☐ Bidirectional 8-bit parallel bus buffer
- ☐ Three-state output
- ☐ High drive capability system bus output (I_{OL} = 12 mA)
- ☐ Compatible with μPD70108C, μPD70116C and other CMOS or NMOS designs
- ☐ μPD71086 — non-inverted system bus output
  μPD71087 — inverted system bus output
- ☐ Single +5 V ±10% power supply
- ☐ 20 Pin plastic DIP (300 mil)
- ☐ Industrial temperature range: −40 to +85 °C

Ordering Information

Part Number	Package Type	Output
μPD71086C	20-pin plastic DIP	Non-inverted
μPD71087C	20-pin plastic DIP	Inverted
μPD71086G	20-pin SO plastic	
μPD71087G	20-pin SO plastic	

Pin Configuration



Pin Identification

No.	Symbol	Function
1	LB_0	CPU local data bus, bit 0
2	LB_1	CPU local data bus, bit 1
3	LB_2	CPU local data bus, bit 2
4	LB_3	CPU local data bus, bit 3
5	LB_4	CPU local data bus, bit 4
6	LB_5	CPU local data bus, bit 5
7	LB_6	CPU local data bus, bit 6
8	LB_7	CPU local data bus, bit 7
9	$\overline{OE}$	Output enable input
10	V_{SS}	Ground
11	BUF$\overline{R}$/W	Buffer read/write input
12	$SB_7/\overline{SB_7}$	System data bus, bit 7
13	$SB_6/\overline{SB_6}$	System data bus, bit 6
14	$SB_5/\overline{SB_5}$	System data bus, bit 5
15	$SB_4/\overline{SB_4}$	System data bus, bit 4
16	$SB_3/\overline{SB_3}$	System data bus, bit 3
17	$SB_2/\overline{SB_2}$	System data bus, bit 2
18	$SB_1/\overline{SB_1}$	System data bus, bit 1
19	$SB_0/\overline{SB_0}$	System data bus, bit 0
20	V_{DD}	+5 V power supply

Pin Functions

LB_7-LB_0 [Local Data Bus]

LB_7-LB_0 are three state Inputs/Outputs which connect to the CPU local data bus. They input and output data between the CPU and memory, I/O, or other peripherals. Data read/write mode is controlled by the BUF$\overline{R}$/W signal input.

SB_7-SB_0/$\overline{SB}_7$-$\overline{SB}_0$ [System Data Bus]

SB_7-SB_0/$\overline{SB}_7$-$\overline{SB}_0$ are three state Inputs/Outputs which connect to the system bus, along with the memory. I/O, or other peripherals. μPD71086 outputs non-inverted signals, SB_7-SB_0. μPD71087 outputs inverted signals, $\overline{SB}_7$-$\overline{SB}_0$.

$\overline{OE}$ [Output Enable]

$\overline{OE}$ input controls the output buffers. When $\overline{OE}$ is high, all output buffers go to the high-impedance state. When $\overline{OE}$ is low, data is output from the buffers specified by the BUF$\overline{R}$/W signal.

BUF$\overline{R}$/W [Buffer Read/Write]

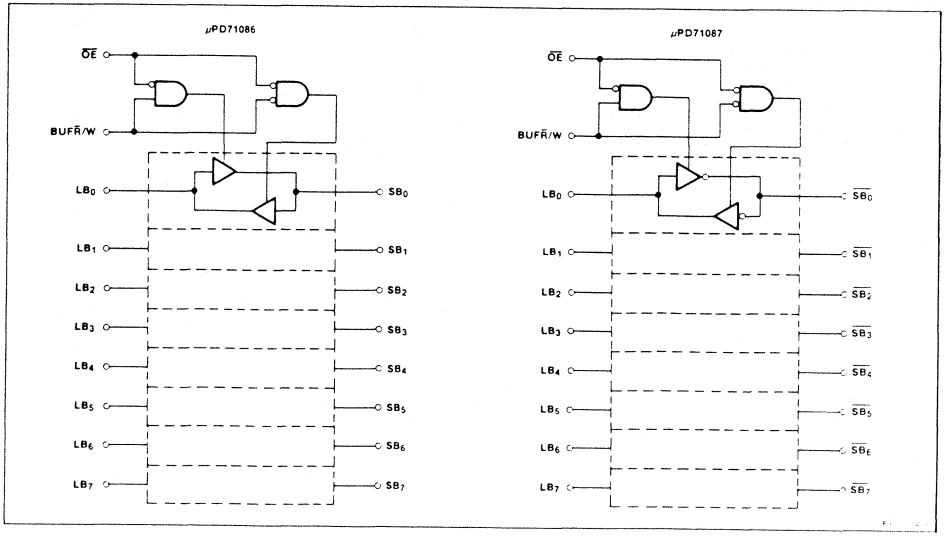
The data read/write mode is controlled by the BUF$\overline{R}$/W signal input. When BUF$\overline{R}$/W is high, LB lines are in input mode and SB lines are in output mode. When BUF$\overline{R}$/W is low, SB lines are in input mode, and LB lines are output. See table 1.

Table 1. Data Read/Write Mode

$\overline{OE}$	BUF$\overline{R}$/W	LB Pins	SB/$\overline{SB}$ Pins	Mode
Low	Low	Output	Input	System bus to local bus
Low	High	Input	Output	Local bus to system bus
High	Low	—	—	High impedance
High	High	—	—	High impedance

Note: When $\overline{OE}$ is high, all local and system bus pins go to high-impedance state.

Block Diagram



Absolute Maximum Ratings

(T_A = 25°C, V_{SS} = 0 V)

Power supply voltage, V_{DD}	−0.5 to +7.0 V
Input voltage, V_I	−1.0 to V_{DD} + 1 V
Output voltage, V_O	−0.5 to V_{DD} + 0.5 V
Power dissipation, P_D	500 mW
Operating temperature, T_{opt}	−40°C to +85°C
Storage temperature, T_{stg}	−65°C to +150 °C

Comment: Exposing the device to stresses above those listed in the absolute maximum ratings could cause permanent damage. Exposure to absolute maximum ratings for extended periods may affect device reliability.

Capacitance

(T_A = 25°C, V_{DD} = +5 V)

Parameter	Symbol	Limits Min	Limits Max	Units	Test Conditions
Input Capacitance	C_I		24	pF	f_c = 1 MHz

DC Characteristics

(T_A = −45°C to +85°C, V_{DD} = 5 V ±10%)

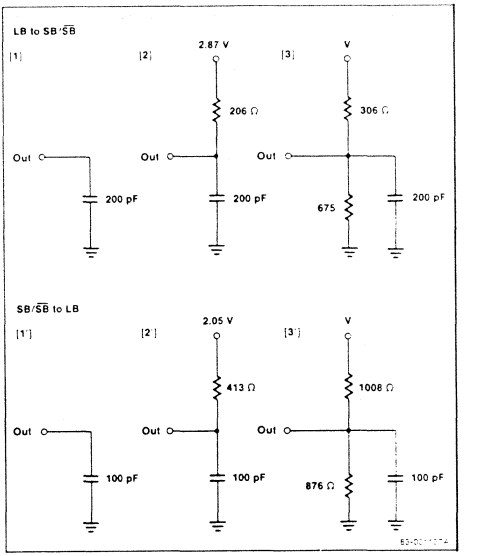
Parameter	Symbol	Limits Min	Limits Max	Units	Test Conditions
Input voltage high	V_{IH}	2.2		V	
Input voltage low	V_{IL}		0.8	V	
Output voltage high	V_{OH}	V_{DD} − 0.8		V	I_{OH} = −4 mA
Output voltage low	V_{OL}		0.45	V	LB, I_{OL} = 4 mA
Output voltage low	V_{OL}		0.45	V	SB, I_{OL} = 12 mA
Input leakage current	I_{IL}	−1.0	1.0	μA	$V_I = V_{DD}, V_{SS}$
Leakage current, high impedance	I_{OFF}	−1.0	1.0	μA	$\overline{OE} = V_{DD}$
Power supply current (static)	I_{DD}		80	μA	$V_I = V_{DD}, V_{SS}$
Power supply current (dynamic)	I_{DDdyn}		40	mA	f_{in} = 2 MHz

AC Characteristics

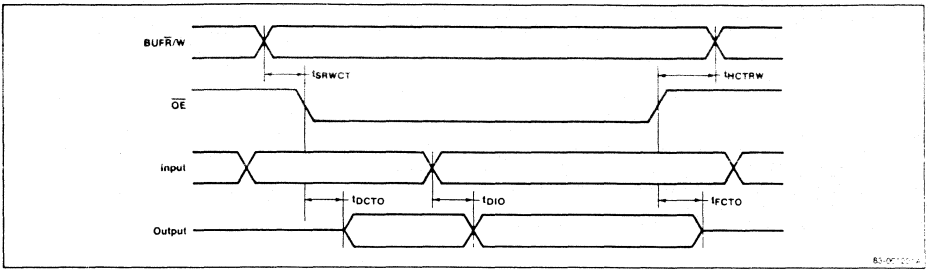
(T_A = −40°C to +85°C, V_{DD} = 5 V ± 10%)

Parameter	Symbol	Limits Min	Limits Max	Units	Test Conditions
Input to output delay	t_{DIO}	5	40	ns	Load (1), (1') and (2), (2')
BUFR/$\overline{W}$ hold time from $\overline{OE}$	t_{HCTRW}	5		ns	
BUFR/$\overline{W}$ setup time to $\overline{OE}$	t_{SRWCT}	10		ns	
Data float time from $\overline{OE}$	t_{FCTO}	5	30	ns	Load (3) and (3')
Data output delay from $\overline{OE}$	t_{DCTO}	10	40	ns	Load (3) and (3')
Signal rise time	t_R		20	ns	0.8 to 2.0 V
Signal fall time	t_F		12	ns	2.0 to 0.8 V

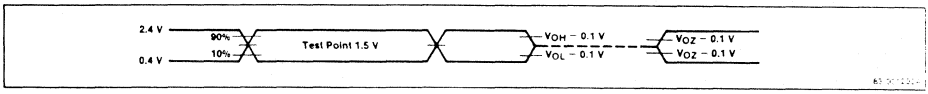
Loading Circuit for AC Test



Timing Waveforms



Input Waveform for AC Test



Description

The μPD71088 is a CMOS system bus controller for a μPD70108 or μPD70116 CPU processor system. It controls the memory or I/O system bus.

Features

- ☐ CMOS technology
- ☐ Bus controller for microcomputer system expansion
- ☐ Command outputs for system bus control
- ☐ Control outputs for I/O peripheral bus control
- ☐ High drive capability for command and control outputs (I_{OL} = 12 mA)
- ☐ Three-state outputs for command outputs
- ☐ Advanced I/O and memory write command outputs
- ☐ μPD70108, μPD70116 compatible
- ☐ +5 V ±10% single power supply
- ☐ 20-pin plastic DIP (300 mil)
- ☐ Industrial temperature range: −40 to +85 °C

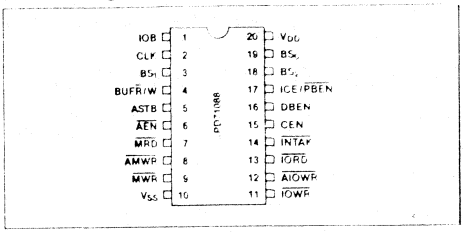
Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD71088C	20-pin plastic DIP	8 MHz
μPD71088G	20-pin plastic SO	8 MHz

Pin Identification

No.	Symbol	Function
1	IOB	Input/output bus mode input
2	CLK	Clock input
3	BS_1	Bus status input 1
4	BUFR/W	Buffer read/write output
5	ASTB	Address strobe output
6	$\overline{AEN}$	Address enable input
7	$\overline{MRD}$	Memory read output
8	$\overline{AMWR}$	Advanced memory write output
9	$\overline{MWR}$	Memory write command output
10	V_{SS}	Ground
11	$\overline{IOWR}$	I/O write command output
12	$\overline{AIOWR}$	Advanced I/O write command output
13	$\overline{IORD}$	I/O read command output
14	$\overline{INTAK}$	Interrupt acknowledge output
15	CEN	Command enable input
16	DBEN	Data buffer enable output
17	ICE/$\overline{PBEN}$	Interrupt cascade enable/Peripheral data bus enable output
18	BS_2	Bus status input 2
19	BS_0	Bus status input 0
20	V_{DD}	Power supply

Pin Configuration



Pin Functions

BS_0-BS_2 [Bus Status Inputs 0 - 2]

The BS_0-BS_2 inputs are connected to the encoded CPU status outputs. The μPD71088 decodes these status outputs into command and control outputs for timing control. See table 1 for an explanation of these inputs.

CLK [Clock]

The CLK input is connected to the same clock output that drives the CPU clock, usually the CLK output of a μPD71084 or a μPD71011. It is the internal system clock of the μPD71088.

$\overline{AEN}$ [Address Enable]

The $\overline{AEN}$ input controls the command output buffers. When IOB is low, a low-level $\overline{AEN}$ causes the command buffers to output command output signals. A high-level $\overline{AEN}$ makes all command lines go to high impedance. When IOB is high, the μPD71088 is in I/O bus mode, and the command lines are not affected by $\overline{AEN}$.

CEN [Command Enable]

The CEN input controls DBEN, $\overline{PBEN}$ and all command outputs. When CEN is high, all these outputs are active. When CEN is low, they are inactive.

IOB [I/O Bus Mode]

When the IOB input is high, the bus control mode is I/O bus mode. When IOB is low, the bus control mode is system bus mode.

$\overline{MRD}$ [Memory Read Command]

The $\overline{MRD}$ output is the signal to read data from a memory device. $\overline{MRD}$ is three-state, active low.

$\overline{MWR}$ [Memory Write Command]

The $\overline{MWR}$ output is the signal to write data to a memory device. $\overline{MWR}$ is three-state, active low.

$\overline{AMWR}$ [Advanced Memory Write Command]

This command output is the same as $\overline{MWR}$, except that it is generated one state (clock cycle) earlier than $\overline{MWR}$.

$\overline{IORD}$ [I/O Read Command]

The $\overline{IORD}$ output is the signal to read data from an I/O device. $\overline{IORD}$ is three-state, active low.

$\overline{IOWR}$ [I/O Write Command]

The $\overline{IOWR}$ output is the signal to write data to an I/O device. $\overline{IOWR}$ is three-state, active low.

$\overline{AIOWR}$ [Advanced I/O Write Command]

This command output is the same as $\overline{IOWR}$, except that it is generated one state (clock cycle) earlier than $\overline{IOWR}$.

$\overline{INTAK}$ [Interrupt Acknowledge]

The $\overline{INTAK}$ output acknowledges interrupt requests. Requesting devices output an interrupt vector address in response to $\overline{INTAK}$. $\overline{INTAK}$ is three-state, active low.

ASTB [Address Strobe]

The ASTB output control signal latches the address outputs from the CPU into an external address latch, such as a μPD71082 or μPD71083. Address data should be strobed with the trailing edge (high to low) of ASTB.

DBEN [Data Buffer Enable]

The DBEN output activates a data bus buffer/driver such as a μPD71086 or μPD71087 to input or output data between the CPU local bus and the memory or I/O system bus.

BUF$\overline{R}$/W [Buffer Read/Write]

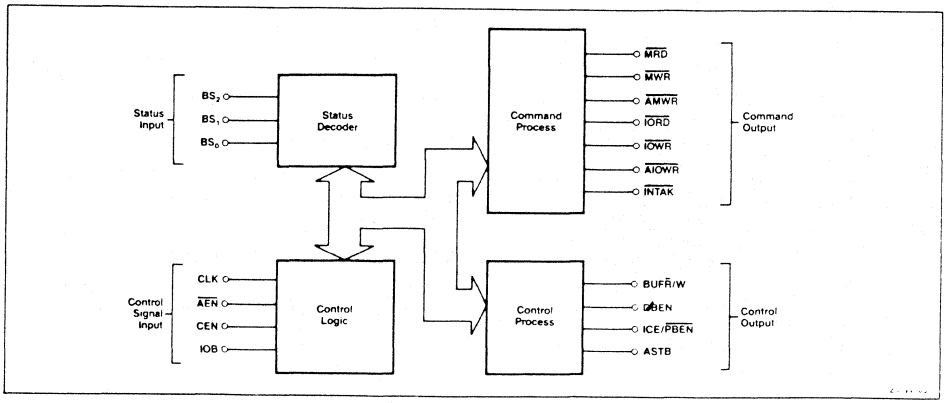
The BUF$\overline{R}$/W output controls the direction in which data moves through a transceiver between the CPU and the memory or I/O peripherals. When BUF$\overline{R}$/W is high, data is transferred from the CPU local bus to the memory or I/O system bus. When BUF$\overline{R}$/W is low, data is transferred from the memory or I/O system bus to the CPU local bus.

ICE/$\overline{PBEN}$ [Interrupt Cascade Enable/Peripheral Data Bus Enable]

The meaning of this output signal depends on IOB. If IOB is low (system bus mode), it is the ICE output. ICE controls the cascade address transfer from a master priority interrupt controller to slave priority interrupt controllers. The slave reads the address from the master when ICE goes high.

When IOB is high, it becomes $\overline{PBEN}$. $\overline{PBEN}$ controls the I/O bus the same way that DBEN controls the system bus. In this case, however, the output is active low.

Block Diagram



Absolute Maximum Ratings

(T_A = 25°C, V_{SS} = 0 V)

Power supply voltage, V_{DD}	−0.5 to +7.0 V
Input voltage, V_I	−1.0 to V_{DD} + 1.0 V
Output voltage, V_O	−0.5 to V_{DD} + 0.5 V
Power dissipation, P_D	500 mW
Operating temperature, T_{opt}	−40 to +85°C
Storage temperature, T_{stg}	−65 to +150°C

Comment: Exposing the device to stresses above those listed in the Absolute Maximum Ratings could cause permanent damage. Exposure to absolute maximum ratings for extended periods may affect device reliability.

DC Characteristics

(T_A = −40°C to +85°C, V_{DD} = 5 V ± 10%)

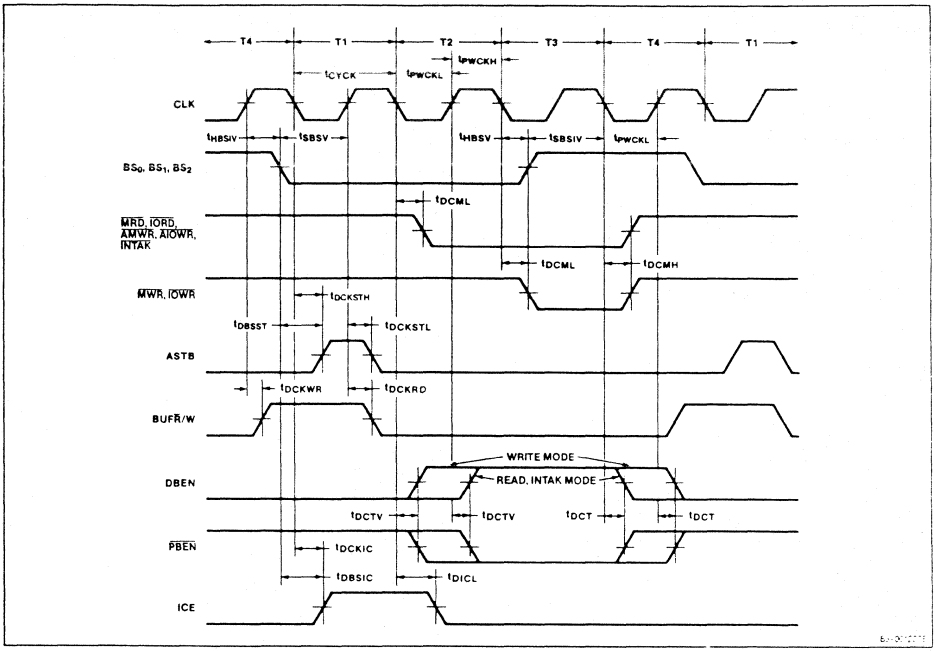
Parameter	Symbol	Limits Min	Limits Max	Units	Test Conditions
Input voltage high	V_{IH}	2.2		V	
Input voltage low	V_{IL}		0.8	V	
Output voltage high	V_{OH}	V_{DD} − 0.8		V	I_{OH} = −4 mA
Output voltage low command	V_{OL}		0.45	V	I_{OL} = 12 mA,
Output voltage low control	V_{OL}		0.45	V	I_{OL} = 4 mA,
Input current leakage	I_{IL}	−1.0	1.0	μA	$V_I = V_{DD}, V_{SS}$
Leakage current at high impedance	I_{OFF}	−10	10	μA	
Power supply current (static)	I_{DD}		80	μA	$V_I = V_{DD}, V_{SS}$
Power supply current (dynamic)	I_{DDdyn}		20	mA	F_{in} = 10 MHz

AC Characteristics

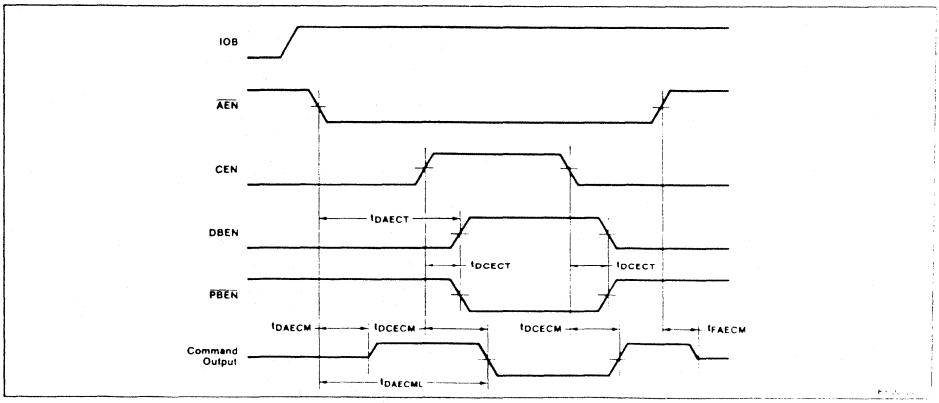
(T_A = −40°C to +85°C, V_{DD} = 5 ± 10%)

Parameter	Symbol	Limits Min	Limits Max	Units	Test Conditions
CLK cycle period	t_{CYCK}	125		ns	
CLK pulse with low	t_{PWCKL}	60		ns	
CLK pulse width high	t_{PWCKH}	40		ns	
Setup time for bus status active to CLK↑	t_{SBSV}	40		ns	
Hold time for bus status inactive from CLK↓	t_{HBSV}	10		ns	
Setup time for bus status inactive to CLK↓	t_{SBSIV}	35		ns	
Hold time for bus status inactive from CLK↑	t_{HBSIV}	10		ns	
DBEN, $\overline{PBEN}$ active	t_{DCTV}	10	50	ns	I_{OL} = 4 mA, I_{OH} = −4 mA, C_L = 100 pF
DBEN, $\overline{PBEN}$ inactive delay	t_{DCT}	10	50	ns	
ASTB active delay from CLK↓	t_{DCKSTH}		30	ns	
ASTB active delay from status	t_{DBSST}		25	ns	
ASTB inactive delay from CLK↑	t_{DCKSTL}	7	25	ns	
ICE active delay from CLK↓	t_{DCKIC}		30	ns	
ICE inactive delay from CLK↓	t_{DICL}	10	50	ns	
ICE active delay from status	t_{DBSIC}		25	ns	
BUF$\overline{R}$/W ↓ output delay	t_{DCKRD}		60	ns	
BUF$\overline{R}$/W ↑ output	t_{DCKWR}		40	ns	
$\overline{AEN}$ to DBEN delay	t_{DAECT}		30	ns	
CEN to DBEN, $\overline{PBEN}$ delay	t_{DCECT}		30	ns	
CEN to command delay	t_{DCECM}		t_{CLML}	ns	
Command active delay from CLK ↓	t_{DCML}	10	40	ns	
Command inactive delay	t_{DCMH}	10	40	ns	
Command output delay from $\overline{AEN}$	t_{DAECML}		40	ns	
Command active output delay from $\overline{AEN}$	t_{DAECML}	100	295	ns	
Command disable delay from $\overline{AEN}$ ↑	t_{FAECM}		50	ns	
Input/output rise time	t_R		20	ns	0.8 V to 2.0 V
Input/output fall time	t_F		12	ns	2.0 V to 0.8 V

Timing Waveforms

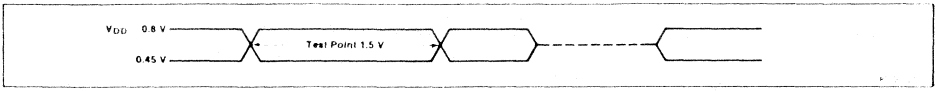


AEN, PBEN, DBEN Timing Diagrams

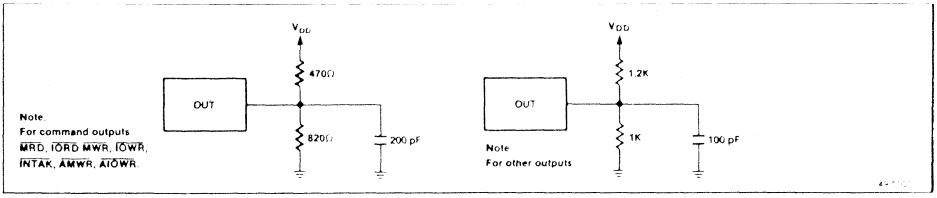


Timing Waveforms (cont)

AC Test Points



Loading Circuit



Bus Controller Funtional Description

Command Logic

The μPD71088 decodes the CPU bus status outputs into command outputs. The bus status outputs (BS_0-BS_2) and their decoded commands are shown in table 1.

Bus Control Mode

The CEN, IOB, and $\overline{AEN}$ signals control the bus controller mode as shown in table 2.

Table 1. Command Logic

BS_2	BS_1	BS_0	CPU Status	μPD71088 Command Output
Low	Low	Low	Interrupt acknowledge	$\overline{INTAK}$
Low	Low	High	I/O read mode	$\overline{IORD}$
Low	High	Low	I/O write mode	$\overline{IOWR}$, $\overline{AIOWR}$
Low	High	High	Halt mode	None
High	Low	Low	Instruction fetch mode	$\overline{MRD}$
High	Low	High	Memory read mode	$\overline{MRD}$
High	High	Low	Memory write mode	$\overline{MWR}$, $\overline{AMWR}$
High	High	High	No bus cycle mode	None

Table 2. Bus Control Mode

Control Input			Command Output		Control Output	
			Memory	I/O		
CEN	IOB	$\overline{AEN}$	$\overline{MRD}$, $\overline{MWR}$, $\overline{AMWR}$	$\overline{IOWR}$, $\overline{AIOWR}$, $\overline{IORD}$, $\overline{INTAK}$	ICE/$\overline{PBEN}$	ASTB, BUFR/W, DBEN
H	H (I/O bus mode)	H	High impedance	Outputs enabled (NC)	$\overline{PBEN}$ (NC)	Outputs enabled (NC)
		L	Outputs enabled			
	L (System bus mode)	H	High impedance	High impedance	ICE (NC)	Outputs enabled (NC)
		L	Outputs enabled	Outputs enabled		
L (Command disable mode)	x	x	H	H	$\overline{PBEN}$ = H	Outputs enabled (DBEN = L: ASTB, BUFR/W are NC)

Note:

x = Don't care, NC = No change, H = High, L = Low

Description

The μPD71611 is a high performance CMOS clock generator/driver for the μPD70616 (V60) microprocessor. The μPD71611 contains a crystal oscillator for use with a fundamental mode crystal. An external clock source can also be used if it is necessary to synchronize the μPD70616 to an external clock.

Reset logic with a Schmitt-trigger input is also included to synchronize a power-on reset signal to the system clock and be used as a system-wide reset signal. The μPD71611 also contains wait state logic for generation of 0 to 7 wait states into any bus cycle.

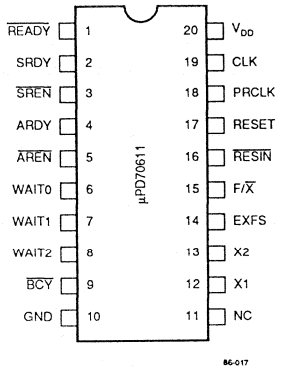
Features

- μPD70616 system clock generator/driver
- 16 MHz system clock (32MHz input divided by two)
- Programmable wait state generator
- Schmitt-trigger reset logic
- Low power CMOS technology
- 20-pin plastic DIP

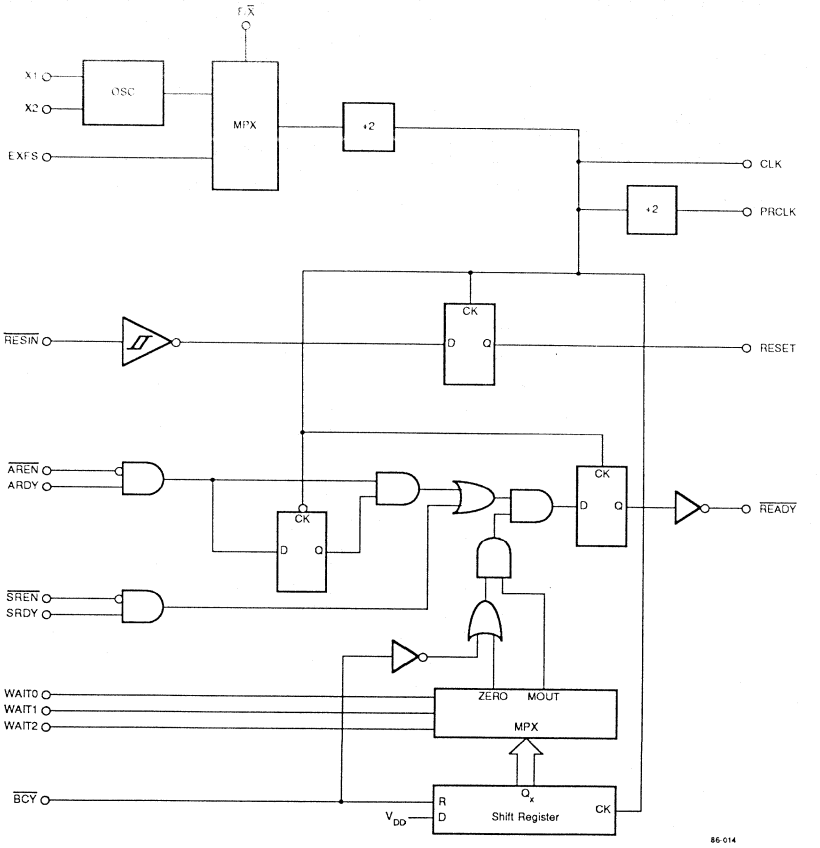
Ordering Information

Part Number	Package	Maximum Frequency
μPD71611C	20-pin plastic DIP	16 MHz

Pin Configuration



Block Diagram



Pin Identification

Symbol		I/O	Function
X1, X2	Crystal Inputs	I/O	I/O terminals for crystal, twice the μPD70616 frequency
EXFS	External Clock Source	In	External clock input pin, twice the μPD70616 frequency
F/X*	Frequency/Crystal Select	In	Clock source multiplexer control
CLK	Clock	Out	μPD70616 system clock, 1/2 the input clock frequency
PRCLK	Peripheral Clock	Out	Peripheral clock, 1/4 the input clock frequency
RESIN*	Reset Input	In	Schmitt trigger reset input
RESET	Reset Out	Out	μPD70616 and system reset output
ARDY	Asynchronous Ready	In	Asynchronous ready input
AREN*	Asynchronous Ready Enable	In	Enable input for ARDY
SRDY	Synchronous Ready	In	Synchronous ready input
SREN*	Synchronous Ready Enable	In	Enable input for SRDY
BCY*	Bus Cycle	In	μPD70616 bus cycle output
WAIT0 WAIT1 WAIT2	Wait State Controls	In	Wait state inputs to add 0 to 7 wait states to a bus cycle
READY*	Ready	Out	Ready output to the μPD70616

Pin Functions

This section describes the operation of the μPD71611 I/O terminals. Inputs and outputs are considered at a logic "0" level when a low level signal is present. Likewise, a logic "1" is represented by a high level signal. Bus states are defined and measured from the rising edge of the clock to the rising edge of the next clock.

X1, X2 [Crystal Inputs] ..... inputs/outputs
The X1 and X2 inputs are used to connect a fundamental mode crystal to the internal oscillator circuitry. The crystal is selected to oscillate at a frequency twice the μPD70616 operating frequency.

EXFS [External Frequency Source] ..... input
The EXFS pin allows an external TTL-level clock source twice the desired operating frequency to be used as the input clock.

F/X* [Frequency/Crystal Select] ..... input
The F/X* input selects either the internal crystal oscillator or an external clock oscillator as the clock source for the μPD70616 and other devices.

CLK [Clock] ..... output
CLK is the μPD70616 processor clock output. The CLK output has additional drive capabilities matched to the requirements of the μPD70616 and associated microprocessors.

PRCLK [Peripheral Clock] ..... output
CLK is the μPD70616 system clock output available for use by peripheral devices.

RESIN* [Reset Input] ..... input
RESIN* is a Schmitt-trigger input used to synchronize the asynchronous reset input to the rising edge of the processor clock before use by the rest of the system.

RESET [Reset Output] ..... output
RESET is an active high synchronized reset signal for the μPD70616 and peripheral devices.

ARDY [Asynchronous Ready Input] ..... input
The ARDY input is used by ready signals which are not synchronized to the μPD70616 clock. This input is internally applied to a synchronizer before being used as a ready output to the processor.

AREN* [Asynchronous Ready Enable] ..... input
AREN* is an enable for the ARDY input. If ARDY is not used in a system, AREN* can be pulled up to the positive power supply to disable the asynchronous ready logic.

SRDY [Synchronous Ready Input] ..... input
The SRDY input is used by ready signals which are synchronized to the μPD70616 clock.

SREN* [Synchronous Ready Enable] ..... input
SREN* is an enable for the SRDY input. If SRDY is not used in a system, SREN* can be pulled up to the positive power supply to disable the synchronous ready logic.

BCY* [Bus Cycle] ..... input
The μPD70616 indicates the start of a new bus cycle by asserting the BCY* output. The μPD71611 uses BCY* to control the operation of the wait state logic.

WAIT2–0 [Wait State Mode Inputs] ..... inputs
The WAIT2–0 inputs are decoded to determine the number of wait states the μPD71611 should automatically insert into the bus cycle. These inputs can be dynamically changed on a bus cycle basis to insert from 0 to 7 seven wait states into a bus cycle.

READY* [Ready Output] ..... output
READY* is an active low output used by slow memory and peripheral devices to insert wait states into a μPD70616 bus cycle.

V_{DD} [Power Supply]
The V_{DD} pin supplies +5 Volt power to the μPD71611.

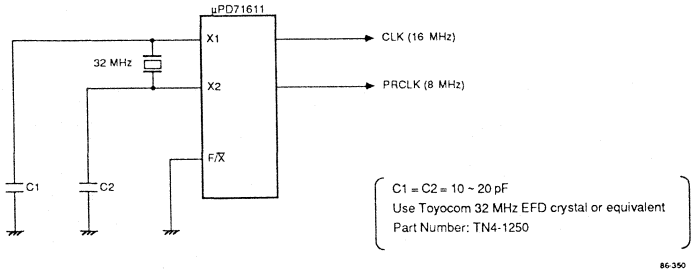
GND [Ground]
The GND pin is the power supply return.

Operational Description

The μPD71611 serves as the system clock generator/driver for the μPD70616 (V60) microprocessor. The primary clock source can be selected from an internal crystal oscillator and fundamental mode crystal or from an external TTL-level clock. The source clock is then divided by two to generate the μPD70616 clock (CLK) and by four to generate the peripheral clock (PRCLK).

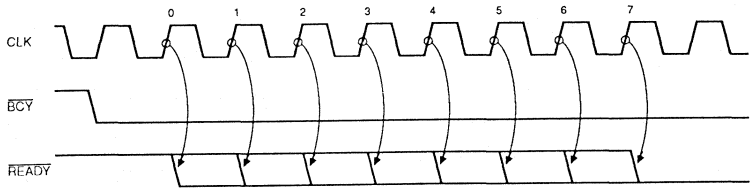
The μPD71611 contains additional logic for synchronization of a reset input and the generation of processor wait states. Figure 1 shows a typical μPD71611 design example using the on-chip clock oscillator logic.

Figure 1. Crystal Oscillator Example



Three different types of wait states are accommodated by the μPD71611. Both synchronous and asynchronous wait ready inputs are available, each with a corresponding enable input. Zero to seven wait states can also be automatically inserted into a bus cycle using the WAIT2–0 inputs.

Figure 2. WAIT2–0 and READY* Timing



WAIT2	0	0	0	0	1	1	1	1
WAIT1	0	0	1	1	0	0	1	1
WAIT0	0	1	0	1	0	1	0	1
Wait States	0	1	2	3	4	5	6	7

86-351

Absolute Maximum Ratings

T_A = +25°C

Power Supply Voltage, V_{DD}	−0.5 V to +7.0 V
Input Voltage, V_I	−1.0 V to V_{DD} + 1.0 V
Output Voltage, V_O	−0.5 V to V_{DD} + 0.5 V
Operating Temperature, T_{OPT}	−40°C to +85°C
Storage Temperature, T_{STG}	−65°C to +150°C
Power Dissipation, P_D	500mW

Comment: Exposing the device to stresses above those listed in the Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

T_A = +25°C, V_{DD} = 0 V

Parameter	Symbol	Limits Min	Max	Unit	Conditions
Input Capacitance	C_I		10	pf	f = 1 MHz

DC Characteristics

T_A = −40°C to +85°C, V_{DD} = +5 V ±5%

Parameter	Symbol	Limits Min	Max	Unit	Conditions
Input Voltage Low	V_{IL}		0.8	V	
Input Voltage High	V_{IH}	2.2		V	except RESIN*
		2.6		V	RESIN* input
Output Voltage Low	V_{OL}		0.45	V	I_{OL} = 4mA
Output Voltage High	V_{OH}	V_{DD} − 0.4		V	CLK output, I_{OH} = −4mA
		V_{DD} − 0.8		V	except CLK, I_{OH} = −4mA
Input Current	I_I	−1.0	1.0	μA	
RESIN* Hysteresis		0.25		V	
Supply Current (Static)	I_{DD}		200	μA	
Supply Current (Dynamic)	I_{DDdyn}		50	mA	f_{in} = 32 MHz, outputs open

AC Characteristics

T_A = −40°C to +85°C, V_{DD} = +5 V ±5%

Parameter	Symbol	Limits Min	Max	Unit	Conditions
EXFS Cycle Time	t_{CYFS}	28		ns	
EXFS Pulse Width High	t_{PWFSH}	10		ns	2.2 V measurement point
EXFS Pulse Width Low	t_{PWFSL}	10		ns	0.8 V measurement point
OSC Cycle Time	f_{OSC}		32	MHz	
CLK Cycle Time	t_{CYCK}	60		ns	
CLK Pulse Width High	t_{PWCKH}	25		ns	3.0 V measurement point
CLK Pulse Width Low	t_{PWCKL}	25		ns	1.5 V measurement point
CLK Rise Time	t_{LHCK}		5	ns	1.5 V → 3.0 V
CLK Fall Time	t_{HLCK}		5	ns	3.0 V → 1.5 V
CLK Delay from EXFS↓	t_{DCKH}	0	20	ns	CLK↑
CLK Delay from EXFS↓	t_{DCKL}	0	20	ns	CLK↑

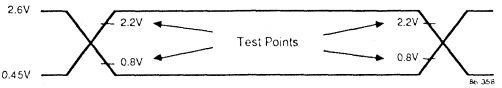
AC Characteristics (cont)

T_A = −40°C to +85°C, V_{DD} = +5 V ±5%

Parameter	Symbol	Limits Min	Limits Max	Unit	Conditions
PRCLK Cycle Time	t_{CYPRK}	120		ns	
PRCLK Pulse Width High	t_{PWPRKH}	t_{CYCK} − 15		ns	
PRCLK Pulse Width Low	t_{PWPRKL}	t_{CYCK} − 15		ns	
PRCLK↑ Delay from CLK↓	t_{DPRKH}		20	ns	
PRCLK↓ Delay from CLK↓	t_{DPRKL}		20	ns	
RESIN* Setup to CLK↓	t_{SRICK}	20		ns	
RESIN* Hold from CLK↓	t_{HCKRI}	0		ns	
RESET* Delay from CLK↓	t_{DCKRS}		10	ns	
SREN* Setup to CLK↑	t_{SSRECK}	20		ns	
SREN* Hold from CLK↑	t_{HCKSRE}	0		ns	
SRDY Setup to CLK↑	t_{SSRYCK}	20		ns	
SRDY Hold from CLK↑	t_{HCKSRY}	0		ns	
AREN* Setup to CLK↓	t_{SARECK}	20		ns	
AREN* Hold from CLK↓	t_{HCKARE}	0		ns	
ARDY Setup to CLK↓	t_{SARYCK}	20		ns	
ARDY Hold from CLK↓	t_{HCKARY}	0		ns	
READY* Output Delay from CLK↑	t_{DCKRDY}		10	ns	READY*↑
			8	ns	READY*↓
BCY* Setup to CLK↑	t_{SBCCK}	15		ns	
BCY* Hold from CLK↑	t_{HCKRE}	5		ns	
WAIT0, 1, 2 Setup to CLK↑	t_{SRYCK}	15		ns	
WAIT0, 1, 2 Hold from CLK↑	t_{HCKRY}	5		ns	
Input Rise Time	t_{RI}		15	ns	0.8 V → 2.2 V
Input Fall Time	t_{FI}		8	ns	2.2 V → 0.8 V
Output Rise Time	t_{RO}		10	ns	0.8 V → 2.2 V
Output Fall Time	t_{FO}		6	ns	2.2 V → 0.8 V

Timing Waveforms

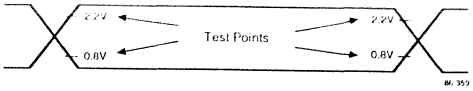
AC Test Input (except RESIN*)



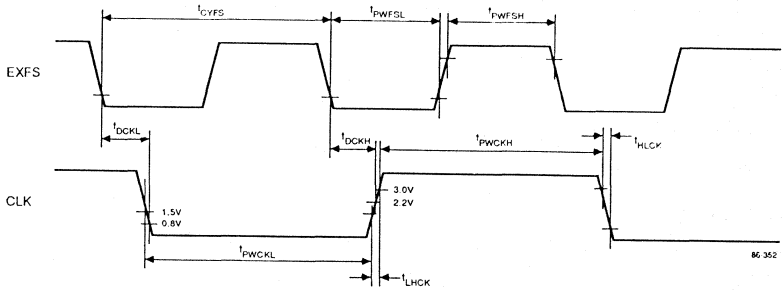
(When $\overline{RESIN}$: Input high level is 3.0V, low level is 0.45V
High level test point is 2.6V, low level test point is 0.8V)

Timing Waveforms (cont)

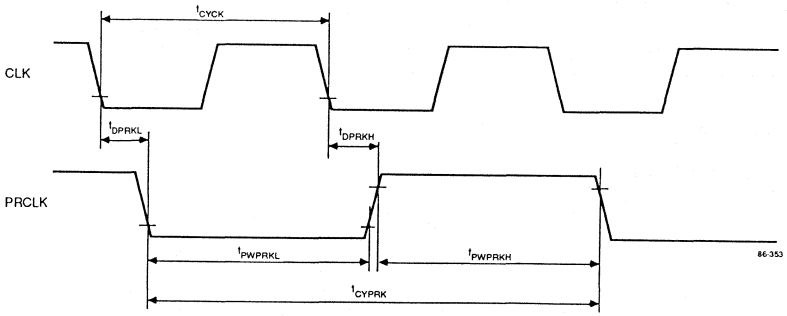
AC Test Output (except CLK)



Clock (CLK) Timing

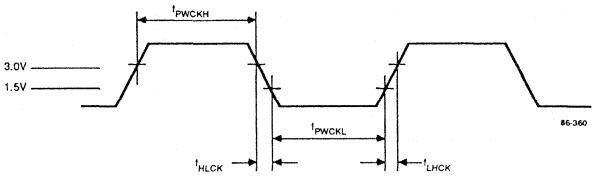


Peripheral Clock (PRCLK) Timing

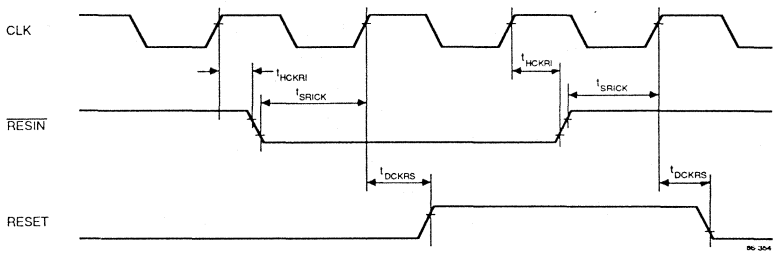


Timing Waveforms (cont)

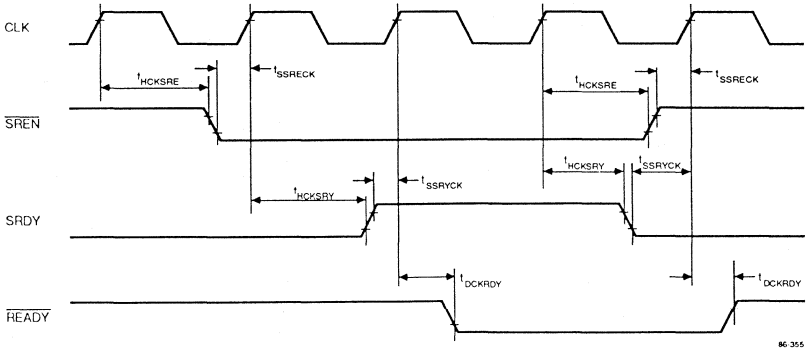
Clock (CLK) Output Timing



Reset Timing

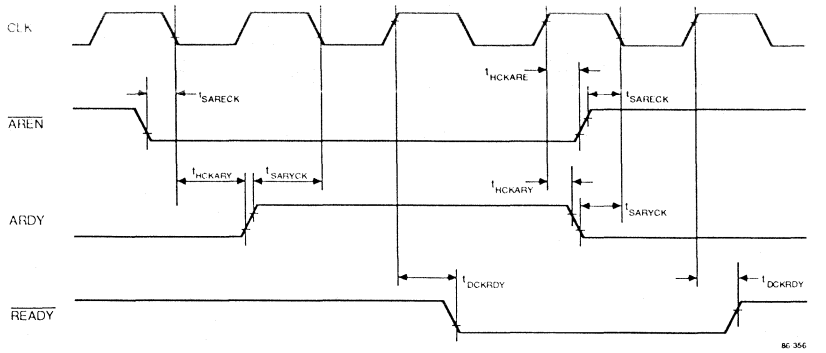


Synchronous Ready Timing

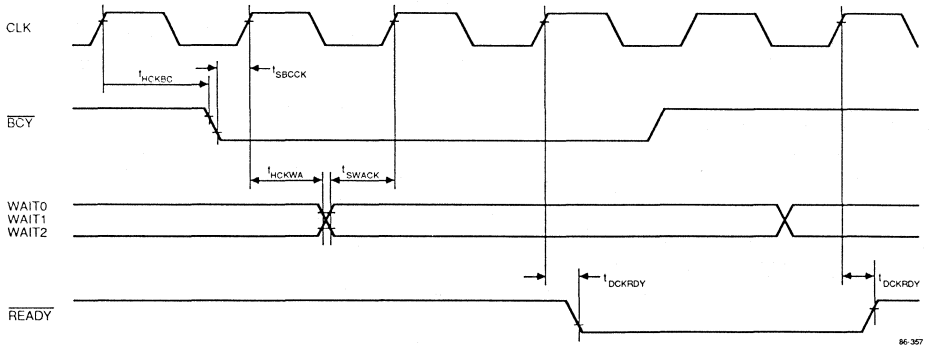


Timing Waveforms (cont)

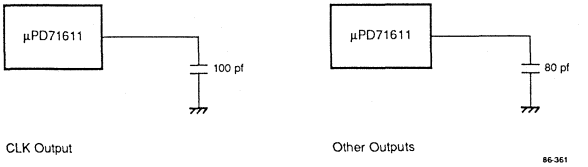
Asynchronous Ready Timing



Wait State Timing

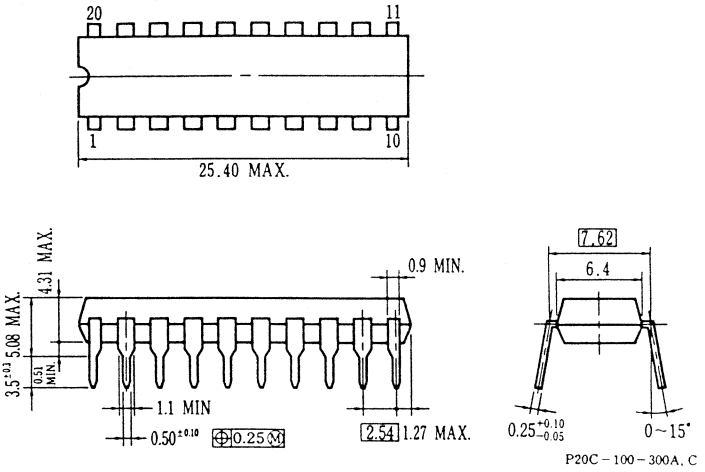


Loading Circuits



Packaging Information

20-Pin Plastic DIP Package (300 mil)



μPD71613 SYSTEM BUS CONTROLLER FOR V60

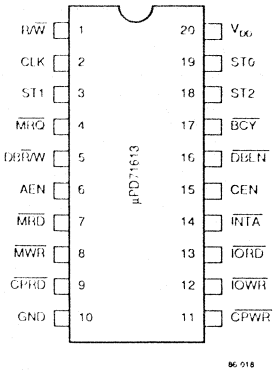
Description

The μPD71613 is a high performance CMOS bus controller for the μPD70616 (V60) microprocessor. The μPD71613 decodes the μPD70616 status outputs and generates the memory, I/O and coprocessor read/write strobes. A separate interrupt acknowledge output is also provided for interfacing to interrupt controllers.

Features

- High output drive (I_{OL} = 16 mA)
- Decodes μPD70616 bus status for
  - memory read/write
  - I/O read/write
  - coprocessor read/write
  - interrupt acknowledge
- 3-state command outputs
- CMOS technology
- 20-pin plastic DIP

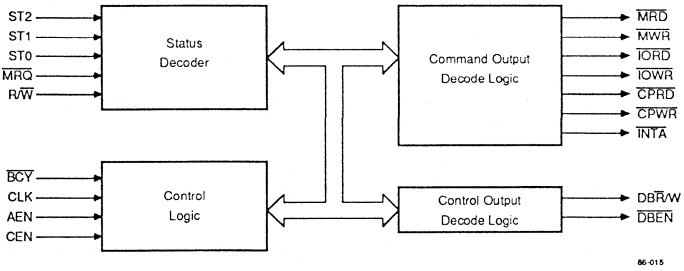
Pin Configuration



Ordering Information

Part Number	Package	Maximum Frequency
μPD71613C	20-pin plastic DIP	16 MHz

Block Diagram



Pin Identification

Symbol		I/O	Function
ST2-ST0	Bus Status	In	μPD70616 bus status inputs
CLK	Clock	In	μPD70616 clock input
MRQ*	Memory Request	In	μPD70616 memory request strobe
R/W*	Read/Write	In	μPD70616 bus cycle direction input
BCY*	Bus Cycle	In	μPD70616 bus cycle active input
AEN	Address Enable	In	Command output buffer control pin
CEN	Command Enable	In	Command output control pin
MRD*	Memory Read	3-state output	Memory read strobe output
MWR*	Memory Write	3-state output	Memory write strobe output
IORD*	I/O Read	3-state output	I/O read strobe output
IOWR*	I/O Write	3-state output	I/O write strobe output
CPRD*	Coprocessor Read	3-state output	Coprocessor read strobe output
CPWR*	Coprocessor Write	3-state output	Coprocessor write strobe output
INTA*	Interrupt Acknowledge	Out	Interrupt acknowledge output
DBEN*	Data Bus Enable	Out	External data bus buffer enable output
DBR*/W	Data Buffer Read/Write	Out	Data bus buffer direction output

Pin Functions

This section describes the operation of the μPD71613 terminals. Inputs and outputs are considered at a logic "0" level when a low level signal is present. Likewise, a logic "1" is represented by a high level signal. Bus states are defined and measured from the rising edge of the clock to the rising edge of the next clock.

ST2-ST0 [Bus Status]..... inputs
The ST2–ST0 inputs are connected to the encoded CPU bus status outputs. The bus status inputs are decoded into the command and control outputs for timing control.

CLK [Clock]..... input
CLK is the μPD70616 system clock from the μPD71611 clock generator.

BCY* [Bus Cycle]..... input
The μPD70616 indicates the start of a new bus cycle by asserting the BCY* output. The μPD71613 uses BCY* to generate the timing for all command and control outputs.

MRQ* [Memory Request]..... input
MRQ* is a μPD70616 output which indicates whether or not the bus cycle is in the memory address space or in some other address space.

R/W* [Read/Write]..... input
R/W* is the bus cycle direction status from the μPD70616.

AEN [Address Enable]..... input
The AEN input is the three-state control for the command output buffers. When AEN is high, all output buffers are enabled and the decoded command is determined by the input status. When AEN is low, all command output buffers are in the high impedance state.

CEN [Command Enable]..... input
CEN controls the DBEN* and all command outputs. When CEN is high, all outputs are enabled and controlled by the status inputs. When CEN is low, DBEN* and the command outputs are forced to the inactive state.

MRD* [Memory Read]..... output
MRD* is an active low three-state output strobe used to read data from memory.

MWR* [Memory Write]..... output
MWR* is an active low three-state output strobe used to write data to memory.

IORD* [I/O Read]..... output
IORD* is an active low three-state output strobe used to read data from a peripheral device.

IOWR* [I/O Write]..... output
IOWR* is an active low three-state output strobe used to write data to a peripheral device.

CPRD* [Coprocessor Read]..... output
CPRD* is an active low three-state output strobe used to read data from a coprocessor device.

CPWR* [Coprocessor Write]..... output
CPWR* is an active low three-state output strobe used to write data to a coprocessor.

INTA* [Interrupt Acknowledge]..... output
The INTA* output is used to indicate to interrupt controllers that an interrupt acknowledge bus cycle is taking place. The selected interrupt controller is responsible for supplying the interrupt vector.

DBEN* [Data Buffer Enable]..... output
DBEN* is used to enable the three-state output buffers of the data bus transceivers. This output is only asserted during valid μPD70616 bus cycles.

DBR*/W [Data Buffer Read/Write]..... output
This output controls the direction of the external data bus transceivers. When DBR*/W is high, data will be transferred from the μPD70616 local bus to an I/O or memory location. When DBR*/W is low, data will be transferred from memory or I/O peripherals to the μPD70616 local bus.

V_{DD} [Power Supply]
The V_{DD} pin supplies +5 Volt power to the μPD71613.

GND [Ground]
The GND pin is the power supply return.

Operational Description

The μPD71613 serves as the system bus controller for the μPD70616 (V60) microprocessor. The μPD71613 monitors the μPD70616 status (ST2–ST0), memory request (MRQ*) and read/write (R/W*) outputs and during valid bus cycles (determined by the μPD70616 BCY* output), drives the command and control outputs. Command outputs consist of the memory, I/O, coprocessor and interrupt acknowledge strobe signals. Control outputs are the data buffer enable and data buffer direction signals.

Figure 1 depicts a typical μPD70616 system design using both the μPD71613 and the μPD71611 clock generator. Table 1 contains a state table of the command and control outputs.

Figure 1. Basic System Configuration

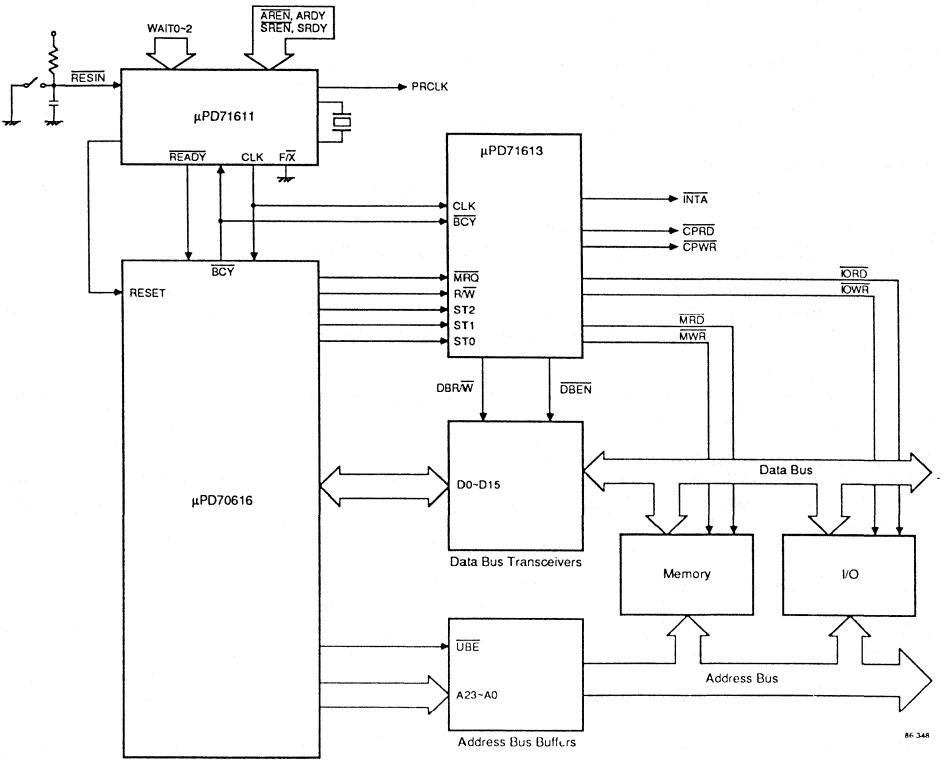


Table 1. Command and Control Output State Table

$\overline{MRQ}$	R/$\overline{W}$	Status			Bus Cycle	Command Outputs	Control Outputs	
		ST2	ST0	ST1			$\overline{DBEN}$	DB R/$\overline{W}$
0	0	0	0	0	Coprocessor Memory Write	$\overline{MWR}$, $\overline{CPRD}$	0	1
		0	0	1	String Mode Memory Write	$\overline{MWR}$	0	1
		0	1	0	Memory Write with Short Pass	$\overline{MWR}$	0	1
		0	1	1	Single Mode Memory Write	$\overline{MWR}$	0	1
		1	0	0	Single Mode Memory Write	$\overline{MWR}$	0	1
		1	0	1	Translation Table Memory Write	$\overline{MWR}$	0	1
		1	1	0	Translation Table Memory Write	$\overline{MWR}$	0	1
		1	1	1	Translation Table Memory Write	$\overline{MWR}$	0	1
	1	0	0	0	Coprocessor Memory Read	$\overline{MRD}$, $\overline{CPWR}$	0	0
		0	0	1	String Mode Memory Read	$\overline{MRD}$	0	0
		0	1	0	String Mode Memory Read	$\overline{MRD}$	0	0
		0	1	1	Single Mode Memory Read	$\overline{MRD}$	0	0
		1	0	0	System Base Table Access	$\overline{MRD}$	0	0
		1	0	1	Translation Table Access	$\overline{MRD}$	0	0
		1	1	0	Demand Mode Instruction Fetch	$\overline{MRD}$	0	0
		1	1	1	Instruction Prefetch	$\overline{MRD}$	0	0
1	0	0	0	0	Coprocessor Write	$\overline{CPWR}$	0	1
		0	0	1	String Mode I/O Write	$\overline{IOWR}$	0	1
		0	1	0	Reserved	–	0	1
		0	1	1	Single Mode I/O Write	$\overline{IOWR}$	0	1
		1	0	0	Halt Acknowledge	–	1	1
		1	0	1	Halt Acknowledge	–	1	1
		1	1	0	None	–	0	1
		1	1	1	Reserved	–	0	1
	1	0	0	0	Coprocessor Read	$\overline{CPRD}$	0	0
		0	0	1	String Mode I/O Read	$\overline{IORD}$	0	0
		0	1	0	Reserved	–	0	0
		0	1	1	Single Mode I/O Read	$\overline{IORD}$	0	0
		1	0	0	Halt Acknowledge	–	1	0
		1	0	1	Halt Acknowledge	–	1	0
		1	1	0	Interrupt Acknowledge	$\overline{INTA}$	0	0
		1	1	1	Reserved	–	0	0

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"0" is a logic low level, "1" is a logic high level

Absolute Maximum Ratings

T_A = +25°C

Power Supply Voltage, V_{DD}	–0.5 V to +7.0 V
Input Voltage, V_I	–1.0 V to V_{DD} + 1.0 V
Output Voltage, V_O	–0.5 V to V_{DD} + 0.5 V
Operating Temperature, T_{OPT}	–40°C to +85°C
Storage Temperature, T_{STG}	–65°C to +150°C
Power Dissipation, P_D	500 mW

Comment: Exposing the device to stresses above those listed in the Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

T_A = +25°C, V_{DD} = 0 V

		Limits			
Parameter	Symbol	Min	Max	Unit	Conditions
Input Capacitance	C_I		12	pf	f = 16 MHz

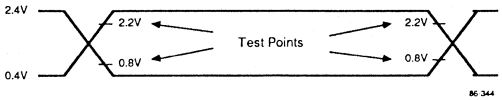
DC Characteristics

T_A = –40°C to +85°C, V_{DD} = +5 V ±10%

		Limits			
Parameter	Symbol	Min	Max	Unit	Conditions
Input Voltage High	V_{IH}	2.2		V	
Input Voltage Low	V_{IL}		0.8	V	
Output Voltage High	V_{OH}	V_{DD} – 0.8		V	Command outputs, I_{OH} = –4mA
		V_{DD} – 0.8		V	Control outputs, I_{OH} = –4mA
Output Voltage Low	V_{OL}		0.45	V	Command outputs, I_{OL} = 16mA
			0.45	V	Control outputs, I_{OL} = 8mA
Input Current	I_I	–1.0	1.0	μA	V_I = V_{DD}, V_{SS}
3-state Output Leakage Current	I_{OFF}	–10	10	μA	
Static Supply Current	I_{DD}		80	μA	V_I = V_{DD}, V_{SS}
Dynamic Supply Current	I_{DDdyn}		30	mA	f_{in} = 16 MHz

Timing Waveforms

AC Input/Output Test



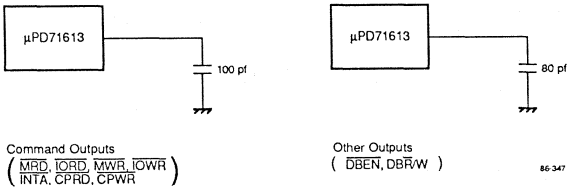
AC Characteristics

T_A = −40°C to +85°C, V_{DD} = +5 V ±10% Output Pin Load Capacitance: 100 pf

Parameter	Symbol	Limits Min	Limits Max	Unit	Conditions
CLK Cycle Time	t_{CYCK}	60		ns	
CLK Pulse Width High	t_{PWCKH}	25		ns	
CLK Pulse Width Low	t_{PWCKL}	25		ns	
ST2-ST0, MRQ*, R/W* Setup to CLK↑	t_{SSTCK}	15		ns	
ST2-ST0, MRQ*, R/W* Hold from CLK↑	t_{HCKST}	5		ns	
BCY* Setup to CLK↑	t_{SBYCK}	15		ns	
BCY* Hold from CLK↑	t_{HCKBY}	5		ns	
Command Active Delay from CLK↑	t_{DCKCML}	3	15	ns	
Command Inactive Delay from CLK↓	t_{DCKCMH}	3	15	ns	
Command Inactive Delay from BCY*↑	t_{DBYCMH}	3	15	ns	
Command Output On Delay from AEN↑	t_{DAECM}	3	15	ns	
Command Active Delay from AEN↑	t_{DAECML}	80	160	ns	
Command Output Float Delay from AEN↓	t_{FAECM}		40	ns	
Command Active Delay from CEN↑	t_{DCECML}	3	15	ns	
Command Inactive Delay from CEN↓	t_{DCECMH}	3	15	ns	
DBEN* Inactive Delay from CLK↑	t_{DCKDE}	3	15	ns	
DBEN* Active Delay from AEN↑	t_{DAEDE}	3	15	ns	
DBEN* Active Delay from CEN↑	t_{DCEDEL}	3	15	ns	
DBEN* Inactive Delay from CEN↓	t_{DCEDEH}	3	15	ns	
DBR*/W↑ Delay from CLK↑	t_{DCKDM}	3	15	ns	
DBR*/W↓ Delay from R/W*	t_{DRWDM}	3	15	ns	
Input Rise Time	t_{RI}		12	ns	0.8 V → 2.2 V
Input Fall Time	t_{FI}		8	ns	2.2 V → 0.8 V
Output Rise Time	t_{RO}		10	ns	0.8 V → 2.2 V
Output Fall Time	t_{FO}		6	ns	2.2 V → 0.8 V

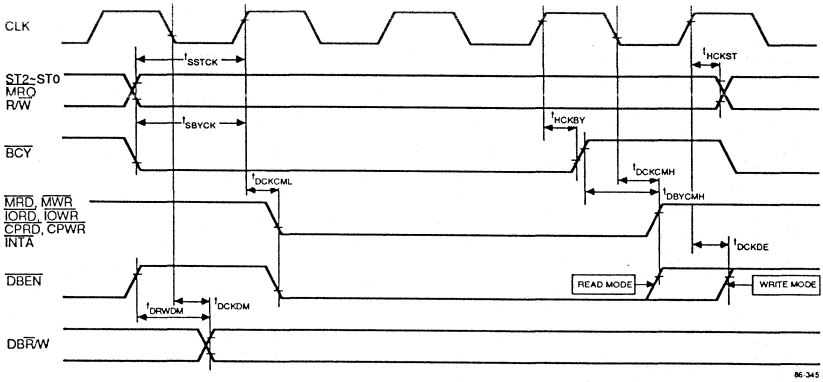
Timing Waveforms (cont)

Loading Circuits

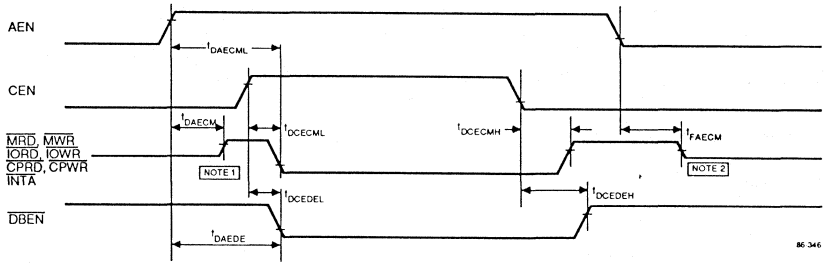


Timing Waveforms (cont)

Command/Control Output Timing

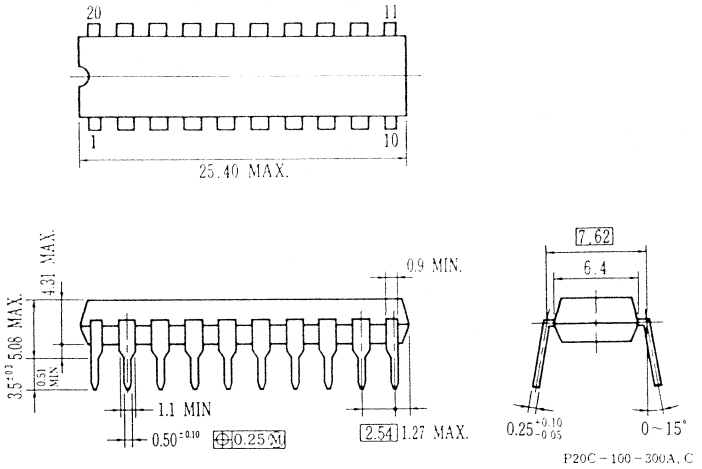


Command Output Timing



Note 1. This measurement point is 0.1V above the float voltage.
Note 2. This measurement point is 0.1V below the high level output voltage. For a low level output,, the measurement point is 0.1V above the low level output voltage.

Package Information



μPD82C43
CMOS INPUT/OUTPUT EXPANDER FOR μPD8048/C48 FAMILY

Description

The μPD82C43 input/output expander is directly compatible with the μPD8048/C48 family of single-chip microcomputers. Using CMOS technology, the μPD82C43 provides high drive capabilities while requiring only a single +5 V supply voltage.

The μPD82C43 interfaces to the μPD8048/C48 family through a 4-bit I/O port and offers four 4-bit bidirectional static I/O ports. The ease of expansion allows for multiple μPD82C43s to be added using the bus port.

The bidirectional I/O ports of the μPD82C43 act as an extension of the I/O capabilities of the μPD8048/C48 microcomputer family. They are accessible with their own ANL, MOV, and ORL instructions.

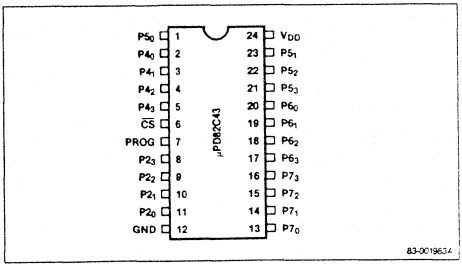
Features

- ☐ Four 4-bit I/O ports
- ☐ High output drive
- ☐ Logical AND and OR directly to ports
- ☐ Compatible with industry standard 8243
- ☐ Direct extension of resident μPD8048/C48 I/O ports
- ☐ Fully compatible with μPD8048/C48 microcomputer family
- ☐ CMOS technology
- ☐ Single +5 V supply

Ordering Information

Part Number	Package Type
μPD82C43C	24-pin plastic DIP
μPD82C43CX	24-pin plastic skinny DIP

Pin Configuration



Pin Identification

No.	Symbol	Function
1, 23-21	$P5_0$-$P5_3$	4-bit I/O port 5
2-5	$P4_0$-$P4_3$	4-bit I/O port 4
6	$\overline{CS}$	Chip select input
7	PROG	Clock input
8-11	$P2_3$-$P2_0$	4-bit I/O CPU interface port 2
12	GND	Ground
13-16	$P7_0$-$P7_3$	4-bit I/O port 7
17-20	$P6_3$-$P6_0$	4-bit I/O port 6
24	V_{DD}	+5 V power supply

Pin Functions

$P2_0$-$P2_3$ (Port 2)

A 4-bit bidirectional port which contains the I/O port address and instruction code on a high to low transition of PROG. During a low to high transition of PROG, port 2 contains either the data for a selected output port if a write operation, or the data from a selected output port (before a low to high transition) if a read operation. Data on port 2 may be directly written, read, ANDed or ORed with previous data.

$P4_0$-$P4_3$ (Port 4)

A 4-bit I/O port. May be programmed for input (during read), low impedance latched output (after write), or high impedance (after read).

$P5_0$-$P5_3$ (Port 5)

A 4-bit I/O port. May be programmed for input (during read), low impedance latched output (after write), or high impedance (after read).

$P6_0$-$P6_3$ (Port 6)

A 4-bit I/O port. May be programmed for input (during read), low impedance latched output (after write), or high impedance (after read).

$P7_0$-$P7_3$ (Port 7)

A 4-bit I/O port. May be programmed for input (during read), low impedance latched output (after write), or high impedance (after read).

$\overline{CS}$ (Chip Select)

A chip select input. A high on $\overline{CS}$ inhibits any change of output or internal status.

PROG (Clock Input)

A high to low transition on PROG indicates that the op-code and the addressed port information are available on port 2. A low to high transition indicates that data is available on port 2.

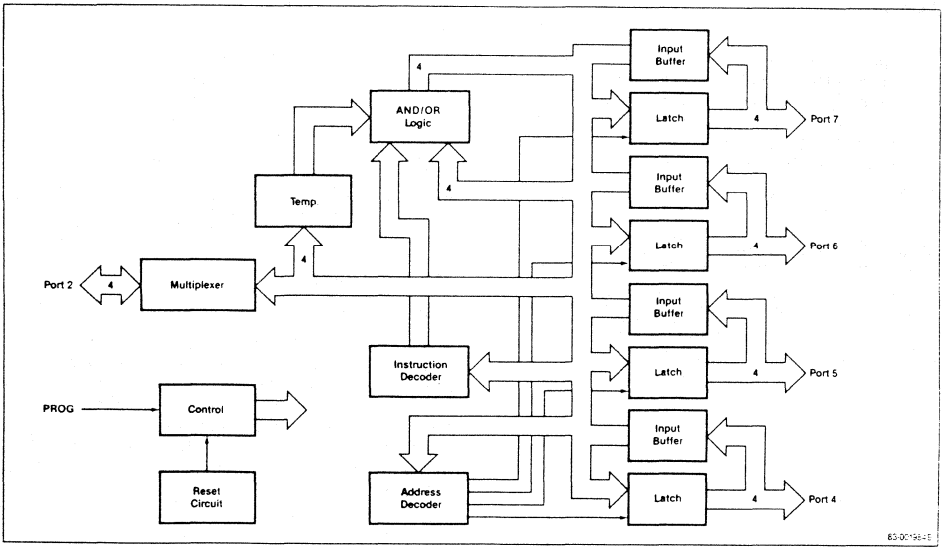
Ground

Ground.

V_{DD} (Power Supply)

+5 V power supply input.

Block Diagram



Absolute Maximum Ratings

$T_A = 25°C$

Power supply voltage, V_{DD}	−0.5 V to +7 V(1)
Input voltage, V_I	−0.3 V to V_{DD} +0.3 V
Output voltage, V_O	−0.3 V to V_{DD} +0.3 V
Operating temperature, T_{OPT}	−40°C to +85°C
Storage temperature, T_{STG}	−65°C to +150°C
Power dissipation, P_D	1.0 W

Note:
(1) With respect to ground.

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

$T_A = -40°C$ to $+85°C$; $V_{DD} = +5\,V \pm 10\%$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage high	V_{IH}	$V_{DD}-2.0$		V_{DD}	V	
Input voltage low	V_{IL}	−0.3		+0.8	V	
Output voltage high (port 4–7)	V_{OH1}	$V_{DD}-0.5$			V	$I_{OH} = -240\,\mu A$
Output voltage high (port 2)	V_{OH2}	$V_{DD}-0.5$			V	$I_{OH} = -100\,\mu A$
Output voltage low (port 4–7)	V_{OL1}			+0.45	V	$I_{OL} = 5$ mA, (Note 1)
Output voltage low (port 7)	V_{OL2}			+1	V	$I_{OL} = +20$ mA
Output voltage low (port 2)	V_{OL3}			+0.45	V	$I_{OL} = 0.6$ mA
Sum of all I_{OL} from 16 outputs	I_{OL}			80	mA	5 mA each pin
Input leakage current (port 4–7)	I_{IL1}			±1	μA	$V_{IN} = V_{DD}$ to 0 V
Input leakage current (port 2, $\overline{CS}$, PROG)	I_{IL2}			±1	μA	$V_{IN} = V_{DD}$ to 0 V
V_{DD} supply current	I_{DD1}		100	300	μA	
Power down supply current	I_{DD2}		1	10	μA	

Note:
(1) Refer to graph of additional sink current drive.

DC Characteristics (cont)

$T_A = -40°C$ to $+85°C$; $V_{DD} = +2.5\,V$ to $+6\,V$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage high	V_{IH}	$0.7\,V_{DD}$		V_{DD}	V	
Input voltage low	V_{IL}	−0.3		$+0.18\,V_{DD}$	V	
Output voltage high (port 4–7)	V_{OH1}	$0.75\,V_{DD}$			V	$I_{OH} = -120\,\mu A$
Output voltage high (port 2)	V_{OH2}	$0.75\,V_{DD}$			V	$I_{OH} = -50\,\mu A$
Output voltage low (port 4–7)	V_{OL1}			+0.45	V	$I_{OL} = +2.5$ mA
Output voltage low (port 7)	V_{OL2}			+1	V	$I_{OL} = +7$ mA
Output voltage low (port 2)	V_{OL3}			+0.45	V	$I_{OL} = +0.3$ mA
Output current low (port 4–7)	I_{OL}			40	mA	+2.5 mA each pin
Input leakage current (port 4–7)	I_{IL1}			±1	μA	$V_{IN} = V_{DD}$ to 0 V
Input leakage current (port 2, $\overline{CS}$, PROG)	I_{IL2}			±1	μA	$V_{IN} = V_{DD}$ to 0 V
V_{DD} supply current	I_{DD1}		100	300	μA	Operation mode (Note 1)
Power down supply current	I_{DD2}		1	10	μA	Standby mode

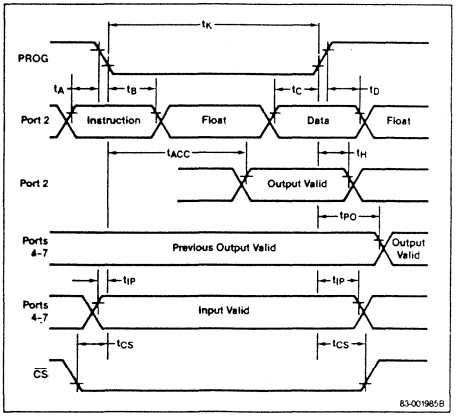
Note:
(1) $I_{OH} = 0\,\mu A$, PROG pulse cycle = 5 μs min.

AC Characteristics

$T_A = -40°C$ to $+85°C$, $V_{DD} = +5V \pm 10\%$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Code valid before PROG	t_A	100			ns	80 pF load
Code valid after PROG	t_B	0			ns	20 pF load
Data valid before PROG	t_C	200			ns	80 pF load
Data valid after PROG	t_D	20			ns	20 pF load
Port 2 floating after PROG	t_H	0		150	ns	20 pF load
PROG negative pulse width	t_K	700			ns	
Ports 4–7 valid after PROG	t_{PO}			700	ns	100 pF load
Ports 4–7 valid before / after PROG	t_{IP}	100			ns	
Port 2 valid after PROG	t_{ACC}	90		650	ns	80 pF load
$\overline{CS}$ valid before / after PROG	t_{CS}	50			ns	

Timing Waveform



AC Characteristics

$T_A = -40°C$ to $+85°C$, $V_{DD} = +2.5V$ to $+6V$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Command input setup time to PROG ↓	t_A	300			ns	Port 2 (control port, address) 80 pF load
Command input setup time after PROG ↓	t_B	0			ns	Port 2 (control port, address) 20 pF load
Data input setup time to PROG ↑	t_C	600			ns	Port 2 (write mode) 80 pF load
Data input hold time after PROG ↑	t_D	80			ns	Port 2 (write mode) 20 pF load
Data float delay time from PROG ↑	t_H	0		400	ns	Port 2 (read mode) 20 pF load
PROG pulse width	t_K	2			μs	
$\overline{CS}$ input setup time to PROG ↓ $\overline{CS}$ input hold time after PROG ↑	t_{CS}	200			ns	
Data output delay time from PROG ↑	t_{PO}			2	ns	Port 4–7, 100 pF load
Data input setup time to PROG ↓ Data input hold time after PROG ↑	t_{IP}	100			ns	Port 4–7
Data output delay time from PROG ↓	t_{ACC}			3.5	μs	Port 2, 80 pF load

Figure 1. Current Sinking Capability (Note 1)

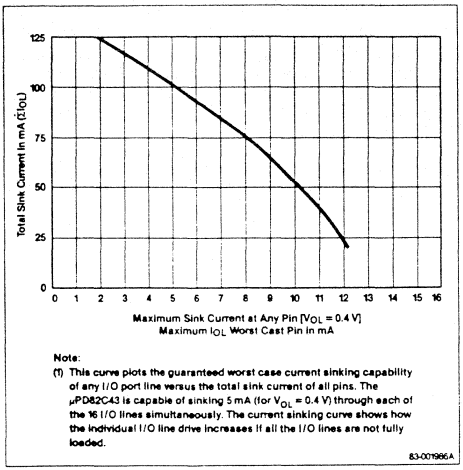
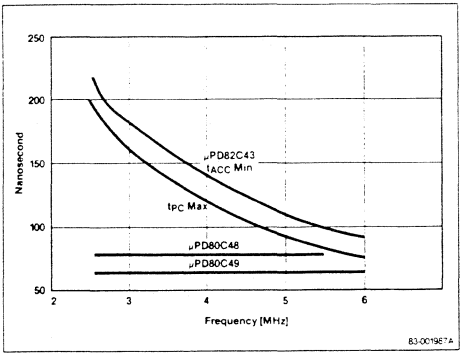


Figure 2. t_{ACC} (Min)/μPD82C43 vs t_{PC} (Max)/μPD80C48, μPD80C49



Functional Description

The I/O capabilities of the μPD8048/C48 family can be enhanced in four I/O port increments of 4 bits each using one or more μPD82C43s. These additional I/O lines are addressed as ports 4-7. The following lists the operations which can be performed on ports 4-7.

- Logical AND accumulator to port
- Logical OR accumulator to port
- Transfer port to accumulator
- Transfer accumulator to port

Port 2 ($P2_0$-$P2_3$) forms the 4-bit bus through which the μPD82C43 communicates with the host processor. The PROG output from the μPD8048/C48 family provides the necessary timing to the μPD82C43. There are two 4-bit nibbles involved in each data transfer. The first nibble contains the opcode and port address followed by the second nibble containing the 4-bit data. Multiple μPD82C43s can be used for additional I/O. The output lines from the μPD8048/C48 family can be used to form the chip selects for additional μPD82C43s.

Power On Initialization

Applying power to the μPD82C43 sets ports 4-7 to the high impedance mode and port 2 to the input mode. The state of the PROG pin at power on may be either high or low. The PROG pin must make a high to low transition in order to exit from the power on mode. The power on sequence is initiated any time V_{DD} drops below 1 V. Table 1 following shows how the first 4-bit nibble of a data transfer instruction is decoded.

Table 1. Port 2 Instruction Decoding

$P2_3$	$P2_2$	Instruction Code	$P2_1$	$P2_0$	Address Code
0	0	Read	0	0	Port 4
0	1	Write	0	1	Port 5
1	0	ORLD	1	0	Port 6
1	1	ANLD	1	1	Port 7

For example, a 0010 appearing on $P2_3$-$P2_0$, respectively, would result in a read of port 6.

Read Mode

There is one read mode in the μPD82C43. A falling edge on the PROG pin latches the op code and port address from input port 2. The port address and read operation are then decoded, causing the appropriate outputs to be high impedance and the input buffers switched on. The rising edge of PROG terminates the read operation. The port (4, 5, 6, or 7) that was selected by the port address ($P2_1$-$P2_0$) is returned to the high impedance mode, and port 2 is switched to the input mode.

Generally, in the read mode a port will be an input and in the write mode it will be an output. If during program operation the μPD82C43's modes are changed, the first read pulse immediately following a write should be ignored. The subsequent read signals are valid. Reading a port will then force that port to a high impedance state.

Write Modes

There are three write modes in the μPD82C43. The MOVD P_p, A instruction from the μPD8048/C48 family writes the new data directly to the specified port (4, 5, 6, or 7). The old data previously latched at that port is lost. The ORLD P_p, A instruction performs a logical OR between the new data and the data currently latched at the selected port. The result is then latched at that port. The final write mode uses the ANLD P_p, A instruction. It performs a logical AND between the new data and the data currently latched at the specified port. The result is latched at that port.

The data remains latched at the selected port following the logical manipulation until new data is written to that port.

NEC

NMOS SYSTEM SUPPORT PRODUCTS 7

Section 7 – NMOS System Support Products (cont)

Section 7 – BIPOLAR System Support Products

μPD8155/56
2048-BIT STATIC MOS RAM WITH I/O PORTS AND TIMER

Description

The μPD8155 and μPD8156 are μPD8085A family components having 256 × 8-bit static RAM, 3 programmable I/O ports, and a programmable timer. They directly interface to the multiplexed μPD8085A bus with no external logic. The μPD8155 has an active low chip enable while the μPD8156 is active high.

The μPD8155 and μPD8156 contain 2048 bits (256 × 8) of static RAM. The 256 words of memory may be selected anywhere within the system's 64K memory space by coding the upper 8 bits of address from the μPD8085A as a chip select.

The two general purpose 8-bit ports (PA and PB) may be programmed for input or output either in interrupt or status mode. The single 6-bit port (PC) may be used as a control for PA and PB or as a general purpose I/O port. The μPD8155 and μPD8156 are programmed for their system personalities by writing into their command/status (C/S) registers upon system initialization.

The timer is a single 14-bit down counter which is programmable for 4 modes of output operation; see table 3.

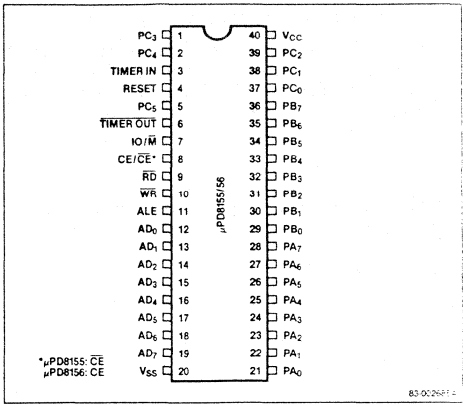
Features

- 256 × 8-bit static RAM
- Two programmable 8-bit I/O ports
- One programmable 6-bit I/O port
- Single +5 V ± 10% power supply
- Directly interfaces to the μPD8085A and μPD8085A-2
- Programmable 14-bit binary counter/timer

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD8155C/55HC	40-pin plastic DIP	3 MHz
μPD8155C-2/55HC-2	40-pin plastic DIP	5 MHz
μPD8156C/56HC	40-pin plastic DIP	3 MHz
μPD8156C-2/56HC-2	40-pin plastic DIP	5 MHz

Pin Configuration



Pin Identification

No.	Symbol	Function
1, 2, 5, 37-39	PC_0-PC_5	6-bit I/O port or control lines
3	TIMER IN	Timer clock input
4	RESET	Reset input
6	$\overline{\text{TIMER OUT}}$	Timer counter output
7	IO/$\overline{M}$	I/O or memory select input
8	CE/$\overline{CE}$	Chip enable input
9	$\overline{RD}$	Read strobe input
10	$\overline{WR}$	Write strobe input
11	ALE	Address low enable input
12-19	AD_0-AD_7	Low address/data bus I/O
20	V_{SS}	Ground
21-28	PA_0-PA_7	8-bit I/O port A
29-36	PB_0-PB_7	8-bit I/O port B
40	V_{CC}	+5 V power supply

Pin Functions

AD_0-AD_7 (Low Address/Data Bus)

Three-state address/data (AD) lines that interface with the CPU lower 8-bit address/data bus. The 8-bit address is loaded into the internal address latch on the falling edge of ALE. The 8-bit data is then written to or read from the chip, based on $\overline{WR}$ and $\overline{RD}$ strobe inputs.

PA_0-PA_7 (Port A)

8-bit general purpose I/O port. Data direction is selected by programming the command status register.

PB_0-PB_7 (Port B)

8-bit general purpose I/O port. Data direction is selected by programming the command status register.

PC_0-PC_5 (Port C)

6-bit general purpose I/O port or control signals for PA and PB. Port C function is selected by programming the command status register.

ALE (Address Low Enable)

This input control signal latches the address on the AD_0-AD_7 lines and the states of CE/$\overline{CE}$ and IO/$\overline{M}$ into the chip on the falling edge of ALE.

CE/$\overline{CE}$ (Chip Enable)

The chip enable input is active low for μPD8155 and active high for μPD8156.

IO/$\overline{M}$ (I/O or Memory Select)

This input selects either internal RAM memory if low or I/O and command status registers if high.

RESET (Reset)

The reset input from μPD8085A initializes ports A, B, and C to the input mode.

TIMER IN (Timer Clock In)

Clock input to the 14-bit binary down counter.

$\overline{TIMER\ OUT}$ (Timer Counter Output)

The timer output is programmable for 4 output waveform modes. The selected output waveform can be a single pulse or a continuous pulse train, or it can be a single square wave or a continuous square wave.

$\overline{RD}$ (Read Strobe)

The $\overline{RD}$ input will strobe the addressed RAM data onto the AD bus if the IO/$\overline{M}$ pin is low; otherwise the content of the selected I/O port or command status registers will be strobed onto the AD bus.

$\overline{WR}$ (Write Strobe)

The $\overline{WR}$ input will strobe the available data on the AD bus into addressed RAM location or I/O ports and command status registers depending on IO/$\overline{M}$.

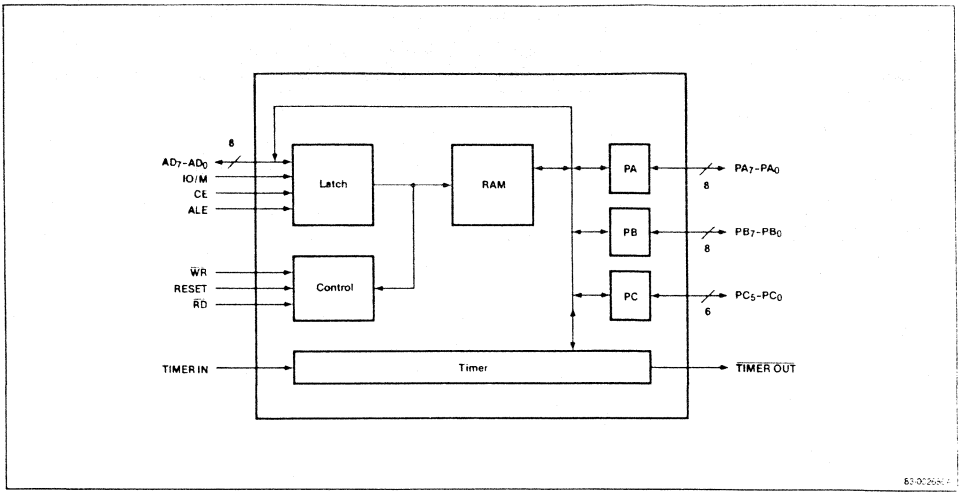
V_{CC} (Power Supply)

+5 V power supply input.

V_{SS} (Ground)

Ground.

Block Diagram



Absolute Maximum Ratings

$T_A = 25°C$

Power supply voltage, V_{CC}	−0.5 V to +7 V
Operating temperature, T_{OPT}	0°C to +70°C
Storage temperature, T_{STG}	−65°C to +150°C
Power dissipation, P_D	1.5 W

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

$T_A = 0°C$ to $+70°C$, $V_{CC} = +5\,V \pm 10\%$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage low	V_{IL}	−0.5		0.8	V	
Input voltage high	V_{IH}	2.0		$V_{CC}+0.5$	V	
Output voltage low	V_{OL}			0.45	V	$I_{OL} = 2.0$ mA
Output voltage high	V_{OH}	2.4			V	$I_{OH} = 400\,\mu A$
Input leakage current	I_{LI}			±10	μA	$V_I = V_{CC}$ to 0 V
Output leakage current	I_{LO}			±10	μA	$0.45\,V \leqslant V_{OUT} \leqslant V_{CC}$
Power supply current (V_{CC})	I_{CC}			180	mA	8155/56, 8155-2/56-2
				125	mA	8155H/56H, 8155H-2/56H-2
Chip enable leakage	μPD8155 I_{IL}(CE)			+100	μA	$V_I = V_{CC}$ to 0 V
	μPD8156			−100	μA	$V_I = V_{CC}$ to 0 V

AC Characteristics

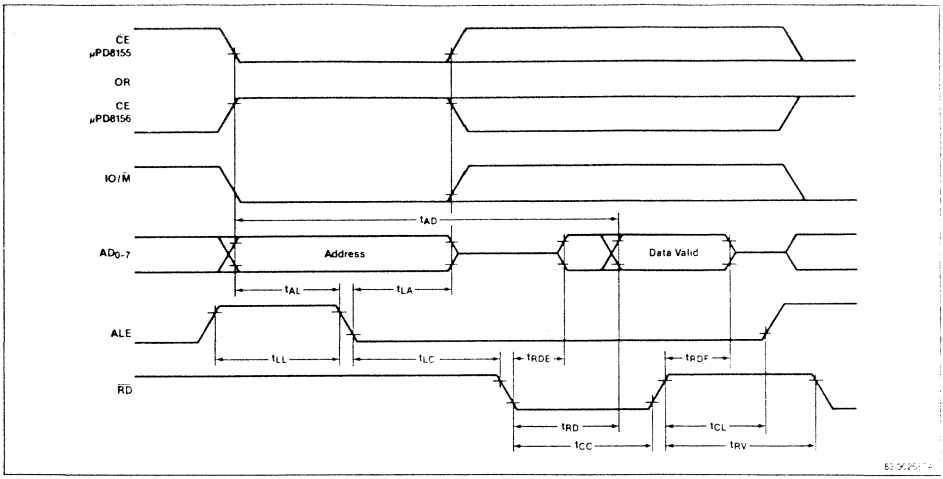
$T_A = 0°C$ to $+70°C$, $V_{CC} = 5\ V \pm 10\%$

Parameter	Symbol	Limits μPD8155/56/55H/56H Min	Limits μPD8155/56/55H/56H Max	Limits μPD8155-2/56-2/55H-2/56H-2 Min	Limits μPD8155-2/56-2/55H-2/56H-2 Max	Unit	Test Conditions(1)
Address to latch setup time	t_{AL}	50		30		ns	
Address hold time after latch	t_{LA}	80		30		ns	
Latch to READ / WRITE control	t_{LC}	100		40		ns	
Valid data out delay from READ control	t_{RD}		170		140	ns	
Address stable to data out valid	t_{AD}		400		330	ns	
Latch enable width	t_{LL}	100		70		ns	
Data bus float after READ	t_{RDF}	0	100	0	80	ns	
READ / WRITE control to latch enable	t_{CL}	20		10		ns	
READ / WRITE control width	t_{CC}	250		200		ns	
Data in to WRITE setup time	t_{DW}	150		100		ns	
Data in hold time after WRITE	t_{WD}	0		0		ns	
Recovery time between controls	t_{RV}	300		200		ns	
WRITE to port output	t_{WP}		400		300	ns	
Port input setup time	t_{PR}	70		50		ns	
Port input hold time	t_{RP}	50		10		ns	
Strobe to buffer full	t_{SBF}		400		300	ns	
Strobe width	t_{SS}	200		150		ns	
READ to buffer empty	t_{RBE}		400		300	ns	
Strobe to INTR on	t_{SI}		400		300	ns	
READ to INTR off	t_{RDI}		400		300	ns	
Port setup time to strobe	t_{PSS}	50		0		ns	
Port hold time after strobe	t_{PHS}	120		100		ns	
Strobe to buffer empty	t_{SBE}		400		300	ns	
WRITE to buffer full	t_{WBF}		400		300	ns	
WRITE to INTR off	t_{WI}		400		300	ns	
TIMER IN to $\overline{\text{TIMER OUT}}$ low	t_{TL}		400		300	ns	
TIMER IN to $\overline{\text{TIMER OUT}}$ high	t_{TH}		400		300	ns	
Data bus enable from READ control	t_{RDE}	10		10		ns	
Clock TIMER IN	t_{CYC}	320		200		ns	
CLK rise and fall time	t_r, t_f		30		30	ns	
CLK pulse width	t_1	80		40		ns	
	t_2	120		70		ns	

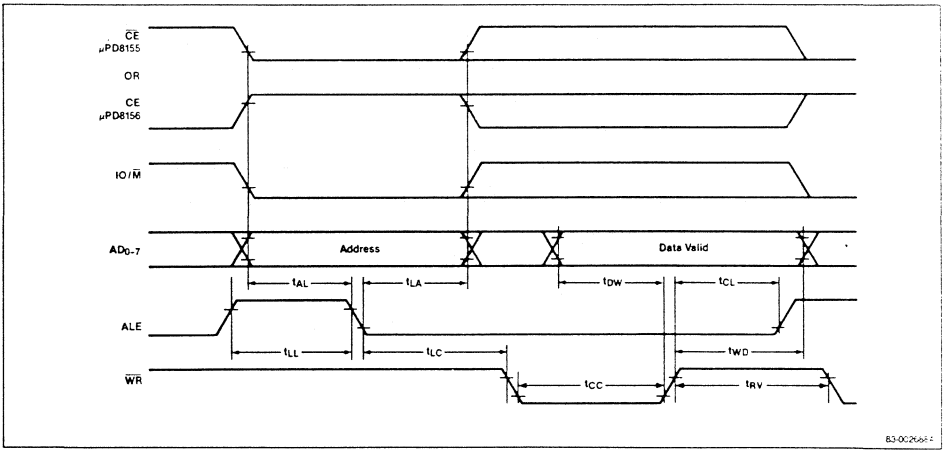
Note:
(1) 150 pF load

Timing Waveforms

Read Cycle

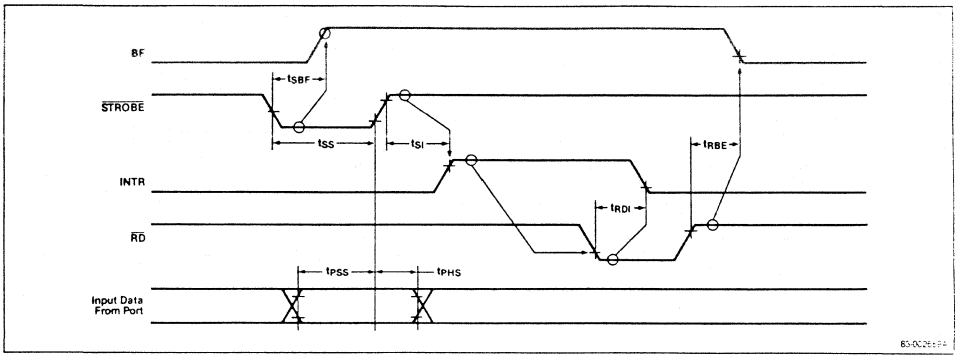


Write Cycle

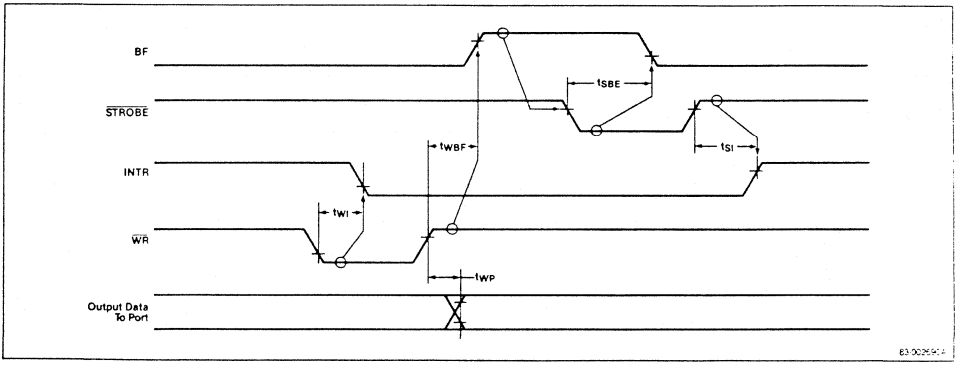


Timing Waveforms (cont)

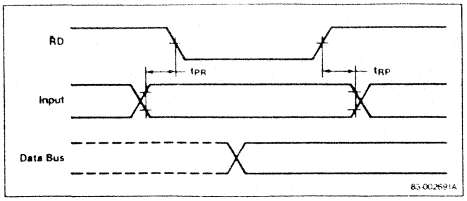
Strobed Input Mode



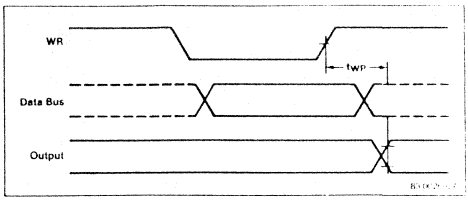
Strobed Output Mode



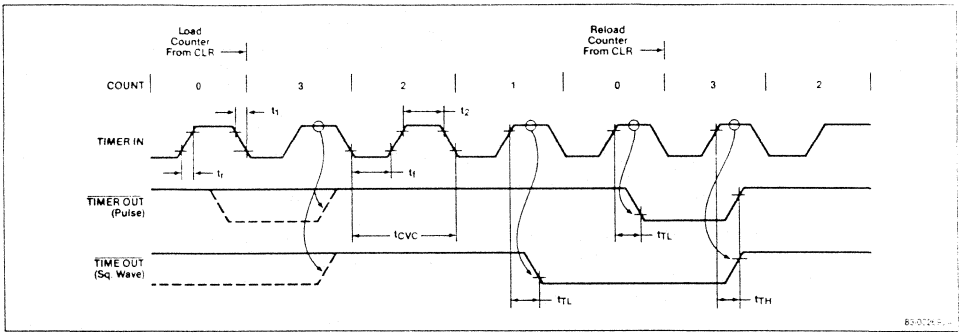
Basic Input Mode



Basic Output Mode



Time Output



Functional Description

Command Status Register

The command status register is an 8-bit register which must be programmed before the μPD8155/56 can perform any useful functions. Its purpose is to define the mode of operation of the three ports and the timer. Programming of the device may be accomplished by writing to I/O address XXXXX000 (X = don't care) with a specific bit pattern. Reading of the command status register can be accomplished by performing an I/O read operation at address XXXXX000. The pattern returned will be a 7-bit status report of PA, PB and the timer. The bit patterns for the command status register read and write are shown in tables 1 and 2.

Table 1. Command Status Write

TM2	TM1	IEB	IEA	PC_2	PC_1	PB	PA

where:
TM2-TM1 = Define timer mode
IEB = Enable port B interrupt
IEA = Enable port A interrupt
PC_2-PC_1 = Define port C mode
PB/PA = Define port B/A as in or out(1)

The timer mode of operation is programmed as follows during command status write:

TM2	TM1	Timer Mode
0	0	Don't affect timer operation
0	1	Stop timer counting
1	0	Stop counting after TC
1	1	Start timer operation

Interrupt enable status is programmed as follows:

IEB/IEA	Interrupt Enable Port B/A
0	No
1	Yes

Port C may be placed in four possible (Alt) modes of operation as outlined below. The modes are selected during command status write as follows:

PC_2	PC_1	Port C Mode
0	0	Alt 1
0	1	Alt 3
1	0	Alt 4
1	1	Alt 2

The function of each pin of port C in the four possible modes is outlined as follows:

Pin	Alt 1	Alt 2	Alt 3(2)	Alt 4(2)
PC_0	In	Out	A INTR	A INTR
PC_1	In	Out	A BF	A BF
PC_2	In	Out	A STB	A STB
PC_3	In	Out	Out	B INTR
PC_4	In	Out	Out	B BF
PC_5	In	Out	Out	B STB

Note:

(1) PB/PA sets port B/A mode: 0 = input; 1 = output

(2) In Alt 3 and Alt 4 modes, the control signals are initialized as follows:

Control	Input	Output
STB (Input strobe)	Input control	Output control
INTR (Interrupt request)	Low	High
BF (Buffer full)	Low	Low

Table 2. Command Status Read

	TI	INTE B	B BF	INTR B	INTE A	A BF	INTR A

where:

TI = Indicates a timer interrupt. This bit is set when terminal count is reached. It is reset when starting a new count, or a hardware reset occurs, or after reading the CS register.

INTE B/A = Port B/A interrupt. High = active.

B/A BF = Indicates whether port B/A is full if in input mode or empty if in output mode. High = active.

INTR B/A = Port B/A interrupt request. High = active.

The programming address summary for the status, ports, and timer are as follows:

I/O Address	Number of Bits	Function
XXXXX000	8	Command status
XXXXX001	8	PA
XXXXX010	8	PB
XXXXX011	6	PC
XXXXX100	8	Timer low
XXXXX101	8	Timer high

Timer Operation

The internal timer is a 14-bit binary down counter capable of operating in 4 output modes which are programmable at any time during operation. Any TTL clock meeting timer in requirements (see AC Characteristics) may be used as a time base and fed to the timer input. The timer output may be looped around and cause an interrupt or may be used as I/O control. The output modes are defined in table 3 and programmed as the two MSBs of the higher order byte of the timer count register.

Table 3. Timer Output Modes

M_2	M_1	Operation
0	0	Single square wave cycle from start to terminal count
0	1	Continuous square wave (period = count length)
1	0	Single pulse at terminal count
1	1	Continuous single pulse occurring at terminal count

Programming the timer requries two words to be written to the μPD8155/56 at I/O address XXXXX100 and XXXXX101 for the low and high order bytes, respectively. Valid count length must be between 0002H and 3FFFH. The bit assignments for the high and low programming words of the timer count register are as follows:

Word	*Timer Count Register*								*I/O Address*
High byte	M_2	M_1	T_{13}	T_{12}	T_{11}	T_{10}	T_9	T_8	XXXXX101
Low byte	T_7	T_6	T_5	T_4	T_3	T_2	T_1	T_0	XXXXX100

The control of the timer is performed by TM2 and TM1 of the command status word.

Note that counting will be stopped by a hardware reset. A start command must be issued via the command status register to begin counting. A new mode and/or count length can be loaded while the counter is counting, but will not be used until a start command is issued.

When an external nonsynchronous event is used as the timer input, the signal must first be synchronized to the system clock. A D-type flip-flop can be used for this purpose.

Description

The μPB8216 and μPB8226 are 4-bit parallel bidirectional bus drivers specifically designed to buffer microcomputer system components. All inputs are low power TTL compatible. For driving MOS, the DO outputs provide a high 3.65 volts (V_{OH}); for high-capacitance terminated bus structures, the DB outputs provide a high 55 mA (I_{OL}) capability. The noninverting μPB8216 and the inverting μPB8226 bus drivers are available to meet a wide variety of applications for buffering in microcomputer systems.

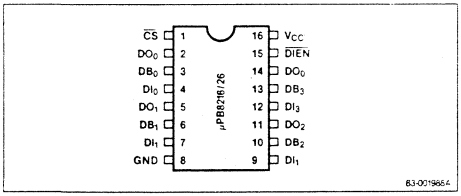
Features

- Low input load current; 0.25 mA maximum
- High output drive capability for driving system data bus
- 3.65 V output high voltage for direct interface to CPU
- Three-state outputs
- Reduces system package count

Ordering Information

Part Number	Package Type
μPB8216C	16-pin plastic DIP
μPB8226C	16-pin plastic DIP

Pin Configuration



Pin Identification

No.	Symbol	Function
1	$\overline{CS}$	Chip select input
2	DO_0	Data output, bit 0
3	DB_0	Data bus, bit 0
4	DI_0	Data input, bit 0
5	DO_1	Data output, bit 1
6	DB_1	Data bus, bit 1
7	DI_1	Data input, bit 1
8	GND	Ground
9	DI_2	Data input, bit 2
10	DB_2	Data bus, bit 2
11	DO_2	Data output, bit 2
12	DI_3	Data input, bit 3
13	DB_3	Data bus, bit 3
14	DO_3	Data output, bit 3
15	$\overline{DIEN}$	Data in enable
16	V_{CC}	+5 V power supply

Pin Functions

DB_0-DB_3 (Bidirectional Data Bus)

Three-state data lines that interface with the system data bus. Data direction and high impedance output are functions of the $\overline{CS}$ and $\overline{DIEN}$ control signals.

DI_0-DI_3 (Data Input)

The four data input lines receive data from the CPU and make it available to the system data bus when both $\overline{CS}$ and $\overline{DIEN}$ are active low.

DO_0-DO_3 (Data Output)

The four data output lines make data available to the CPU from the system data bus when $\overline{CS}$ is active low and $\overline{DIEN}$ is active high.

$\overline{CS}$ (Chip Select)

Chip select enables the chip's I/O capability when active low. When $\overline{CS}$ is high, the output drivers go to a high impedance state.

$\overline{DIEN}$ (Data In Enable)

$\overline{DIEN}$ is the data flow direction control signal. When low, data on the chip's input lines (DI_0-DI_3) from the CPU is made available to the system data bus (DB_0-DB_3). When high, data on the chip's data bus lines (DB_0-DB_3) is output to the CPU (providing $\overline{CS}$ is active low enabled).

V_{CC} (Power Supply)

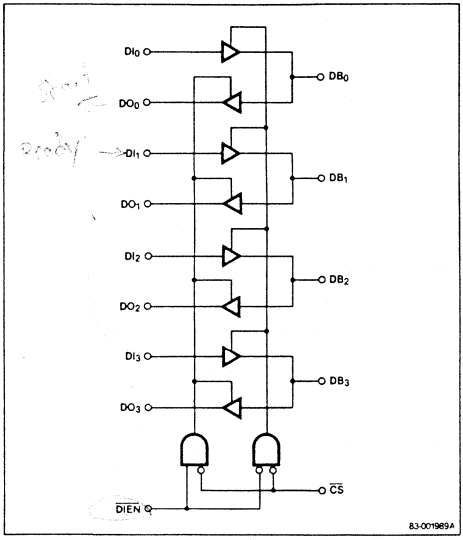
+5 V power supply input.

GND (Ground)

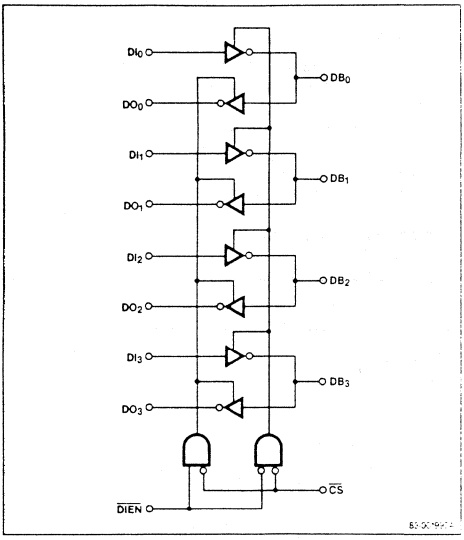
Ground.

Block Diagrams

μPB8216



μPB8226



Functional Description

Microprocessors like the μPD8080A are MOS devices and are generally capable of driving a single TTL load. This also applies to MOS memory devices. This type of drive is sufficient for small systems with a few components, but often it is necessary to buffer the microprocessor and memories when adding components or expanding to a multiboard system.

Bidirectional Driver

Each buffered line of the μPB8216/26 4-bit driver consists of two separate buffers. They are three-state in nature to achieve direct bus interface and bidirectional capability. On one side of the driver the output of one buffer and the input of another are tied together (DB). This is used to interface to the system side components such as memories, I/O, etc. Its interface is directly TTL-compatible and it has a high drive (55 mA). For maximum flexibility on the other side of the driver, the inputs and outputs are separate. They can be tied together so that the driver can be used to buffer a true bidirectional bus such as the 8080A data bus. The DO outputs on this side of the driver have a special high voltage output drive capability (3.65 V) so that direct interface to the 8080A processor is achieved with a maximum noise level of 650 mV.

Control Gating $\overline{CS}$, $\overline{DIEN}$

The $\overline{CS}$ input is used for device selection. When $\overline{CS}$ is high, the output drivers are all forced to their high impedance state. When it is low, the device is selected (enabled) and the data flow direction is determined by the $\overline{DIEN}$ input.

The $\overline{DIEN}$ input controls the data flow direction (see block diagrams for complete truth table). This directional control is accomplished by forcing one of the pair of buffers to its high impedance state. This allows the other to transmit its data. This is accomplished by a simple two-gate circuit.

The μPB8216/26 is a device that will reduce component count in microcomputer systems and at the same time enhance noise immunity to assure reliable, high performance operation.

Absolute Maximum Ratings

$T_A = 25°C$

Power supply voltage, V_{CC}	−0.5 V to +7.0 V
Input voltage, V_I	−1.0 V to +5.5 V
Output voltage, V_O	−1.0 V to +5.5 V
Operating temperature, T_{OPT}	0°C to +70°C
Storage temperature, T_{STG}	−65°C to +150°C
Output current, I_O	125 mA

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance (Note 1)

$T_A = 25°C$, $V_{CC} = 5$ V

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input capacitance	C_I			8	pF	f = 1.0 MHz
Output capacitance	C_{O1}			10(2)	pF	$V_{BIAS} = 2.5$ V
Output capacitance	C_{O2}			18(3)	pF	

Note:

(1) This parameter is not 100% tested.

(2) DO output.

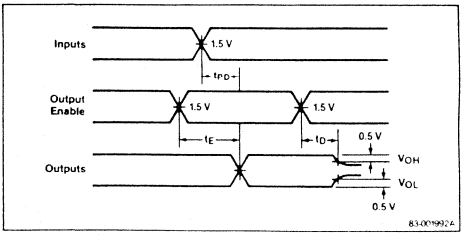
(3) DB output.

DC Characteristics

$T_A = 0°C$ to $+70°C$; $V_{CC} = +5\,V \pm 5\%$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage low	V_{IL}			0.95	V	
Input voltage high	V_{IH}	2.0			V	
Output voltage low	V_{OL1}			0.48	V	DO outputs; $I_{OL} = 15$ mA
				0.48	V	DB outputs $I_{OL} = 25$ mA
	V_{OL2}			0.7	V	8216; DB outputs; $I_{OL} = 55$ mA
				0.7	V	8226; DB outputs $I_{OL} = 50$ mA
Output voltage high	V_{OH1}	3.65			V	DO outputs; $I_{OH} = -1$ mA
	V_{OH2}	2.4			V	DB outputs; $I_{OH} = -10$ mA
Input forward voltage clamp	V_C			−1.0	V	$I_C = -5$ mA
Input load current	I_{F1}			−0.5	mA	($\overline{DIEN}$, $\overline{CS}$); $V_F = 0.45$ V
	I_{F2}			−0.25	mA	(All other inputs); $V_F = 0.45$ V
Input leakage current	I_{R1}			20	μA	($\overline{DIEN}$, $\overline{CS}$); $V_R = 5.25$ V
	I_{R2}			10	μA	(DI inputs); $V_R = 5.25$ V
Output leakage current (3-state)	I_O			20	μA	DO outputs; $V_O = 0.45 / 5.25$ V
				100	μA	DB outputs
Output short circuit current	I_{OS}	−15		−65	mA	DO outputs; $V_O = 0$ V
		−30		−120	mA	DB outputs $V_{CC} = 5.0$ V
Power supply current	I_{CC}			130	mA	8216
				120	mA	8226

Timing Waveform



AC Characteristics

$T_A = 0°C$ to $+70°C$, $V_{CC} = +5\,V \pm 5\%$ (Note 1)

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input to output delay DO outputs	t_{PD1}			25	ns	$C_L = 30$ pF, $R_1 = 300\,\Omega$, $R_2 = 600\,\Omega$, (Note 4)
Input to output delay DB outputs	t_{PD2}			30	ns	8216: $C_L = 300$ pF, $R_1 = 90\,\Omega$, $R_2 = 180\,\Omega$, (Note 4)
				25	ns	8226: $C_L = 300$ pF, $R_1 = 90\,\Omega$, $R_2 = 180\,\Omega$, (Note 4)
Output enable time	t_E			65	ns	8216; (Notes 2 & 4)
				54	ns	8226; (Notes 2 & 4)
Output disable time	t_D			35	ns	(Notes 3 & 4)

Note:

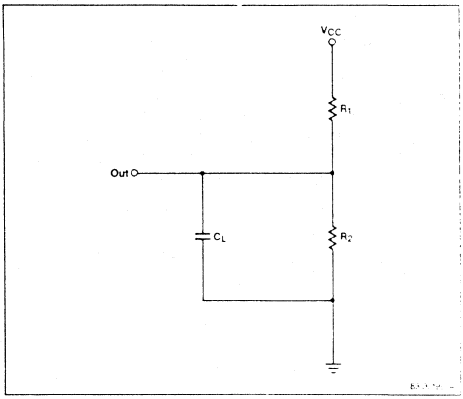
(1) Typical values are for $T_A = 25°C$, $V_{CC} = +5.0$ V.

(2) DO outputs, $C_L = 30$ pF, $R_1 = 300/10$ kΩ, $R_2 = 600/1$ kΩ
DB outputs, $C_L = 300$ pF, $R_1 = 90/10$ kΩ, $R_2 = 180/1$ kΩ.

(3) DO outputs, $C_L = 5$ pF, $R_1 = 300/10$ kΩ, $R_2 = 600/1$ kΩ
DB outputs, $C_L = 5$ pF, $R_1 = 90/10$ kΩ, $R_2 = 180/1$ kΩ.

(4) Input pulse amplitude: 2.5 V.
Input rise and fall times of 5 ns between 1 and 2 V.
Output loading is 5 mA and 10 pF.
Speed measurements are made at 1.5 V levels.

Test Load Circuit



μPD8237A
HIGH-PERFORMANCE PROGRAMMABLE DMA CONTROLLER

Description

The μPD8237A high performance DMA controller is a peripheral interface circuit for microprocessor systems. It is designed to improve system performance by allowing external devices to directly transfer information to or from the system memory. Memory-to-memory transfer capability is also provided. The μPD8237A offers a wide variety of programmable control features to enhance data throughput and allow dynamic reconfiguration under program control.

The μPD8237A is designed to be used with an external 8-bit address register such as the 8282. It contains four independent channels and may be expanded to any number of channels by cascading additional controller chips.

The three basic transfer modes allow the user to program the types of DMA service. Each channel can be individually programmed to autoinitialize to its original condition following an end of process (EOP).

Each channel has a full 64K-byte address and word count capability.

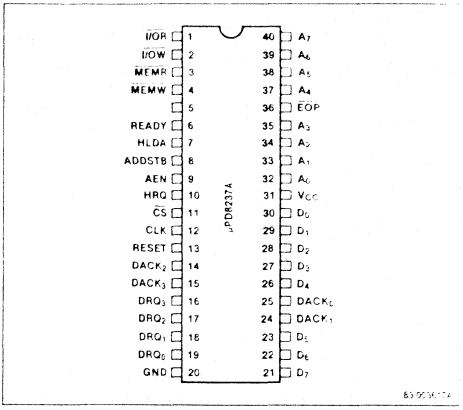
Features

- ☐ Memory-to-memory transfers
- ☐ Memory block initialization
- ☐ Address Increment or decrement
- ☐ Four independent DMA channels
- ☐ Multiple transfer modes: block, demand, single word, cascade
- ☐ Independent autoinitialization of all channels
- ☐ Enable/disable control of individual DMA requests
- ☐ Independent polarity control of DREQ and DACK signals
- ☐ End of process input for terminating transfers
- ☐ Software DMA requests
- ☐ High performance: transfers up to 1.6 Mbs
- ☐ Directly expandable to any number of channels

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD8237AC-5	40-pin plastic DIP	5 MHz

Pin Configuration



Pin Identification

No.	Symbol	Function
1	$\overline{I/OR}$	I/O read control signal
2	$\overline{I/OW}$	I/O write control signal
3	$\overline{MEMR}$	Memory read output
4	$\overline{MEMW}$	Memory write output
5	—	Fixed, high level input
6	READY	Ready input
7	HLDA	Hold acknowledge input
8	ADDSTB	Address strobe output
9	AEN	Address enable output
10	HRQ	Hold request output
11	$\overline{CS}$	Chip select input
12	CLK	Clock input
13	RESET	Reset input
14, 15 24, 25	$DACK_2$, $DACK_3$ $DACK_1$, $DACK_0$	DMA acknowledge output
16-19	DRQ_3-DRQ_0	DMA request input
20	GND	Ground
21-23, 26-30	D_7-D_5 D_4-D_0	I/O data bus
31	V_{CC}	Power supply
32-35	A_0-A_3	I/O address bus
36	$\overline{EOP}$	I/O end of process
37-40	A_4-A_7	Output address bus

Pin Functions

D_0-D_7 (I/O Data Bus)

During an I/O read, the CPU enables these lines as outputs, allowing it to read an address register, a word count register, or the status or temporary register. During an I/O write, these lines are enabled as inputs, allowing the CPU to program the μPD8237A control registers. During DMA cycles, the eight MSBs of the address are output to the data bus to be strobed to an external latch via ADDSTB.

A_4-A_7 (Output Address Bus)

These lines, active only during DMA service, are outputs that provide the four MSBs of the address.

A_0-A_3 (I/O Address Bus)

During DMA active states, these lines are outputs that provide the 4 LSBs of the output address bus. During DMA idle states, these lines are inputs, allowing the CPU to load or examine control registers.

DRQ_0-DRQ_3 (DMA Request Input)

These are asynchronous channel request inputs used by peripherals to request DMA service. In a fixed priority scheme, DRQ_3 has the lowest. The polarity of these lines is programmable; however, reset initializes them to active high.

HLDA (Hold Acknowledge)

Indicates that the CPU has relinquished control of the system buses.

HRQ (Hold Request)

Requests control of the system bus. The μPD8237A issues this signal in response to software requests or DRQ inputs from peripherals.

$DACK_0$-$DACK_3$ (DMA Acknowledge Output)

These lines indicate an active channel. They are sometimes used to select a peripheral. Only one DACK may be active at any time. All DACK lines are inactive unless DMA has control of the bus. The polarity of these lines is programmable; however, reset initializes them to active low.

$\overline{EOP}$ (End of Process)

$\overline{EOP}$ signals that DMA service has been completed. When the word count of a channel becomes zero, the μPD8237A pulses $\overline{EOP}$ low to notify the peripheral that DMA service is complete. The peripheral may pull $\overline{EOP}$ low to prematurely end DMA service. Internal or external receipt of $\overline{EOP}$ causes the currently active channel to end service, set its TC bit in the status register, and reset its request bit. If the channel is programmed for autoinitialization, the current registers are updated from the base registers. Otherwise, the channel's mask bit is set and the contents of the register are unaltered.

$\overline{EOP}$ is output when TC for channel 1 occurs during memory-to-memory transfers. $\overline{EOP}$ applies to the channel with an active DACK. When $DACK_0$-$DACK_3$ are inactive, external $\overline{EOP}$s are ignored.

Use of an external pull-up resistor of 3.3 kΩ or 4.7 kΩ is recommended. This pin ($\overline{EOP}$) cannot sink the current passed by a 1 kΩ or 4.7 kΩ pull-up.

RESET

Clears the command, status, request, and temporary registers, the first/last flip flop, and sets the mask register. The μPD8237A is in idle state after a reset.

$\overline{CS}$ (Chip Select)

The CPU uses $\overline{CS}$ to select the μPD8237A as an I/O device during an I/O read or write by the CPU. This provides CPU communication on the data bus. $\overline{CS}$ may be held low during multiple transfers to or from the μPD8237A as long as $\overline{I/OR}$ or $\overline{I/OW}$ is toggled following each transfer.

READY

This signal can extend memory read and write pulses for slow memories or I/O peripherals.

CLK (Clock)

Controls internal operations and data transfer rate.

AEN (Address Enable)

This signal allows the external latch to output the upper address byte by disabling the system bus during DMA cycles. Use HLDA and AEN to deselect I/O peripherals that may be erroneously accessed during DMA transfers. The μPD8237A deselects itself during DMA transfers.

ADDSTB (Address Strobe)

This signal strobes the upper address byte form D_0-D_7 into an external latch.

$\overline{\text{MEMR}}$ (Memory Read)

This signal accesses data from a specified memory location during memory-to-peripheral or memory-to-memory transfers.

$\overline{\text{MEMW}}$ (Memory Write)

This signal writes data to a specified memory location during peripheral-to-memory or memory-to memory transfers.

$\overline{\text{I/OR}}$ (I/O Read)

In the idle state, this signal is an input control line used by the CPU to read control registers. In the active state, the μPD8237A uses $\overline{\text{I/OR}}$ as an output control signal to access data from a peripheral during a DMA write.

$\overline{\text{I/OW}}$ (I/O Write)

In the idle state, the CPU uses $\overline{\text{I/OW}}$, as an input control signal to load information to the μPD8237A. In the active state, the μPD8237A uses $\overline{\text{I/OW}}$ as an output control signal to load data to a peripheral during a DMA read.

The rising edge of $\overline{\text{WR}}$ must follow each data byte transfer in order for the CPU to write to the μPD8237A. Holding $\overline{\text{I/OW}}$ low while toggling $\overline{\text{CS}}$ does not produce the same effect.

Pin 5

Pin 5 is always tied high.

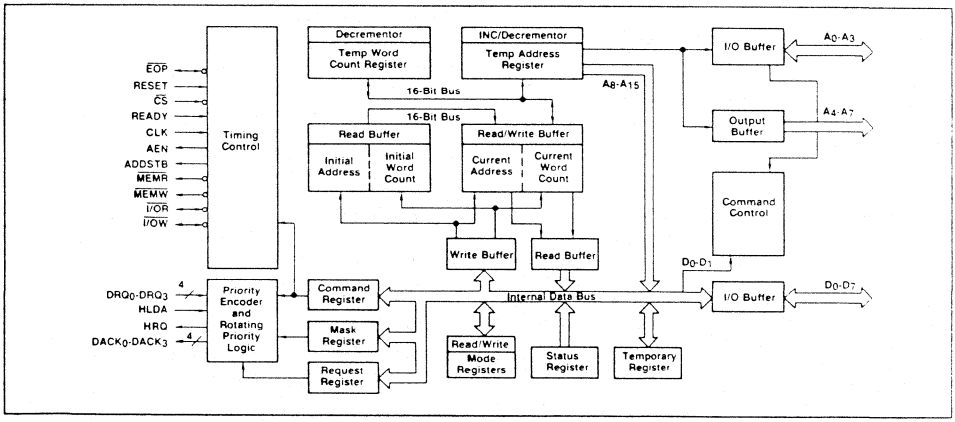
V_{CC}

Power supply.

GND

Ground.

Block Diagram



Functional Description

The μPD8237A has three basic control logic blocks, as shown in the block diagram. The command control block decodes commands issued by the CPU to the μPD8237A before DMA requests are serviced. It also decodes the mode control word of each channel. The timing control block generates the external control signals and the internal timing. The priority encoder block settles priority contentions among channels simultaneously requesting service.

DMA Operation

The μPD8237A operates in two states: idle and active. Each of these is made up of several smaller states equal to one clock cycle. The inactive state, S1, is entered when there are no pending DMA requests. The controller is inactive in S1, but the CPU may program it. S0 is the initial state for DMA service; the μPD8237A requests a hold, but the CPU has not acknowledged. Transfers may begin upon acknowledgement from the CPU. The normal working states of DMA service are S1, S2, S3, and S4. If more time is needed for a transfer, a wait state, SW, can be inserted using the READY line.

A memory-to-memory transfer requires read-from-memory and write-to-memory operations. The states S11, S12, S13, and S14 provide the read-from operation. S21, S22, S23, and S24 provide the write-to part of the transfer. The byte is stored in the temporary register between operations.

Idle State

When there are no pending service requests, the μPD8237A is in the idle state; more specifically, in S1, DRQ lines and $\overline{CS}$ are sampled to determine requests for DMA service and CPU attempts to inspect or modify the registers of the μPD8237A, respectively. The CPU can read or write to the registers when $\overline{CS}$ and HLDA are low. A_0-A_3 are used as inputs to the μPD8237A and select the registers affected. The $\overline{I/OR}$ and $\overline{I/OW}$ lines select and time the reads and writes. An internal flip-flop generates an additional address bit which determines the upper or lower byte of the address and word count registers. This flip-flop can be reset by master clear, reset, or a software command.

When $\overline{CS}$ and HLDA are low (program phase), the μPD8237A can execute special software commands. When $\overline{CS}$ and $\overline{I/OW}$ are active, the commands are decoded as addresses and do not use the data bus.

Active State

When a channel requests service while the μPD8237A is in idle state, the μPD8237A outputs an HRQ to the CPU and enters the active state. DMA service takes place in the active state, in one of the four modes described below.

DRQ is held active only until the corresponding DACK goes active when a single transfer is performed. If DRQ is held active for a longer period, HRQ will become inactive after each transfer, become active again, and a one-byte transfer will be made after each rising edge of HLDA. This assures a full machine cycle between DMA transfers in 8080A/8085A systems. Timing between the μPD8237A and other bus control protocols depends on the CPU being used.

Block Transfer Mode

In this mode, the μPD8237A makes transfers until it encounters a TC or an external $\overline{EOP}$. Hold DRQ active only until DACK goes active. The channel will autoinitialize at the end of the DMA service if it has been programmed to do so.

Demand Transfer Mode

In this mode, the μPD8237A makes transfers until it encounters a TC or an external $\overline{EOP}$, or until DRQ becomes inactive. This allows the device requesting service to stop the transfers by sending DRQ inactive. The device can resume service by making DRQ active. The current address and current word count registers may be examined during the time between services when the CPU is allowed to operate. Autoinitialization can occur only after a TC or $\overline{EOP}$ at the end of the DMA service. After an autoinitialization, there must be an active-going DRQ edge to begin new DMA service.

Cascade Mode

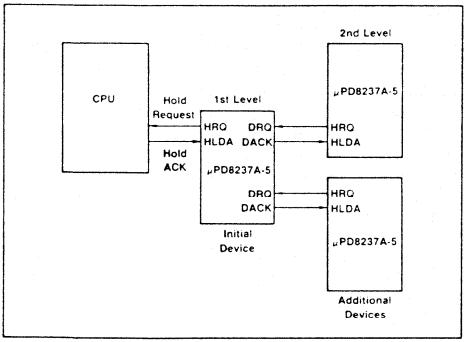
In this mode, you can expand your system by cascading several μPD8237As together. Connect the HLDA and HRQ signals from the additional μPD8237As to the DRQ and DACK signals of a channel of the initial μPD8237A. This scheme allows the additional devices to send the DMA requests through the priority resolution circuitry of the preceding device, preserving the priority chain and forcing the device to wait its turn to acknowledge requests. The cascade channel in the initial device does not output any address or control signals because its only function is that of assigning priorities. The μPD8237A responds to DRQ with DACK, but all outputs except HRQ are disabled.

Figure 1 shows two μPD8237As cascaded into two channels of another one, forming a two-level DMA system. You could add more devices at the second level by using the leftover channels of the first level; likewise, you could add more devices to form a third level by cascading into the channels of the second level.

Transfers

There are three types of transfers that can be performed by the three active transfer modes: read, write, and verify. Read transfers activate $\overline{MEMR}$ and $\overline{I/OW}$ to move memory data to an I/O device. Write transfers activate $\overline{I/OR}$ and $\overline{MEMW}$ to move data from an I/O device to memory. Verify transfers are not really transfers; the μPD8237A goes through the motions of a transfer but the memory and I/O lines are not active.

Figure 1. Two-Level DMA System



Memory-to-Memory Transfers

Use block transfer mode for memory-to-memory transfers. Mask out channels 0 and 1, and initialize the channel 0 word count to the same value as channel 1. Setting bit C0 of the command register to 1 makes channels 0 and 1 operate as memory-to-memory transfer channels. Channel 0 is the source address, channel 1 is the destination address, and the channel 1 word count is used. Initiate the memory-to-memory transfer by setting a DMA request for channel 0. You can write a single source word to a block of memory when channel 0 is programmed for a fixed source address. The μPD8237A responds to external $\overline{EOP}$ signals during these transfers, but no DACK outputs are active. The $\overline{EOP}$ input may be used by data comparators doing block searches to end service when a match is found.

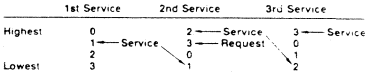
Autoinitialization

A channel may be set for autoinitialize by programming a bit in the mode register. Autoinitialize restores the original values of the current address and current word count registers from the initial address and initial word count registers of that channel. The CPU loads the current and initial registers simultaneously and they are unchanged through DMA service. $\overline{EOP}$ does not set the mask bit when the channel is in autoinitialize. The channel can repeat its service following autoinitialize without CPU intervention.

Priority Resolution

Two software-selectable priority resolution schemes are available on the μPD8237A: fixed priority and rotating priority. In the fixed priority scheme, priority is assigned by the value of the channel number. Channel 3 is the lowest priority and channel 0 is the highest priority.

In the rotating priority scheme, the channel that was just serviced assumes the lowest priority and the other channels move up accordingly. This guarantees that a device requesting service can be adcknowledged after no more than three other devices have been serviced, preventing any channel from monopolizing the system.



The highest priority channel is selected on each active-going HLDA edge. Once service to a channel begins, it cannot be interrupted by a request from a higher priority channel. A higher priority channel gets control only when the lower priority channel releases HRQ. The CPU gets bus control when control passes from channel to channel, ensuring that a rising HLDA edge can be generated to select the new highest priority request.

Transfer Timing

If, you can cut transfer timing, by compressing the transfer time to two clock periods. Since state 3 (S3) extends the access time for the read pulse, you can eliminate S3, making the width of the read pulse equal to the write pulse. A transfer is then made up of S2 to change the address and S4 to perform the read or write. When the address lines A_8-A_{15} need to be updated, S1 states occur.

Generating Addresses

The eight MSBs of the address are multiplexed on the data lines. These bits are output to an external latch during S1, after which they can be placed on the address bus. The falling edge of ADDSTB loads the bits from the data lines to the latch. AEN places the bits on the address bus. The eight LSBs of the address are directly output on lines A_0-A_7 to the address bus.

Sequential addresses are generated during block and demand transfer mode operations because they include several transfers. Often, data in the external address latch does not change; it changes only when a carry or borrow from A_7 to A_8 occurs in the sequence of addresses. S1 states are executed only when A_8-A_{15} need to be updated. In the course of lengthy transfers, S1 states may be executed only once every 256 transfers.

Registers

Table 1 summarizes the registers of the μPD8237A.

Table 1. Register Summary

Register	No.	Bits
Current address registers	4	16
Current word count registers	4	16
Initial address registers	4	16
Initial word count registers	4	16
Command register	1	8
Mode registers	4	6
Request register	1	4
Mask register	1	4
Status register	1	8
Temporary register	1	8
Temporary address register	1	16
Temporary word count register	1	16

Current Address Register. There is a current address register for each channel. This register holds the address used for DMA transfers; the address is incremented or decremented after each transfer and the intermediate values are stored here during the transfer. The CPU writes or reads this register in 8-bit bytes. An autoinitialize restores this register to its initial value.

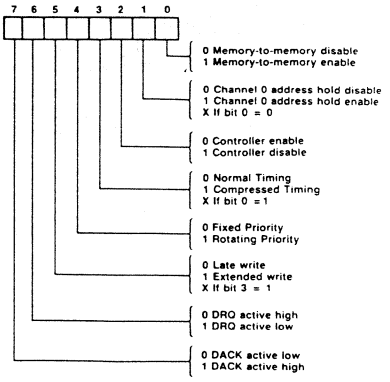
Current Word Count Register. There is a current word count register for each channel. Program this register with the value of the number of words to be transferred, minus one. The word count is decremented after each transfer and intermediate values are stored in this register during the transfer. A TC is generated when the word count is zero. The CPU writes or reads this register in 8-bit bytes during program phase. An autoinitialize restores this register to its initial value. After an internally generated $\overline{EOP}$, the contents of this register with be FFFFH.

Initial Address and Initial Word Count Registers. There is an initial register and an initial word count register for each channel. The initial values of the associated current registers are stored in these registers. The values in these registers are used to restore the current registers at autoinitialize. During DMA programming, the CPU writes the initial registers and the corresponding current registers at the same time, in 8-bit bytes. Intermediate values in the current registers are overwritten if you write to the initial registers while the current registers contain intermediate values. The CPU cannot read the initial registers.

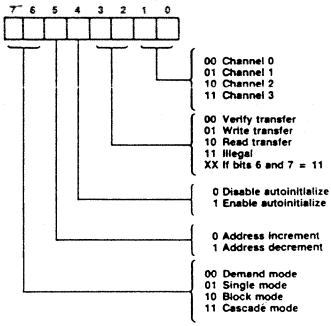
Table 2. Word Count and Address Register Command Codes

Channel	Operation	Signals							Internal Flip-Flop	D_0-D_7
		$\overline{CS}$	$\overline{I/OR}$	$\overline{I/OW}$	A_3	A_2	A_1	A_0		
0	Initial & current address write	0	1	0	0	0	0	0	0	A_0-A_7
		0	1	0	0	0	0	0	1	A_8-A_{15}
	Current address read	0	0	1	0	0	0	0	0	A_0-A_7
		0	0	1	0	0	0	0	1	A_8-A_{15}
	Initial & current word count write	0	1	0	0	0	0	1	0	W_0-W_7
		0	1	0	0	0	0	1	1	W_8-W_{15}
	Current word count read	0	0	1	0	0	0	1	0	W_0-W_7
		0	0	1	0	0	0	1	1	W_8-W_{15}
1	Initial & current address write	0	1	0	0	0	1	0	0	A_0-A_7
		0	1	0	0	0	1	0	1	A_8-A_{15}
	Current address read	0	0	1	0	0	1	0	0	A_0-A_7
		0	0	1	0	0	1	0	1	A_8-A_{15}
	Initial & current word count write	0	1	0	0	0	1	1	0	W_0-W_7
		0	1	0	0	0	1	1	1	W_8-W_{15}
	Current word count read	0	0	1	0	0	1	1	0	W_0-W_7
		0	0	1	0	0	1	1	1	W_8-W_{15}
2	Initial & current address write	0	1	0	0	1	0	0	0	A_0-A_7
		0	1	0	0	1	0	0	1	A_8-A_{15}
	Current address read	0	0	1	0	1	0	0	0	A_0-A_7
		0	0	1	0	1	0	0	1	A_8-A_{15}
	Initial & current word count write	0	1	0	0	1	0	1	0	W_0-W_7
		0	1	0	0	1	0	1	1	W_8-W_{15}
	Current word count read	0	0	1	0	1	0	1	0	W_0-W_7
		0	0	1	0	1	0	1	1	W_8-W_{15}
3	Initial & current address write	0	1	0	0	1	1	0	0	A_0-A_7
		0	1	0	0	1	1	0	1	A_8-A_{15}
	Current address read	0	0	1	0	1	1	0	0	A_0-A_7
		0	0	1	0	1	1	0	1	A_8-A_{15}
	Initial & current word count write	0	1	0	0	1	1	1	0	W_0-W_7
		0	1	0	0	1	1	1	1	W_8-W_{15}
	Current word count read	0	0	1	0	1	1	1	0	W_0-W_7
		0	0	1	0	1	1	1	1	W_0-W_{15}

Command Register. The CPU programs this register during program phase. The register can be cleared with reset.

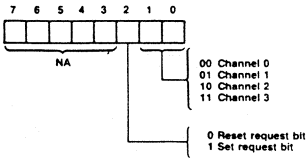


Mode Register. There is a mode register associated with each channel. When the CPU writes to this register during the program phase, bits 0 and 1 determine on which channel mode register the operation is performed.

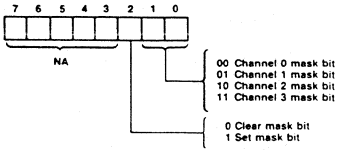


Request Register. This register allows the μPD8237A to respond to DMA requests from software as well as hardware. There is a bit pattern for each channel in the request register. These bits can be prioritized by the priority resolving circuitry and are not maskable. Each bit is set or reset under software control or cleared when TC or an external $\overline{EOP}$ is generated. A reset clears the entire register. The correct data word is loaded by software to set or reset a bit.

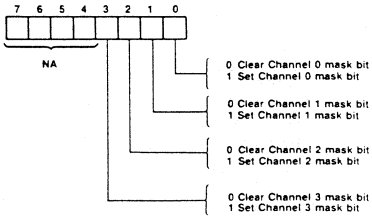
Software requests receive service only when the channel is in block mode. The software request for channel 0 should be set at the beginning of a memory-to-memory transfer.



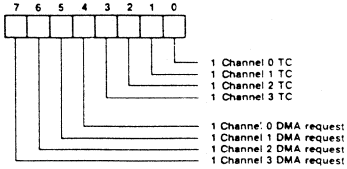
Mask Register. There is a mask bit for each channel which can disable an incoming DRQ. If the channel is not set for autoinitialize, each mask bit is set when its channel produces an $\overline{EOP}$. Each bit can be set or cleared under software control. Reset clears the register. This disallows DMA requests until they are permitted by a clear mask register instruction.



You may also write all four bits of the mask register with a single command.



Status Register. The status register indicates which channels have made DMA requests and which channels have reached TC. Each time a channel reaches TC, including after autoinitialization, bits 0-3 are set. Status read and reset clear these bits. Bits 4-7 are set when a channel is requesting service. The CPU can read the status register.



Temporary Register. The temporary register holds data during memory-to-memory transfers. The CPU can read the last word moved when the transfer is complete. This register always contains the last byte transferred in a memory-to-memory transfer unless cleared by a reset.

Software Commands

There are two software commands that can be executed in the program phase. These commands are independent of data on the data bus.

Clear First/Last Flip-Flop. You may issue this command before reading or writing any word count or address information. It allows the CPU to access registers, addressing upper and lower bytes correctly by initializing the flip-flop to an identifiable state.

Master Clear. This command produces the same effect as reset. It clears the command, status, request, temporary, and internal first/last flip-flop registers, sets the mask register, and causes the μPD8237A to enter idle state.

Table 3 illustrates address codes for the software commands.

Table 3. Software Command Codes

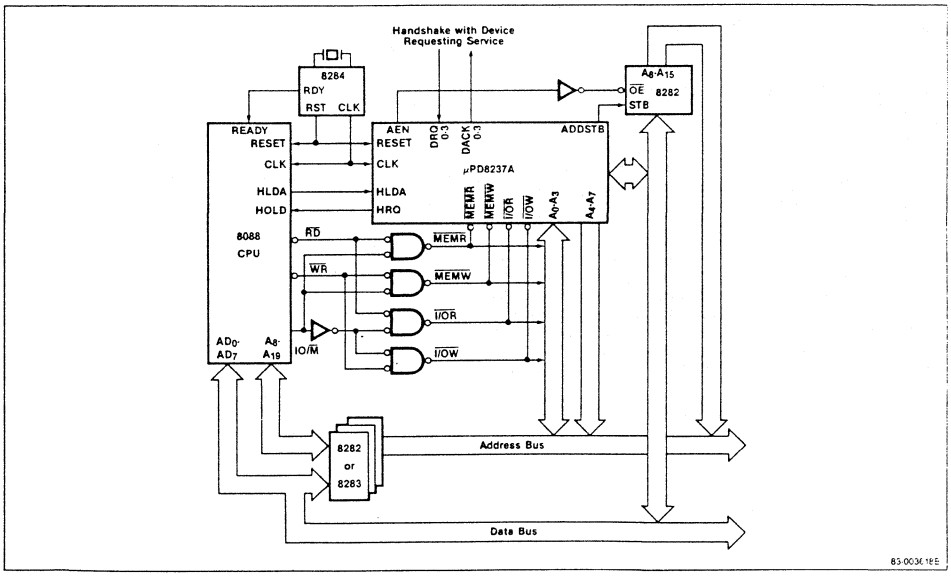
A_3	A_2	A_1	A_0	$\overline{I/OR}$	$\overline{I/OW}$	(1) Operation
1	0	0	0	0	1	Read status register
1	0	0	0	1	0	Write to command register
1	0	0	1	1	0	Write to request register
1	0	1	0	1	0	Write a mask register bit
1	0	1	1	1	0	Write to mode register
1	1	0	0	1	0	Clear byte pointer flip-flop
1	1	0	1	0	1	Read temporary register
1	1	0	1	1	0	Master clear
1	1	1	1	1	0	Write all mask register bits
1	1	1	0	0	1	Clear Mask register

Note:
(1) All other bit combinations are illegal.

Application Example

Figure 2 shows an application using the μPD8237A with an 8088. The μPD8237A sends a hold request to the CPU whenever there is a valid DMA request from a peripheral device. The μPD8237A takes control of the address, data, and control buses when the CPU

Figure 2. μPD8237A DMA Controller Application with 8088 CPU



replies with an HLDA signal. The address for the first transfer appears in two bytes: the eight LSBs are output on A_0-A_7 and the eight MSBs are output on the data bus pins. The contents of the data bus pins are latched to the 8282 to make up the 16 bits of the address bus. Once the address is latched, the data bus transfers data to or from a memory location or I/O device, using the control bus signals generated by the μPD8237A.

AC Characteristics Supplementary Information

All AC timing measurement points are 2.0 V for high and 0.8 V for low, for both inputs and outputs. The loading on the outputs is one TTL gate plus 100 pF of capacitance for the data bus pins, and one TTL gate plus 50 pF for all other outputs.

Recovery time between successive read and write inputs must be at least 400 ns. I/O or memory write pulse widths will be T_{CY}-100 ns for normal DMA transfers and 2 T_{CY}-100 ns for extended cycles. I/O or memory reads will be 2 T_{CY}-50 ns for normal reads and T_{CY}-50 ns for compressed cycles. T_{DQ1} and T_{DQ2} are measured on two different levels: T_{DQ1} at 2.0 V, T_{DQ2} at 3.3 V with a 3.3 kΩ pull-up resistor. DREQ and DACK are both active high and low. DREQ must be held in the active state (user defined) until DACK is returned from the μPD8237A. The AC waveforms assume these are programmed to the active high state.

Absolute Maximum Ratings

T_A = 25°C

Ambient temperature under bias, T_{OPT}	0°C to +70°C
Storage temperature, T_{STG}	−65°C to +150°C
Voltage on any pin with respect to Ground, V_{CC}	−0.5V to +7V
Power dissipation, P_D	1.5 W

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

T_A = 25°C

Parameter	Symbol	Limits Min	Typ(1)	Max	Unit	Test Conditions
Output capacitance	C_O		4	8	pF	fc = 1.0 MHz
Input capacitance	C_I		8	15	pF	Inputs = 0 V
I/O capacitance	C_{IO}		10	18	pF	

Note:
(1) Typical values measured at T_A = 25°C, nominal processing parameters, and nominal V_{CC}.

DC Characteristics

T_A = 0°C to +70°C; V_{CC} = +5 V ± 5%

Parameter	Symbol	Limits Min	Typ(1)	Max	Unit	Test Conditions
Output high voltage	V_{OH}	2.4			V	I_{OH} = −200 μA
		3.3			V	I_{OH} = −100 μA (HRQ only)
Output low voltage	V_{OL}			0.45	V	I_{OL} = 2.0 mA (Data bus)
						I_{OL} = 3.2 mA (Other outputs)
Input high voltage	V_{IH}	2.0		V_{CC} +0.5	V	
Input low voltage	V_{IL}	−0.5		0.8	V	
Input load current	I_{LI}			±10	μA	0V ≤ V_{IN} ≤ V_{CC}
Output leakage current	I_{LO}			±10	μA	0.45 ≤ V_{OUT} ≤ V_{CC}
V_{CC} supply current	I_{CC}		65	130	mA	T_A = +25°C
			75	150	mA	T_A = 0°C

Note:
(1) Typical values measured at T_A = 25°C, nominal processing parameters, and nominal V_{CC}.

AC Characteristics

DMA (Master) Mode

T_A = 0°C to +70°C; V_{CC} = 5V ± 5%; V_{SS} = 0 V

Parameter	Symbol	Limits Min	Typ	Max	Unit
AEN high from CLK low (S1) delay time	t_{AEL}			200	ns
AEN low from CLK high (S1) delay time	t_{AET}			130	ns
ADR active to float delay from CLK high	t_{AFAB}			90	ns
$\overline{READ}$ or $\overline{WRITE}$ float from CLK high	t_{AFC}			120	ns
DB active to float delay from CLK high	t_{AFDB}			170	ns
ADR from $\overline{READ}$ high hold time	t_{AHR}	$t_{CY}-100$			ns
DB from ADDSTB low hold time	t_{AHS}	30			ns
ADR from $\overline{WRITE}$ high hold time	t_{AHW}	$t_{CY}-50$			ns
DACK valid from CLK low delay time	t_{AK}			170	ns
$\overline{EOP}$ high from CLK high delay time	t_{AK}			170	ns
$\overline{EOP}$ low to CLK high delay time	t_{AK}			100	ns
ADR stable from CLK high	t_{ASM}			170	ns
Data bus to ADDSTB low setup time	t_{ASS}	100			ns
Clock high time (transitions ≤ 10 ns)	t_{CH}	80			ns
Clock low time (transitions ≤ 10 ns)	t_{CL}	68			ns
CLK cycle time	t_{CY}	200			ns
CLK high to $\overline{READ}$ or $\overline{WRITE}$ low delay (1)	t_{DCL}			190	ns
$\overline{READ}$ high from CLK high (S-4) delay time (1)	t_{DCTR}			190	ns
$\overline{WRITE}$ high from CLK high (S-4) delay time (1)	t_{DCTW}			130	ns
HRQ valid from CLK high delay time (2)	t_{DQ1} t_{DQ2}			120 120	ns ns
$\overline{EOP}$ low from CLK low setup time	t_{EPS}	40			
$\overline{EOP}$ pulse width	t_{EPW}	220			ns
ADR float to active delay from CLK high	t_{FAAB}			170	ns
$\overline{READ}$ or $\overline{WRITE}$ active from CLK high	t_{FAC}			150	ns

Parameter	Symbol	Limits Min	Typ	Max	Unit
Data bus float to active delay from CLK high	t_{FADB}			200	ns
HLDA valid to CLK high setup time	t_{HS}	75			ns
Input data from $\overline{MEMR}$ high hold time	t_{IDH}	0			ns
Input data to $\overline{MEMR}$ high setup time	t_{IDS}	170			ns
Output data from $\overline{MEMW}$ high hold time	t_{ODH}	10			ns
Output data valid to $\overline{MEMW}$ high	t_{ODV}	125			ns
DRQ to CLK low (S1, S4) setup time	t_{QS}	0			ns
CLK to READY low hold time	t_{RH}	20			ns
READY to CLK low setup time	t_{RS}	60			ns
ADDSTB high from CLK high delay time	t_{STL}			130	ns
ADDSTB low from CLK high delay time	t_{STT}			90	ns

Note:

(1) Net $\overline{I/OW}$ or $\overline{MEMW}$ pulse width for normal write is $t_{CY}-100$ ns and $t_{CY}-100$ ns for extended write. Net $\overline{I/OR}$ or $\overline{MEMR}$ pulse width for normal read to $2t_{CY}-50$ ns and $t_{CY}-50$ ns for compressed read.

(2) T_{DQ1} is measured at 2.0 V. t_{DQ2} is measured at 3.3 V. An external pullup resistor of 3.3Ω connected from HRQ to V_{CC} is assumed for t_{DQ2}.

AC Characteristics (cont)

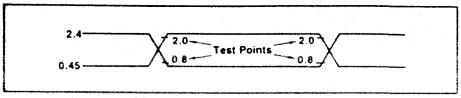
Peripheral Mode

T_A = 0°C to +70°C; V_{CC} = 5 V ± 5%; V_{SS} = 0 V

Parameter	Symbol	Limits Min	Typ	Max	Unit
ADR valid or $\overline{CS}$ low to $\overline{READ}$ low	t_{AR}	50			ns
ADR valid to $\overline{WRITE}$ high setup time	t_{AW}	150			ns
CS low to $\overline{WRITE}$ high setup time	t_{CW}	150			ns
Data valid to $\overline{WRITE}$ high setup time	t_{DW}	150			ns
ADR or CS hold from $\overline{READ}$ high	t_{RA}	0			ns
Data access from $\overline{READ}$ low(1)	t_{RDE}			140	ns
Data bus float delay from $\overline{READ}$ high	t_{RDF}	0		70	ns
Power supply high to RESET low setup time	t_{RSTD}	500			ns
RESET to first I/OR or I/OW	t_{RSTS}	$2t_{CY}$			ns
RESET pulse width	t_{RSTW}	300			ns
$\overline{READ}$ width	t_{RW}	200			ns
ADR from $\overline{WRITE}$ high hold time	t_{WA}	20			ns
CS high from $\overline{WRITE}$ high hold time	t_{WC}	20			ns
Data from $\overline{WRITE}$ high hold time	t_{WD}	30			ns
Write width	t_{WWS}	160			ns

Note:
(1) Data bus output loading is 1 TTL gate plus 100 pF capacitance.

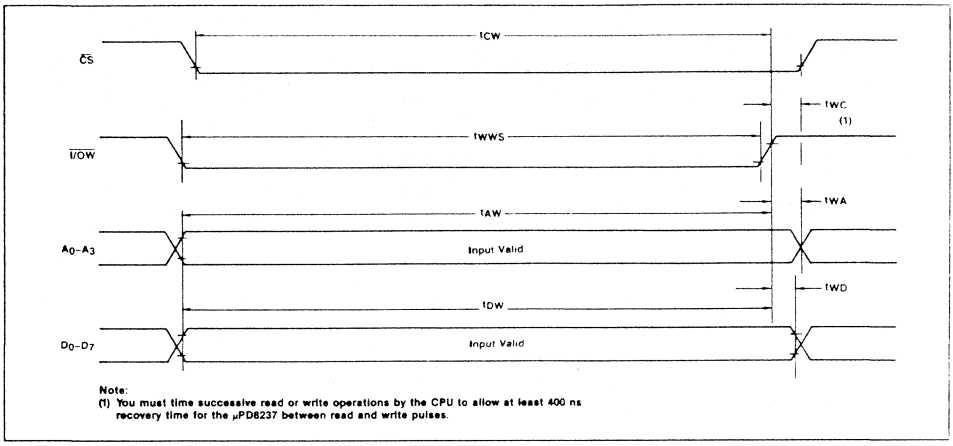
AC Testing Input/Output Waveform



Inputs are driven at 2.4V for logic 1 and 0.45V for logic 0. These timing measurements are made at 2.0V for logic 1 and 0.8V for logic 0. A transition time of 20 ns or less is assumed for input timing parameters. Unless noted, output loading is 1 TTL gate plus 50 pF capacitance.

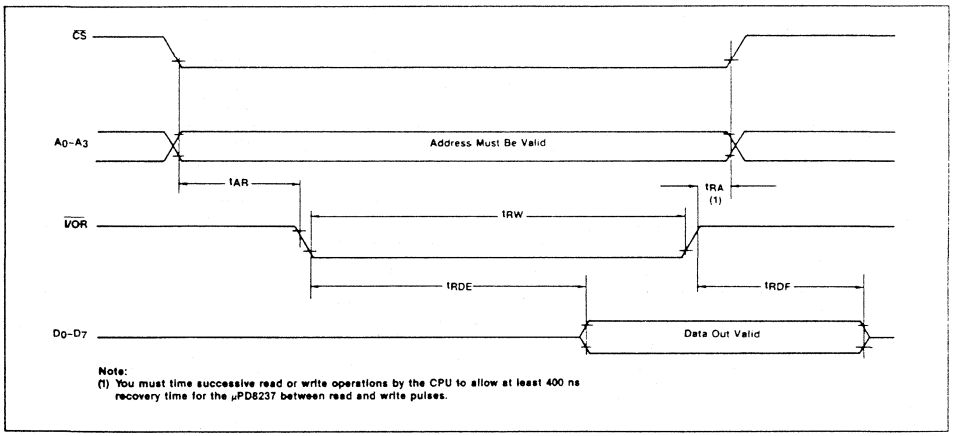
Timing Waveforms

Slave Mode Write



Note:
(1) You must time successive read or write operations by the CPU to allow at least 400 ns recovery time for the μPD8237 between read and write pulses.

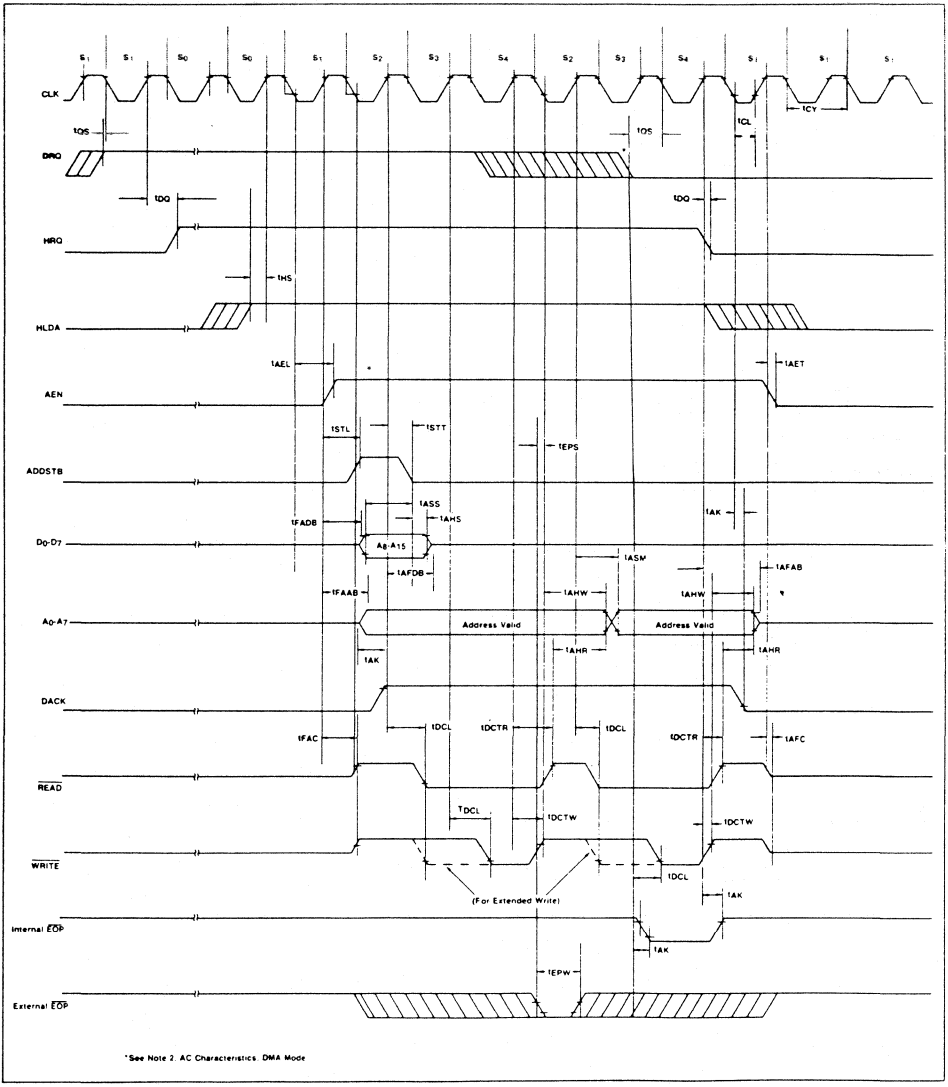
Slave Mode Read



Note:
(1) You must time successive read or write operations by the CPU to allow at least 400 ns recovery time for the μPD8237 between read and write pulses.

Timing Waveforms (cont)

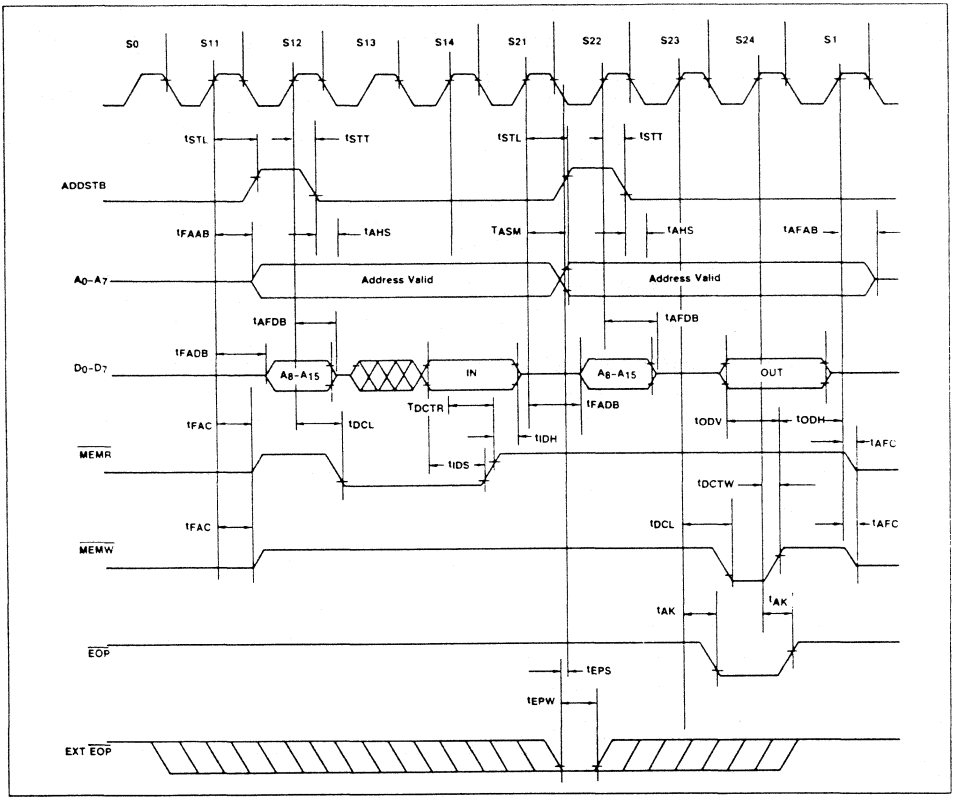
DMA Transfer



*See Note 2, AC Characteristics, DMA Mode

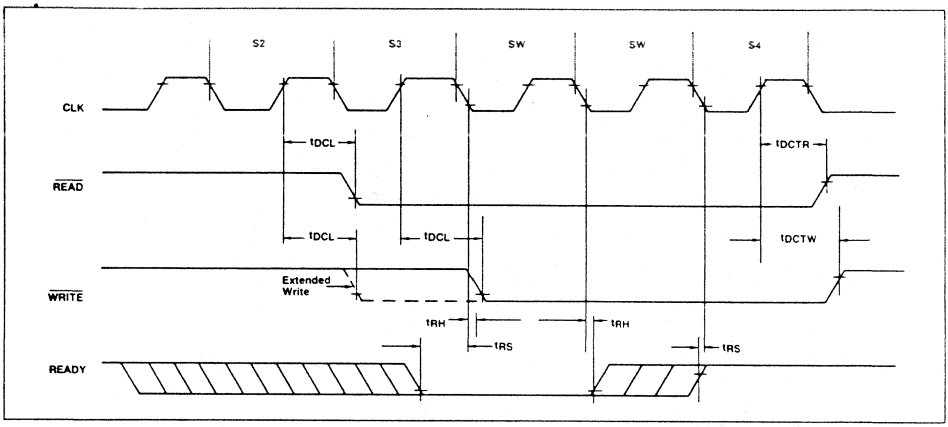
Timing Waveforms (cont)

Memory-to-Memory Transfer

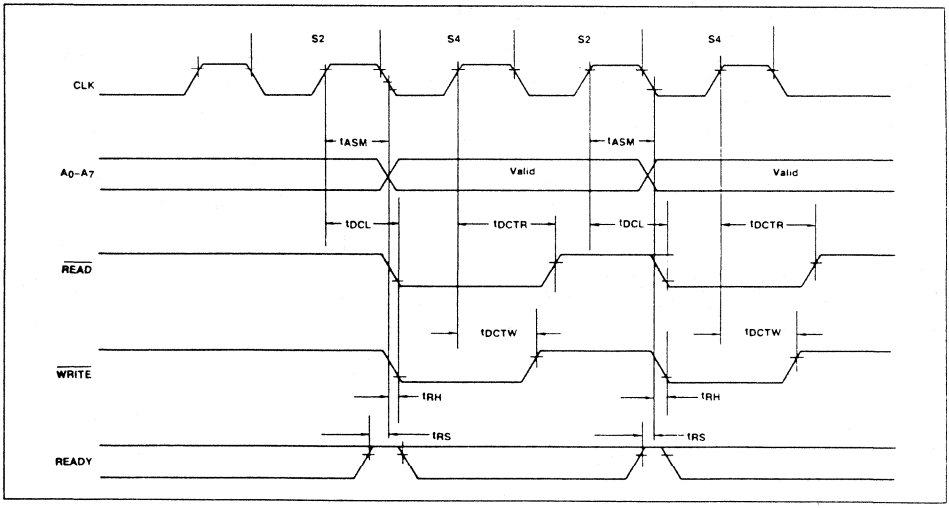


Timing Waveforms (cont)

Ready

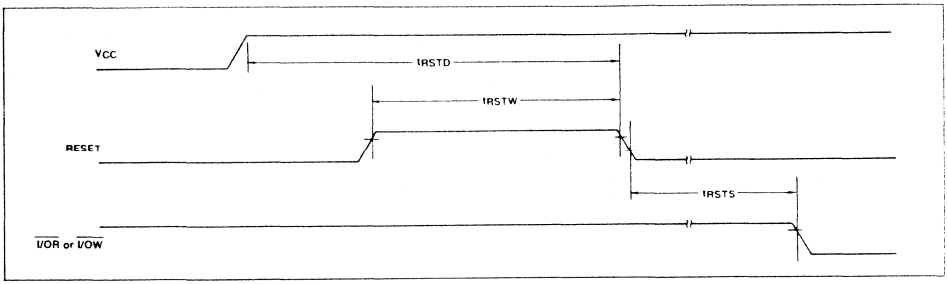


Compressed Transfer



Timing Waveforms (cont)

Reset



μPD8243/H
INPUT/OUTPUT EXPANDER FOR μPD8048 FAMILY

Description

The μPD8243 and μPD8243H input/output expander is directly compatible with the μPD8048 family of single-chip microcomputers. Using NMOS technology the μPD8243 provides high drive capabilities while requiring only a single +5 V supply voltage.

The μPD8243 interfaces to the μPD8048 family through a 4-bit I/O port and offers four 4-bit bidirectional static I/O ports. The ease of expansion allows for multiple μPD8243s to be added using the bus port.

The bidirectional I/O ports of the μPD8243 act as an extension of the I/O capabilities of the μPD8048 microcomputer family. They are accessible with their own ANL, MOV, and ORL instructions.

Another version, μPD8243H, has less total output current sinking capability than μPD8243 but is otherwise identical.

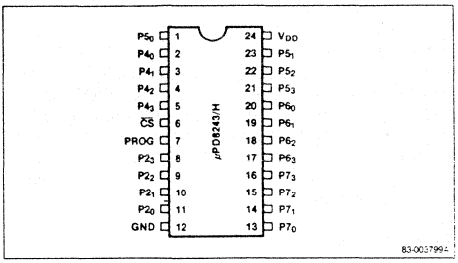
Features

- ☐ Four 4-bit I/O ports
- ☐ High output drive
- ☐ Logical AND and OR directly to ports
- ☐ Compatible with industry standard 8243
- ☐ Direct extension of resident μPD8048 I/O ports
- ☐ Fully compatible with μPD8048 microcomputer family
- ☐ NMOS technology
- ☐ Single +5 V supply

Ordering Information

Part Number	Package Type
μPD8243C	24-pin plastic DIP
μPD8243HC	24-pin plastic DIP

Pin Configuration



Pin Identification

No.	Symbol	Function
1, 21-23	$P5_0$-$P5_3$	4-bit I/O port 5
2-5	$P4_0$-$P4_3$	4-bit I/O port 4
6	$\overline{CS}$	Chip select input
7	PROG	Clock input
8-11	$P2_0$-$P2_3$	4-bit I/O CPU interface port 2
12	GND	Ground
13-16	$P7_0$-$P7_3$	4-bit I/O port 7
17-20	$P6_0$-$P6_3$	4-bit I/O port 6
24	V_{DD}	+5 V power supply

Absolute Maximum Ratings

$T_A = 25°C$

Power supply voltage, V_{DD} (to ground)	−0.5 to +7 V
Operating temperature, T_{OPT}	0 to +70°C
Storage temperature, T_{STG}	−65 to +150°C
Power dissipation, P_D	1.0 W

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Pin Functions

$P2_0$-$P2_3$ (Port 2)

A 4-bit bidirectional port which contains the I/O port address and instruction code on a high to low transition of PROG. During a low to high transition of PROG, port 2 contains either the data for a selected output port if a write operation, or the data from a selected output port (before a low to high transition) if a read operation. Data on port 2 may be directly written, read, ANDed, or ORed with previous data.

$P4_0$-$P4_3$ (Port 4)

A 4-bit I/O port. May be programmed for input (during read), low impedance latched output (after write), or high impedance (after read).

$P5_0$-$P5_3$ (Port 5)

A 4-bit I/O port. May be programmed for input (during read), low impedance latched output (after write), or high impedance (after read).

$P6_0$-$P6_3$ (Port 6)

A 4-bit I/O port. May be programmed for input (during read), low impedance latched output (after write), or high impedance (after read).

$P7_0$-$P7_3$ (Port 7)

A 4-bit I/O port. May be programmed for input (during read), low impedance latched output (after write), or high impedance (after read).

$\overline{CS}$ (Chip Select)

Chip select input. A high on $\overline{CS}$ inhibits any change of output or internal status.

PROG (Clock Input)

A high to low transition on PROG indicates that the op-code and the addressed port information are available on port 2. A low to high transition indicates that data is available on port 2.

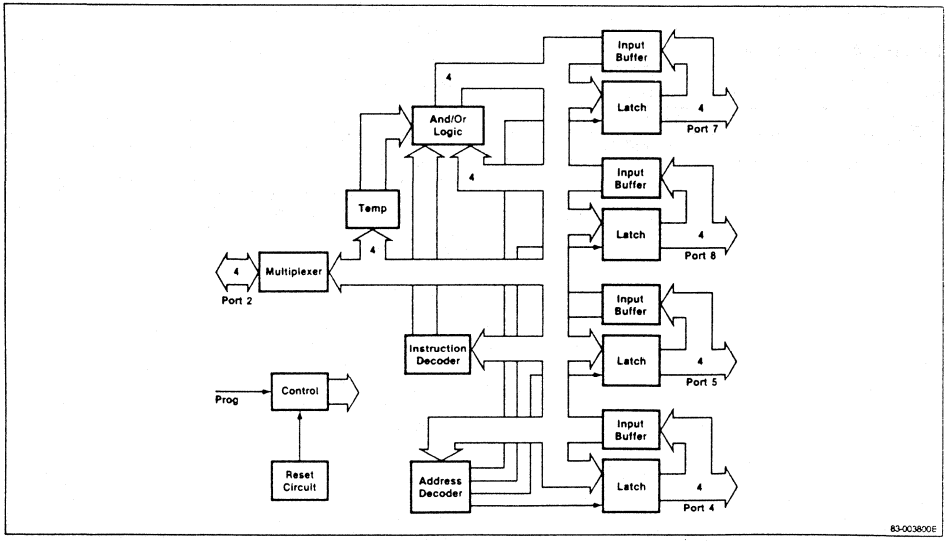
Ground

Ground.

V_{DD} (Power Supply)

+5 V power supply input.

Block Diagram



DC Characteristics

$T_A = 0°C$ to $+70°C$; $V_{DD} = +5\,V \pm 10\%$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage high	V_{IH}	2		$V_{DD}+0.5$	V	
Input voltage low	V_{IL}	−0.5		+0.8	V	
Output voltage high (port 4–7)	V_{OH1}	2.4			V	$I_{OH} = -240\,\mu A$
Output voltage high (port 2)	V_{OH2}	2.4			V	$I_{OH} = -100\,\mu A$
Output voltage low (port 4–7)	V_{OL1}			0.45	V	$I_{OL} = 5$ mA, (Note 1)
Output voltage low (port 7)	V_{OL2}			1	V	$I_{OL} = 20$ mA
Output voltage low (port 2)	V_{OL3}			0.45	V	$I_{OL} = 0.6$ mA
Sum of all I_{OL} from 16 outputs (Note 1)	I_{OL}			100	mA	(8243) 5 mA each pin
				80	mA	(8243H) 5 mA each pin
Input leakage current (port 4–7)	I_{IL1}	−10		20	μA	$V_{IN} = V_{DD}$ to 0 V
Input leakage current (port 2, $\overline{CS}$, PROG)	I_{IL2}	−10		10	μA	$V_{IN} = V_{DD}$ to 0 V
V_{DD} supply current	I_{DD}		10	16	mA	

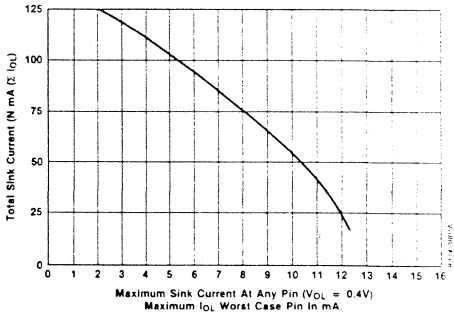
Note:
(1) Refer to graph of current sinking capability.

AC Characteristics

$T_A = 0°C$ to $+70°C$, $V_{DD} = +5\,V \pm 10\%$

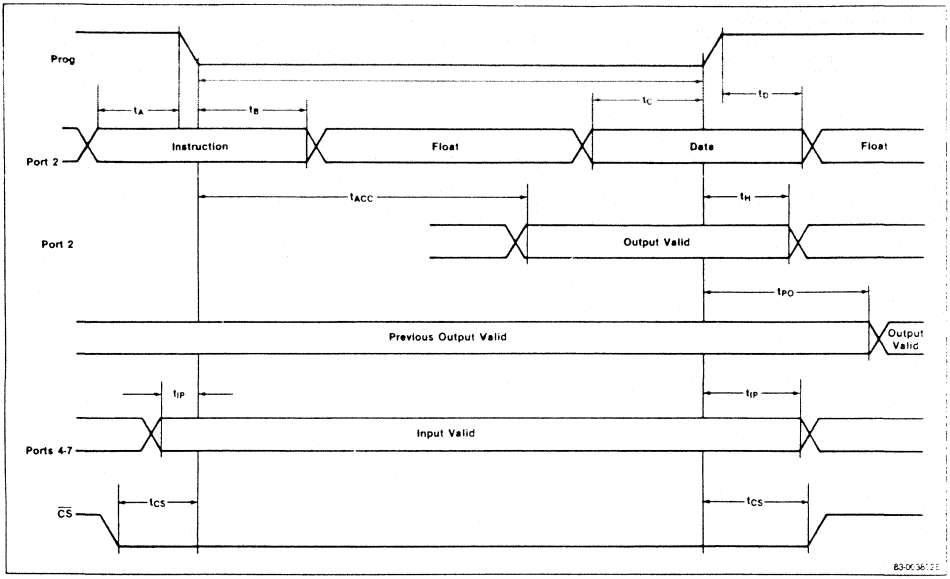
Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Code valid before PROG	t_A	100			ns	80 pF load
Code valid after PROG	t_B	60			ns	20 pF load
Data valid before PROG	t_C	200			ns	80 pF load
Data valid after PROG	t_D	20			ns	20 pF load
Port 2 floating after PROG	t_H	0		150	ns	20 pF load
PROG negative pulse width	t_K	700			ns	
Ports 4–7 valid after PROG	t_{PO}			700	ns	100 pF load
Ports 4–7 valid before / after PROG	t_{IP}	100			ns	
Port 2 valid after PROG	t_{ACC}			650	ns	80 pF load
$\overline{CS}$ valid before / after PROG	t_{CS}	50			ns	

Current Sinking Capability



Note:
This curve plots the guaranteed worst case current sinking capability of any I/O port line versus the total sink current of all pins. The μPD8243 is capable of sinking 5 mA (for $V_{OL} = 0.4$ V) through each of the 16 I/O lines simultaneously. The current sinking curve shows how the individual I/O line drive increases if all the I/O lines are not fully loaded.

Timing Waveform



Functional Description

The I/O capabilities of the μPD8048 family can be enhanced in four I/O port increments of 4-bits each using one or more μPD8243's. These additional I/O lines are addressed as ports 4-7. The following lists the operations which can be performed on ports 4-7.

- Logical AND accumulator to port
- Logical OR accumulator to port
- Transfer port to accumulator
- Transfer accumulator to port

Port 2 ($P2_0$-$P2_3$) forms the 4-bit bus through which the μPD8243 communicates with the host processor. The PROG output from the μPD8048 family provides the necessary timing to the μPD8243. There are two 4-bit nibbles involved in each data transfer. The first nibble contains the opcode and port address followed by the second nibble containing the 4-bit data. Multiple μPD8243's can be used for additional I/O. The output lines from the μPD8048 family can be used to form the chip selects for additional μPD8243's.

Power On Initialization

Applying power to the μPD8243 sets ports 4-7 to the high impedance mode and port 2 to the input mode. The state of the PROG pin at power on may be either high or low. The PROG pin must make a high to low transition in order to exit from the power on mode. The power on sequence is initiated any time V_{DD} drops below 1V. Table 1 following shows how the first 4-bit nibble of a data transfer instruction is decoded.

Table 1. Port 2 Instruction Decoding

$P2_3$	$P2_2$	Instruction Code	$P2_1$	$P2_0$	Address Code
0	0	Read	0	0	Port 4
0	1	Write	0	1	Port 5
1	0	ORLD	1	0	Port 6
1	1	ANLD	1	1	Port 7

For example, an 0010 appearing on $P2_3$-$P2_0$ respectively would result in a read of port 6.

Read Mode

There is one read mode in the μPD8243. A falling edge on the PROG pin latches the opcode and port address from input port 2. The port address and read operation are then decoded causing the appropriate outputs to be high impedance and the input buffers switched on. The rising edge of PROG terminates the read operation. The port (4, 5, 6, or 7) that was selected by the port address ($P2_1$-$P2_0$) is returned to the high impedance mode, and port 2 is switched to the input mode.

Generally, in the read mode a port will be an input and in the write mode it will be an output. If during program operation, the μPD8243's modes are changed, the first read pulse immediately following a write should be ignored. The subsequent read signals are valid. Reading a port will then force that port to a high impedance state.

Write Modes

There are three write modes in the μPD8243. The MOVD P_p, A instruction from the μPD8048 family writes the new data directly to the specified port (4, 5, 6, or 7). The old data previously latched at that port is lost. The ORLD P_p,A instruction performs a logical OR between the new data and the data currently latched at the selected port. The result is then latched at that port. The final write mode uses the ANLD P_p, A instruction. It performs a logical AND between the new data and the data currently latched at the specified port. The result is latched at that port.

The data remains latched at the selected port following the logical manipulation until new data is written to that port.

Description

The μPD8251A and μPD8251AF Universal Synchronous/Asynchronous Receiver/Transmitter (USART) are designed for microcomputer systems data communications. The USART is used as a peripheral and is programmed by the 8085A or other processor to communicate in commonly used serial data transmission techniques including IBM Bi-Sync. The USART receives serial data streams and converts them into parallel data characters for the processor. While receiving serial data, the USART will also accept data characters from the processor in parallel format, convert them to serial format, and transmit. The USART will signal the processor when it has completely received or transmitted a character and requires service. Complete USART status including data format errors and control signals such as TxE and SYNDET, is available to the processor at any time.

Features

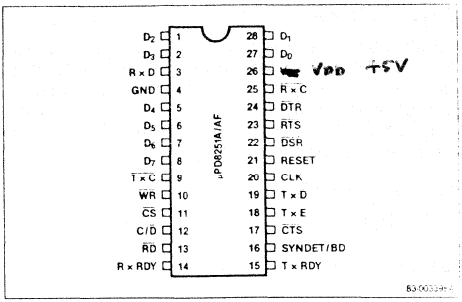
- ☐ Asynchronous or synchronous operation
  - — Asynchronous:
    - -Five 8-bit characters
    - -Clock rate — 1, 16, or 64 x baud rate
    - -Break character generation
    - -Select 1, 1½, or 2 stop bits
    - -False start bit detector
    - -Automatic break detect and handling
  - — Synchronous:
    - -Five 8-bit characters
    - -Internal or external character synchronization
    - -Automatic sync insertion
    - -Single or double sync characters
- ☐ Baud rate (1x mode) — DC to 64K baud
- ☐ Full-duplex, double buffered transmitter and receiver
- ☐ Parity, overrun and framing flags
- ☐ Fully compatible with 8085A/μPD780 (Z80®), etc.
- ☐ All inputs and outputs are TTL-compatible
- ☐ Single +5 V supply, ±10%
- ☐ Separate device receive and transmit TTL clocks
- ☐ NMOS technology

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD8251AC	28-Pin plastic DIP	3/5 MHz
μPD8251AFC	28-Pin plastic DIP	3/5 MHz

Z80 is a registered trademark of Zilog, Inc.

Pin Configuration



Pin Identification

No.	Symbol	Function
1, 2, 27, 28, 5-8	D_7-D_0	Data bus buffer
26	V_{DD}	V_{DD} supply voltage
4	GND	Ground
21	RESET	Reset
20	CLK	Clock pulse
10	$\overline{WR}$	Write data
13	$\overline{RD}$	Read data
12	C/$\overline{D}$	Control / data
11	$\overline{CS}$	Chip select
22	$\overline{DSR}$	Data set ready
24	$\overline{DTR}$	Data terminal ready
23	$\overline{RTS}$	Request to send
17	$\overline{CTS}$	Clear to send
15	TxRDY	Transmitter ready
18	TxE	Transmitter empty
9	$\overline{TxC}$	Transmitter clock
19	TxD	Transmitter data
14	RxRDY	Receiver ready
25	$\overline{RxC}$	Receiver clock
3	RxD	Receiver data
16	SYNDET / BD	Sync detect / break detect

Pin Functions

Data Bus Buffer

An 8-bit, 3-state bi-directional buffer used to interface the USART to the processor data bus. Data is transmitted or received by the buffer in response to input/output or read/write instructions from the processor. The data bus buffer also transfers control words, command words, and status.

V_{DD} Supply Voltage

+5 V supply

Ground

Ground

Read/Write Control Logic

This logic block accepts inputs from the processor control bus and generates control signals for overall USART operation. The mode instruction and command instruction registers that store the control formats for device functional definition are located in the read/write control logic.

Reset

A "one" on this input forces the USART into the "Idle" mode where it will remain until reinitialized with a new set of control words. Minimum RESET pulse width is $6\,t_{CY}$.

Clock Pulse

The CLK input provides for internal device timing and is usually connected to the phase 2 (TTL) output of the μPB8224 clock generator. External inputs and outputs are not referenced to CLK, but the CLK frequency must be at least 30 times the receiver or transmitter clocks in the synchronous mode and 4.5 times for the asynchronous mode.

Write Data

A "zero" on this input instructs the USART to accept the data or control word which the processor is writing out on the data bus.

Read Data

A "zero" on this input instructs the USART to place the data or status information onto the data bus for the processor to read.

Control/Data

The control/data input, in conjunction with the $\overline{WR}$ and $\overline{RD}$ inputs, informs the USART to accept or provide either a data character, control word, or status information via the data bus. 0 = Data; 1 = Control.

Chip Select

A "zero" on this input enables the USART to read from or write to the processor.

Modem Control

The μPD8251A/51AF have a set of control inputs and outputs which may be used to simplify the interface to a modem.

Data Set Ready

The data set ready input can be tested by the processor via status information. The $\overline{DSR}$ input is normally used to test the modem data set ready condition.

Data Terminal Ready

The data terminal ready output can be controlled via the command word. The $\overline{DTR}$ output is normally used to drive modem data terminal ready or rate select lines.

Request to Send

The request to send output can be controlled via the command word. The $\overline{RTS}$ output is normally used to drive the modem request to send line.

Clear to Send

A "zero" on the clear to send input enables the USART to transmit serial data if the TxEN bit in the command instruction register is enabled (one).

Transmit Control Logic

The transmit control logic accepts and outputs all external and internal signals necessary for serial data transmission.

Transmitter Ready

Transmitter ready signals the processor that the transmitter is ready to accept a data character. TxRDY can be used as an interrupt or may be tested through the status information for polled operation. Loading a character from the processor automatically resets TxRDY, on the leading edge.

Transmitter Empty

The transmitter empty output signals the processor that the USART has no further characters to transmit. TxE is automatically reset upon receiving a data character from the processor. In half-duplex, TxE can be used to signal the end of a transmission and request the processor to "turn the line around." The TxEn bit in the command instruction does not effect TxE.

In the synchronous mode, a "one" on this output indicates that a sync character or characters are about to be automatically transmitted as "fillers" because the next data character has not been loaded.

Transmitter Clock

The transmitter clock controls the serial character transmission rate. In the asynchronous mode, the $\overline{\text{TxC}}$ frequency is a multiple of the actual baud rate. Two bits of the mode instruction select the multiple to be 1x, 16x, or 64x the baud rate. In the synchronous mode, the $\overline{\text{TxC}}$ frequency is automatically selected to equal the actual baud rate.

Note that for both synchronous and asynchronous modes, serial data is shifted out of the USART by the falling edge of $\overline{\text{TxC}}$.

Transmitter Data

The transmit control logic outputs the composite serial data stream on this pin.

Receiver Control Logic

This block manages all activities related to incoming data.

Receiver Ready

The receiver ready output indicates that the receiver buffer is ready with an "assembled" character for input to the processor. For polled operation, the processor can check RxRDY using a status read or RxRDY can be connected to the processor interrupt structure. Note that reading the character to the processor automatically resets RxRDY.

Receiver Clock

The receiver clock determines the rate at which the incoming character is received. In the asynchronous mode, the $\overline{\text{RxC}}$ frequency may be 1, 16 or 64 times the actual baud rate, but in the synchronous mode the $\overline{\text{RxC}}$ frequency must equal the baud rate. Two bits in the mode instruction select asynchronous at 1x, 16x, or 64x or synchronous operation at 1x the baud rate.

Unlike $\overline{\text{TxC}}$, data is sampled by the μPD8251A/51AF on the rising edge of $\overline{\text{RxC}}$. (Note 1)

Receiver Data

A composite serial data stream is received by the receiver control logic on this pin.

Sync Detect/Break Detect

The μPD8251A/51AF may be programmed through the mode instruction to operate in either the internal or external sync mode; the SYNDET/BD pin then functions as an output or input respectively. In the internal sync mode, the SYNDET output will go to a "one" when the μPD8251A/51AF has located the SYNC character in the receive mode. If double SYNC character (bi-sync) operation has been programmed, SYNDET will go to "one" in the middle of the last bit of the second SYNC character. SYNDET is automatically reset to "zero" upon a status read or RESET. In the external SYNC mode, a "zero" to "one" transition on the SYNDET input will cause the μPD8251A/51AF to start assembling data character on the next falling edge of $\overline{\text{RxC}}$. The length of the SYNDET input should be at least one $\overline{\text{RxC}}$ period, but may be removed once the μPD8251A/51AF is in SYNC.

In the asynchronous mode, the SYNDET/BD pin functions as a break detect. The BD output will go high when a word of all zeros is received. This word consists of: start bit, data bits, parity bit, and one stop bit. Reset only occurs when Rx data returns to a logic one state or upon chip reset. The state of break detect can be read as a status bit.

Note:

(1) Since the μPD8251A/51AF will frequently be handling both the reception and transmission for a given link, the receive and transmit baud rates will be the same. $\overline{RxC}$ and $\overline{TxC}$ then require the same frequency and may be tied together and connected to a single clock source or baud rate generator.

Examples:

If the baud rate equals 110 (Async):

$\overline{RxC}$ or $\overline{TxC}$ equals 110 Hz (1x)

$\overline{RxC}$ or $\overline{TxC}$ equals 1.76 kHz (16x)

$\overline{RxC}$ or $\overline{TxC}$ equals 7.04 kHz (64x)

If the baud rate equals 300:

$\overline{RxC}$ or $\overline{TxC}$ equals 300 Hz (1x) A or S

$\overline{RxC}$ or $\overline{TxC}$ equals 4800 Hz (16x) A only

$\overline{RxC}$ or $\overline{TxC}$ equals 19.2 kHz (64x) A only

Absolute Maximum Ratings

$T_A = 25°C$

Power supply voltage, V_{DD}	−0.5 V to +7 V
Input voltage, V_I	−0.5 V to +7 V
Output voltage, V_O	−0.5 V to +7 V
Operating temperature, T_{OPT}	−0°C to +70°C
Storage temperature, T_{STG}	−65°C to +150°C

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

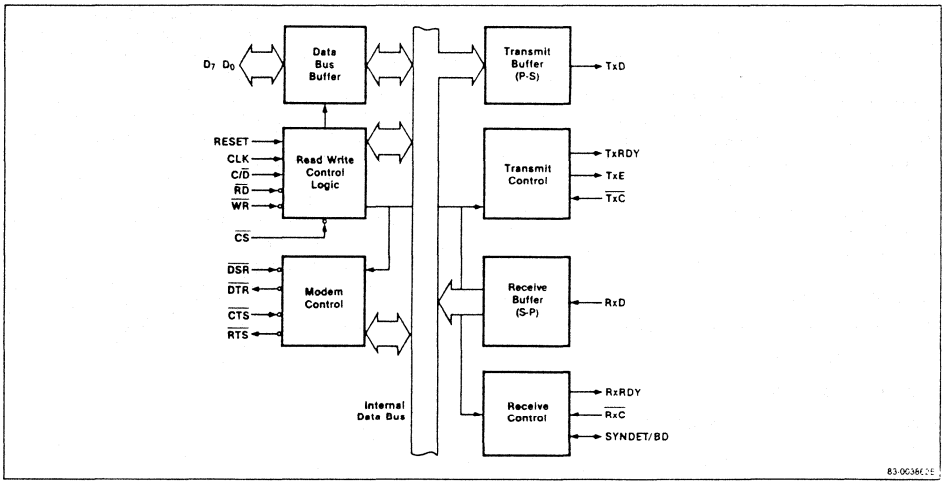
$T_A = 25°C$, $V_{CC} = GND = 0 V$, $f_c = 1.0 MHz$

		Limits				
Parameter	**Symbol**	**Min**	**Typ**	**Max**	**Unit**	**Test Conditions**
Input capacitance	C_{IN}			10	pF	(Note 1)
I/O capacitance	C_{IO}			20	pF	(Note 1)

Note:

(1) All unmeasured pins returned to GND.

Block Diagram



DC Characteristics

$T_A = 0°C$ to $+70°C$, $V_{CC} = +5\,V \pm 10\%$, GND = 0 V

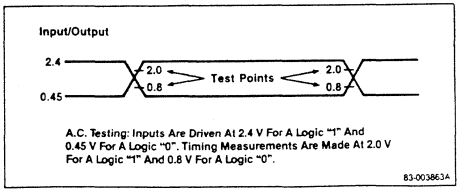
Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage low	V_{IL}	−0.5		+0.8	V	
Input voltage high	V_{IH}	2		V_{CC}	V	
Output voltage low	V_{OL}			+0.45	V	μPD8251: $I_{OL} = 1.7$ mA μPD8251A: $I_{OL} = 2.2$ mA
Output voltage high	V_{OH}	2.4			V	μPD8251: $I_{OH} = -100\,\mu A$ μPD8251A: $I_{OH} = -400\,\mu A$
Output float leakage current	I_{OFL}			±10	μA	$V_{OUT} = 0.45$ V
				10	μA	$0.45\,V \leq V_{OUT} \leq V_{CC}$
Input load current	I_{IL}			10	μA	$0.45\,V \leq V_{IN} \leq V_{CC}$
Power supply current	I_{CC}			100	mA	All outputs = logic 1

AC Characteristics

$T_A = 0°C$ to $+70°C$, $V_{CC} = 5\,V \pm 10\%$; GND = 0 V

Parameter	Symbol	Limits μPD8251A Min	Max	μPD8251AF Min	Max	Unit	Test Conditions
Read							
Address stable before $\overline{RD}$. ($\overline{CS}$, $\overline{CD}$)	t_{AR}	50		0		ns	(Note 7)
Address hold time for $\overline{RD}$. ($\overline{CS}$, $\overline{CD}$)	t_{RA}	50		0		ns	(Note 7)
$\overline{RD}$ pulse width	t_{RR}	250		200		ns	
Data delay from $\overline{RD}$	t_{RD}		250		140	ns	μPD8251A: $C_L = 150$ pF. (Note 8)
$\overline{RD}$ to data floating	t_{DF}	10	100	10	80	ns	

Testing Input, Output Waveform



A.C. Testing: Inputs Are Driven At 2.4 V For A Logic "1" And 0.45 V For A Logic "0". Timing Measurements Are Made At 2.0 V For A Logic "1" And 0.8 V For A Logic "0".

83-003863A

Parameter	Symbol	Limits μPD8251A Min	Max	μPD8251AF Min	Max	Unit	Test Conditions
Write							
Address stable before $\overline{WR}$	t_{AW}	50		0		ns	
Address hold time for $\overline{WR}$	t_{WA}	50		0		ns	
$\overline{WR}$ pulse width	t_{WW}	250		200		ns	
Data set-up time for $\overline{WR}$	t_{DW}	150		100		ns	
Data hold time for $\overline{WR}$	t_{WD}	30		0		ns	
Recovery time between $\overline{WR}$'s	t_{RV}	6		6		t_{CY}	(Note 2)
Other Timing							
Clock period	t_{CY}	0.32	1.35	0.20	1.35	μs	(Note 3)
Clock pulse width high	$t_{\phi W}$	140	$t_{CY} - 90$	70	$t_{CY} - 40$	ns	
Clock pulse width low	$t_{\phi W}$	90		40		ns	
Clock rise and fall time	t_R, t_F	5	20	5	20	ns	
TxD delay from falling edge of TxC	t_{DTx}		1		1	μs	
Rx data set-up time to sampling pulse	t_{SRx}	2				μs	
Rx data hold time to sampling pulse	t_{HRx}	2				μs	
Transmitter input clock frequency	f_{Tx}		64	DC	64	kHz	1x baud rate
			310	DC	310	kHz	16x baud rate
			615	DC	615	kHz	64x baud rate
Transmitter input clock pulse width	t_{TPW}	12		12	t_{CY}		1x baud rate
		1		1	t_{CY}		16x and 64x baud rate
Transmitter input clock pulse delay	t_{TPD}	15		15	t_{CY}		1x baud rate
		3		3	t_{CY}		16x and 64x baud rate

AC Characteristics (cont)

Parameter	Symbol	Limits μPD8251A Min	Limits μPD8251A Max	Limits μPD8251AF Min	Limits μPD8251AF Max	Unit	Test Conditions
Other Timing (cont)							
Receiver input clock frequency	f_{Rx}		64	DC	64	kHz	1x baud rate
			310	DC	310	kHz	16x baud rate
			615	DC	615	kHz	64x baud rate
Receiver input clock pulse width	t_{RPW}	12		12		t_{CY}	1x baud rate
		1		1		t_{CY}	16x and 64x baud rate
Receiver input clock pulse delay	t_{RPD}	15		15		t_{CY}	1x baud rate
		3		3		t_{CY}	16x and 64x baud rate
TxRDY delay from center of data bit	t_{Tx}		8		8	t_{CY}	(Note 9)
TxRDY ↓ from leading edge of $\overline{WR}$	$t_{TxRDY\ CLEAR}$				300	ns	(Note 9)
RxRDY delay from center of data bit	t_{RX}		24		20	t_{CY}	
Internal SYNDET delay from center of data bit	t_{IS}		24			t_{CY}	(Note 9)
RxRDY ↓ from leading edge of $\overline{RD}$	$t_{RxRDY\ CLEAR}$				300	ns	(Note 9)
External SYNDET set-up time before falling edge of RxC	t_{ES}	16		18		t_{CY}	(Note 9)

Parameter	Symbol	Limits μPD8251A Min	Limits μPD8251A Max	Limits μPD8251AF Min	Limits μPD8251AF Max	Unit	Test Conditions
Other Timing (cont)							
TxEMPTY delay from center of data bit	t_{TxE}		20		20	t_{CY}	(Note 9)
Control delay from rising edge of WR (TxE, $\overline{DTR}$, $\overline{RTS}$)	t_{WC}		8		8	t_{CY}	(Note 9)
Control to $\overline{RD}$ set-up time ($\overline{DSR}$, $\overline{CTS}$)	t_{CR}	20		20		t_{CY}	(Note 9)

Note:

(1) AC timing measured at V_{OH} = 2.0 V, V_{OL} = 0.8 V, and with test load circuit below.

(2) This recovery time is for initialization only, when MODE, SYNC1, SYNC2, COMMAND and first DATA BYTES are written into the USART. Subsequent writing of both COMMAND and DATA are only allowed when TxRDY = 1.

(3) The TxC and RxC frequencies have the following limitations with respect to CLK:
For 1x baud rate, f_{Tx} or $f_{Rx} \leq 1/(30\,t_{CY})$
For 16x and 64x baud rate, f_{Tx} or $f_{Rx} \leq 1/(4.5\,t_{CY})$

(4) Reset pulse width = $6\,t_{CY}$ minimum.

(5) $t_{TxRDYCCR} = 2\,t_{CY} + t_{\phi} + t_R + 200$ ns

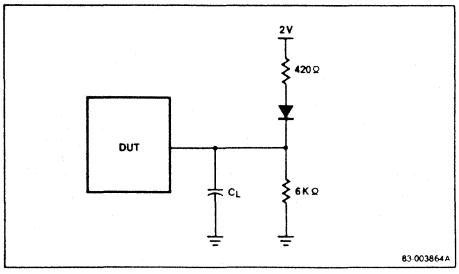
(6) $t_{RxRDYCCR} = 2\,t_{CY} + t_{\phi} + t_R + 170$ ns

(7) Chip Select (CS) and Command/Data (C/D) are considered as addresses.

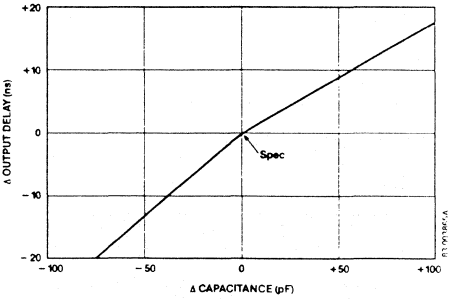
(8) Assumes that address is valid before R_O ↓.

(9) Status update can have a mixmum delay of 26 clock periods from the event affecting the status.

Test Load Circuit

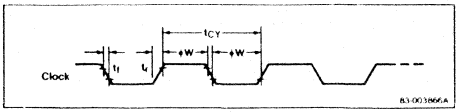


Typical Δ Output Delay Versus Δ Capacitance

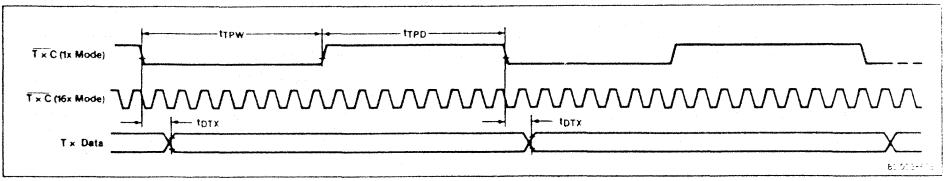


Timing Waveforms

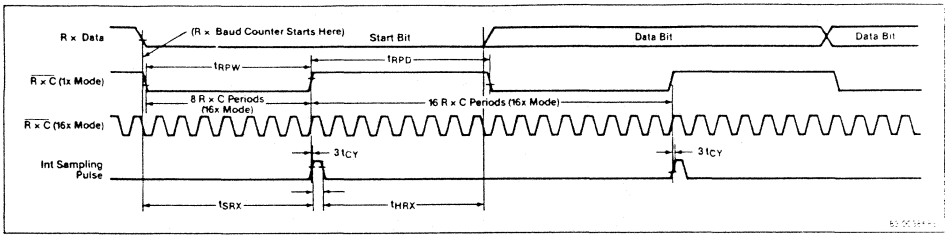
System Clock Input



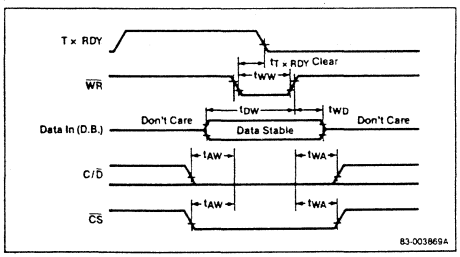
Transmitter Clock and Data



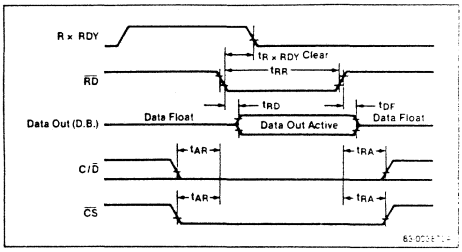
Receiver Clock and Data



Write Data Cycle (Processor → USART)

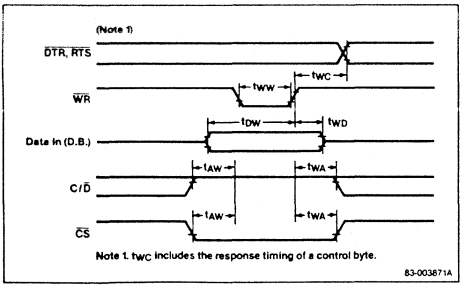


Read Data Cycle (Processor ← USART)

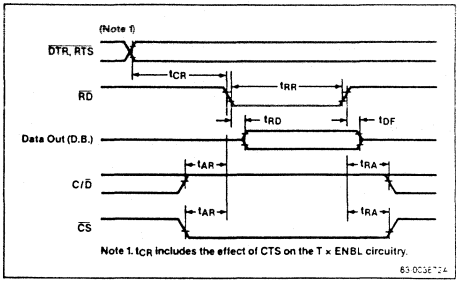


Timing Waveforms (cont)

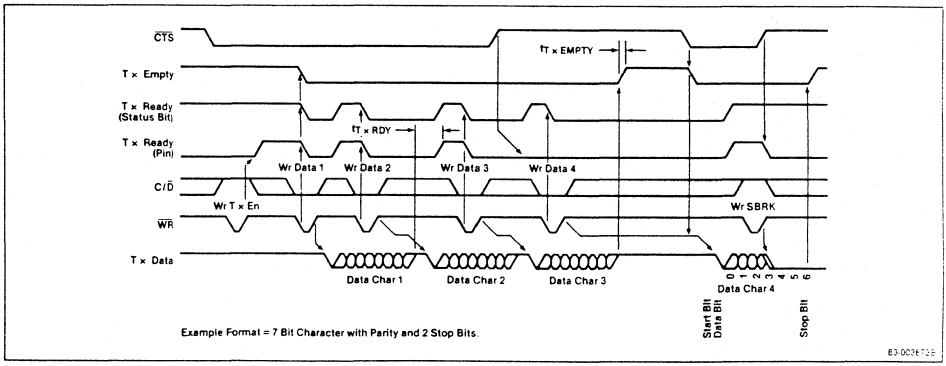
Write Control or Output Port Cycle (Processor → USART)



Read Control or Input Port Cycle (Processor ← USART)

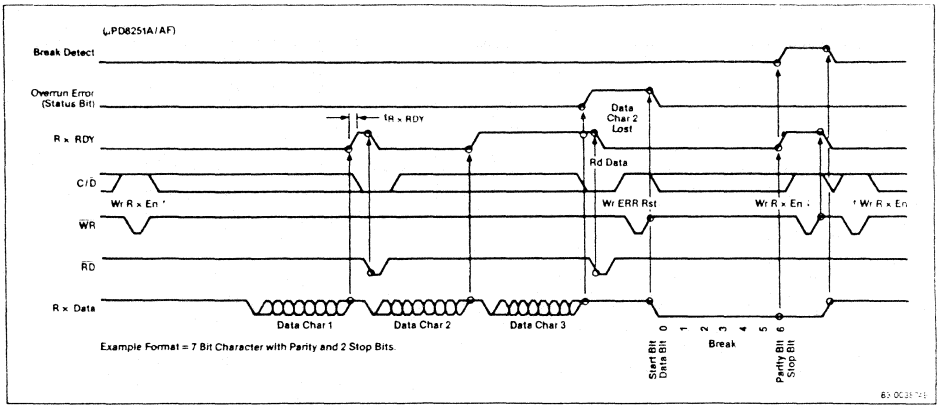


Transmitter Control and Flag Timing (Async Mode)

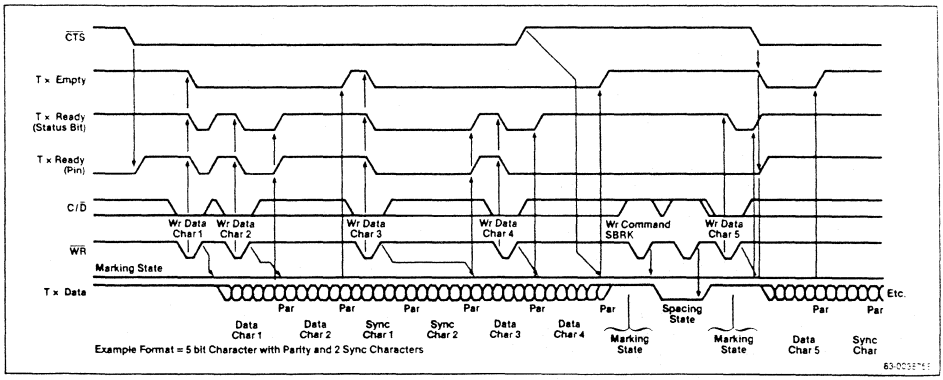


Timing Waveforms (cont)

Receiver Control and Flag Timing (Async Mode)

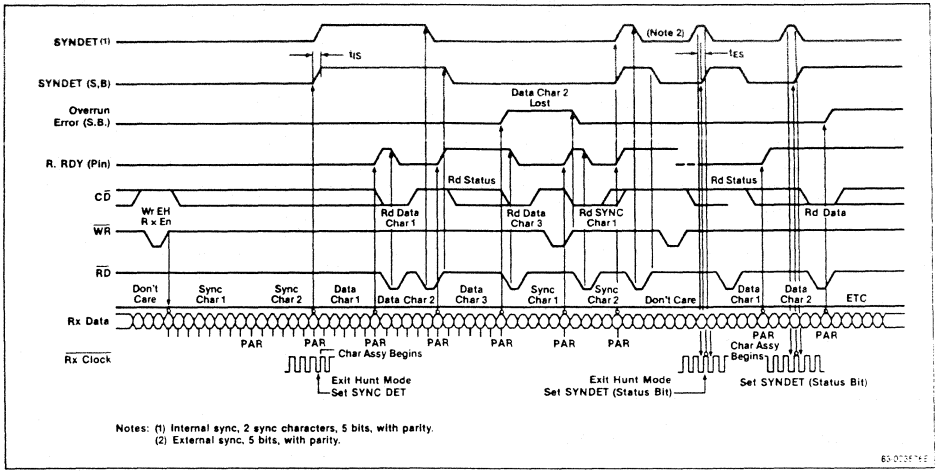


Transmitter Control and Flag Timing (Sync Mode)



Timing Waveforms (cont)

Receiver Control and Flag Timing (Sync Mode)



Notes: (1) Internal sync, 2 sync characters, 5 bits, with parity.
(2) External sync, 5 bits, with parity.

μPD8251AF Enhancements

μPD8251A	μPD8251AF
A previously loaded data character will be retransmitted if Tx was disabled before TxEMPTY by TxEnable ↓ or $\overline{CTS}$ ↑, and is re-enabled by TxEnable ↑ or $\overline{CTS}$ ↓ before a new data character is sent to μPD8251A by the CPU.	A previously loaded character will be flushed out and not transmitted on $\overline{CTS}$ ↓ or TxEnable ↑.
Break detect does not always reset upon RxData returning to a '1' during the last bit of the character following the break. Break detect will latch up, and the device must be cleared by device reset.	Break detect will reset on RxData going to '1'.
On TxEnable ↓ or $\overline{CTS}$ ↑ during the first character of a double-character sync output, the second sync character will not be output.	Will output both sync characters on TxEnable ↓ or $\overline{CTS}$ ↑.
If the status register is read during a status update, an erroneous status read may result.	Some valid status (either new or old) will always be available.
In Rx mode, a hardware or software reset does not force asynchronous mode, clear hunt condition, or require a proper line initialization (1 to 0 transition) before receiving. This may cause reception of garbage characters.	Reset will clear Rx hunt condition, force asynchronous operation (64x clock), and require a proper line initialization before receiving anything.
Break detect will occur on the first complete (start bit to stop bit) break. This situation could be confused with a null frame (all zeros) that also has a framing error.	Will give a framing error at the end of the first complete or partial break, and will give a break detect at the stop bit position of the second contiguous break character.
Sync detect does not reset on status read.	Sync detect will reset on status read.
RxRDY clears within $2\,t_{CY}$'s of $\overline{RD}$ leading edge.	RxRDY will clear on $\overline{RD}$ leading edge.
TxEMPTY oscillates with internal clock when TxEnable ↓ or $\overline{CTS}$ ↑.	TxEMPTY will not oscillate this way.
TxRDY and TxEMPTY clear on $\overline{WR}$ trailing edge (data).	TxRDY, TxEMPTY will clear on $\overline{WR}$ leading edge.
Enter hunt command affects asynchronous Rx by loss of data characters.	Enter hunt will not affect asynchronous operation.
Writing a command will sometimes clear TxRDY or TxEMPTY if C / $\overline{D}$ set up or hold is marginal. Reading status will sometimes clear RxRDY if C / $\overline{D}$ set up or hold is marginal.	C / $\overline{D}$ set up and hold margin will be improved.

μPD8251AF Enhancements (cont)

μPD8251A	μPD8251AF
Rx data overrun error will not occur and garbage data may result if $\overline{RD}$ and $\overline{CS}$ are active during an internal data update	Will indicate an overrun error properly
In asynchronous mode, after a reset, the first TxD bit may be shifted out on either the first or second $\overline{TxC}$ ↓ edge	The first TxD bit will be shifted out on the first $\overline{TxC}$ ↓ edge
RxRDY can glitch when CLK does not have a fixed phase relationship to $\overline{RxC}$	RxRDY will not glitch
The receiver occasionally gives an extra character following the end of break condition	No extra characters will occur

Functional Description

The μPD8251A/51AF Universal Synchronous/Asynchronous Receiver/Transmitters are designed specifically for 8085A microcomputer systems but work with most 8-bit processors. Operations of the μPD8251A/51AF, like other I/O devices in the 8085A family, are programmed by system software for maximum flexibility.

In the receive mode, the μPD8251A/51AF converts incoming serial format data into parallel data and makes certain format checks. In the transmit mode, it formats parallel data into serial form. The device also supplies or removes characters or bits that are unique to the communication format in use. By performing conversion and formatting services automatically, the USART appears to the processor as a simple or "transparent" input or output of byte-oriented parallel data.

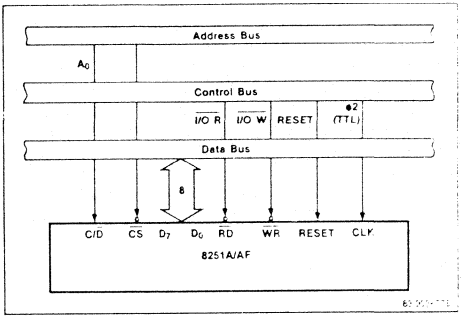
Truth Table

$C/\overline{D}$	$\overline{RD}$	$\overline{WR}$	$\overline{CS}$	MODE
0	0	1	0	μPD8251A / 51AF → Data bus
0	1	0	0	Data bus → μPD8251A / 51AF
1	0	1	0	Status → Data bus
1	1	0	0	Data bus → Control
X	X	X	1	Data bus → 3-state
X	1	1	0	Data bus → 3-state

Transmit Buffer

The transmit buffer receives parallel data from the data bus buffer via the internal data bus, converts parallel to serial data, inserts the necessary characters or bits needed for the programmed communication format and outputs composite serial data on the TxD pin.

μPD8251A/51AF Interface to 8085A Standard System Bus



Receive Buffer

The receive buffer accepts serial data input at the RxD pin and converts the data from serial to parallel format. Bits or characters required for the specific communication technique in use are checked and then an eight-bit "assembled" character is readied for the processor. For communication techniques which require fewer than eight bits, the μPD8251A/51AF set the extra bits to "zero".

Operation

A set of control words must be sent to the μPD8251A/51AF to define the desired mode and communications format. The control words will specifiy the baud rate factor (1x, 16x, 64x), character length (5 to 8), number of STOP bits (1, 1½, 2) asynchronous or synchronous mode, SYNDET (IN or OUT), parity, etc.

After receiving the control words, the μPD8251A/51AF are ready to communicate. TxRDY is raised to signal the processor that the USART is ready to receive a character for transmission. When the processor writes a character to the USART, TxRDY is automatically reset.

Concurrently, the μPD8251A/51AF may receive serial data; and after receiving an entire character, the RxRDY

output is raised to indicate a completed character is ready for the processor. The processor fetch will automatically reset RxRDY.

Note:

The μPD8251A/51AF may provide faulty RxRDY for the first read after power-on or for the first read after receive is re-enabled by a command instruction (RxE). A dummy read is recommended to clear faulty RxRDY. But this is not the case for the first read after hardware or software reset after the device operation has once been established.

The μPD8251A/51AF cannot transmit until the TxEN (transmitter enable) bit has been set by a command instruction and until the $\overline{CTS}$ (clear to send) input is a "zero". TxD is held in the "marking" state after reset awaiting new control words.

USART Programming

The USART must be loaded with a group of two to four control words provided by the processor before data reception and transmission can begin. A RESET (internal or external) must immediately proceed the control words which are used to program the complete operational description of the communications interface. If an external RESET is not available, three successive 00 Hex or two successive 80 Hex command instructions ($C/\overline{D} = 1$) followed by a software reset command instruction (40 Hex) can be used to initialize the μPD8251A/51AF.

There are two control word formats:

1. Mode Instruction
2. Command Instruction

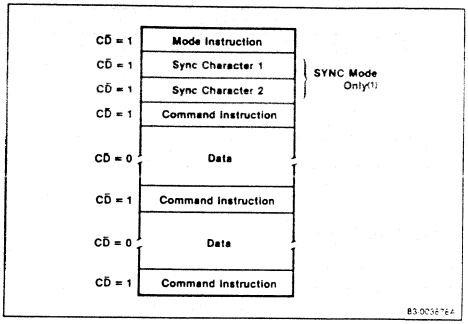
Mode Instruction

This control word specifies the general characteristics of the interface regarding the synchronous or asynchronous mode, baud rate factor, character length, parity, and number of stop bits. Once the mode instruction has been received, SYNC characters or command instructions may be inserted depending on the mode instruction content.

Command Instruction

This control word will be interpreted as a SYNC character definition if immediately preceded by a mode instruction which specified a synchronous format. After the SYNC character(s) are specified or after an asynchronous mode instruction, all subsequent control words will be interpreted as an update to the command instruction. Command instruction updates may occur at any time during the data block. To modify the mode instruction, a bit may be set in the command instruction which causes an internal reset which allows a new mode instruction to be accepted.

Typical Data Block



Mode Instruction Definition

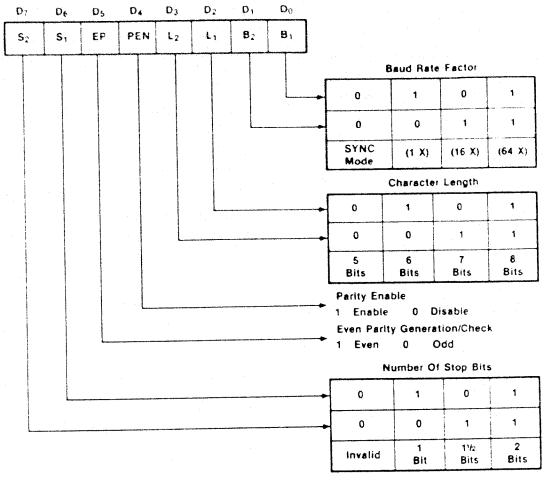
The μPD8251A/51AF can operate in either asynchronous or synchronous communication modes. Understanding how the mode instruction controls the functional operation of the USART is easiest when the device is considered to be two separate components (one asynchronous and the other synchronous) which share the same support circuits and package. Although the format definition can be changed at will or "on the fly," the two modes will be explained separately for clarity.

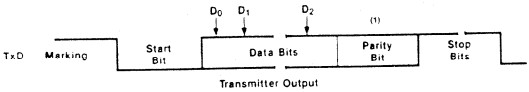
Asynchronous Transmission

When a data character is written into μPD8251A/51AF, the USART automatically adds a start bit (low level or "space") and the number of stop bits (high level or "mark") specified by the mode instruction. If parity has been enabled, an odd or even parity bit is inserted just before the stop bit(s), as specified by the mode instruction. Then, depending on $\overline{CTS}$ and TxEN, the character may be transmitted as a serial data stream at the TxD output. Data is shifted out by the falling edge of $\overline{TxC}$ at $\overline{TxC}$, $\overline{TxC}/16$ or $\overline{TxC}/64$, as defined by the mode instruction.

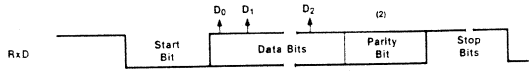
If no data characters have been loaded into the μPD8251A/51AF, or if all available characters have been transmitted, the TxD output remains "high" (marking) in preparation for sending the start bit of the next character provided by the processor. TxD may be forced to send a break (continuously low) by setting the correct bit in the command instruction.

Mode Instruction Format for Asynchronous Mode



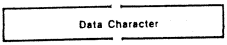


Transmitter Output

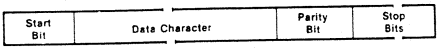


Receiver Input

Processor Byte (5-8 Bits/Char)

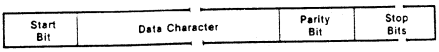


Assembled Serial Data Output (TxD)

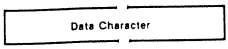


Transmission Format

Serial Data Input (RxD)



Processor Byte (5-8 Bits/Char) (3)



Receive Format

Notes:
(1) Generated by μPD8251A/AF
(2) Does not appear on the Data Bus.
(3) If character length is defined as 5, 6, or 7 bits, the unused bits are set to "zero."

Asynchronous Receive

The RxD input line is normally held "high" (marking) by the transmitting device. A falling edge at RxD signals the possible beginning of a start bit and a new character. The start bit is checked by testing for a "low" at its nominal center as specified by the baud rate. If a "low" is detected again, it is considered valid, and the bit assembling counter starts counting. The bit counter locates the approximate center of the data, parity (if specified), and stop bits. The parity error flag (PE) is set, if a parity error occurs. Input bits are sampled at the RxD pin with the rising edge of $\overline{RxC}$. If a high is not detected for the stop bit, which normally signals the end of an input character, a framing error (FE) will be set. After a valid stop bit, the input character is loaded into the parallel data bus buffer of the μPD8251A/51AF and the RxRDY signal is raised to indicate to the processor that a character is ready to be fetched. If the processor has failed to fetch the previous character, the new character replaces the old and the overrun flag (OE) is set. All the error flags can be reset by setting a bit in the command instruction. Error flag conditions will not stop subsequent USART operation.

Synchronous Transmission

As in asynchronous transmission, the TxD output remains "high" (marking) until the μPD8251A/51AF receive the first character (usually a SYNC character) from the processor. After a command instruction has set TxEN and after clear to send ($\overline{CTS}$) goes low, the first character is serially transmitted. Data is shifted out on the falling edge of $\overline{TxC}$ and the same rate as $\overline{TxC}$.

Once transmission has started, synchronous mode format requires that the serial data stream at TxD continue at the $\overline{TxC}$ rate or SYNC will be lost. If a data character is not provided by the processor before the μPD8251A/51AF transmit buffer becomes empty, the SYNC character(s) loaded directly following the mode instruction will be automatically inserted in the TxD data stream. The SYNC character(s) are inserted to fill the line and maintain synchronization until new data characters are available for transmission. If the μPD8251A/51AF become empty, and must send the SYNC character(s), the TxEMPTY output is raised to signal the processor that the transmitter buffer is empty and SYNC characters are begin transmitted. TxEMPTY is automatically reset by the next character from the processor.

Synchronous Receive

In synchronous receive, character synchronization can be either external or internal. If the internal SYNC mode has been selected, and the enter hunt (EH) bit has been set by a command instruction, the receiver goes into the HUNT mode.

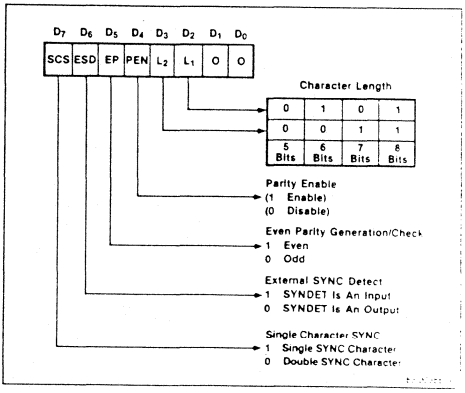
Incoming data on the RxD input is sampled on the rising edge of $\overline{RxC}$, and the receive buffer is compared with the first SYNC character after each bit has been loaded until a match is found. If two SYNC characters have been programmed, the next received character is also compared. When the SYNC character(s) programmed have been detected, the μPD8251A/51AF leave the HUNT mode and are in character synchronization. At this time, the SYNDET (output) is set high. SYNDET is automatically reset by a status read.

If external SYNC has been specified in the mode instruction, a "one" applied to the SYNDET (input) for at least one $\overline{RxC}$ cycle will synchronize the USART.

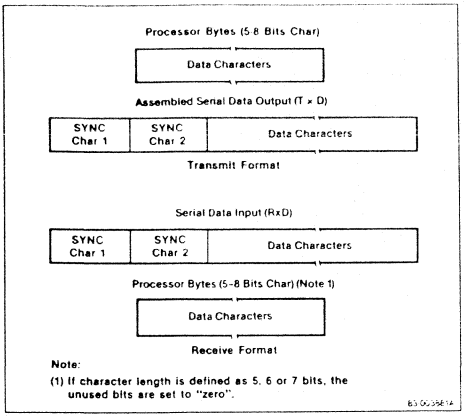
Parity and overrun errors are treated the same in the synchronous as in the asynchronous mode. If not in HUNT, parity will continue to be checked even if the receiver is not enabled. Framing errors do not apply in the synchronous format.

The processor may command the receiver to enter the HUNT mode with a command instruction which sets enter hunt (EH) if synchronization is lost.

Mode Instruction Format for Synchronous Mode



Transmit/Receive Format Synchronous Mode



Command Instruction Format

After the functional definition of the μPD8251A/51AF has been specified by the mode instruction and the SYNC character(s) have been entered (if in SYNC mode), the USART is ready to receive command instructions and begin communication. A command instruction is used to control the specific operation of the format selected by the mode instruction. Enable transmit, enable receive, error reset and modem controls are controlled by the command instruction.

After the mode instruction and the SYNC character(s) (as needed) are loaded, all subsequent "control writes" ($C/\overline{D} = 1$) will load or overwrite the command instruction register. A reset operation (internal via CMD IR or external via the RESET input) will cause the μPD8251A/51AF to interpret the next "control write", which must immediately follow the reset, as a mode instruction.

Status Read Format

It is frequently necessary for the processor to examine the status of an active interface device to determine if errors have occurred or if there are other conditions which require a response from the processor. The μPD8251A/51AF have features which allow the processor to read the device status at any time. A data fetch is issued by the processor while holding the C/D input "high" to obtain device status information. Many of the bits in the status register are copies of external pins. This dual status arrangement allows the μPD8251A/51AF to be used in both polled and interrupt driven environments. Status update can have a maximum delay of 28 clock periods in the μPD8251A/51AF.

Parity Error

When a parity error is detected, the PE flag is set. It is cleared by setting the ER bit in a subsequent command instruction. PE begin set does not inhibit USART operation.

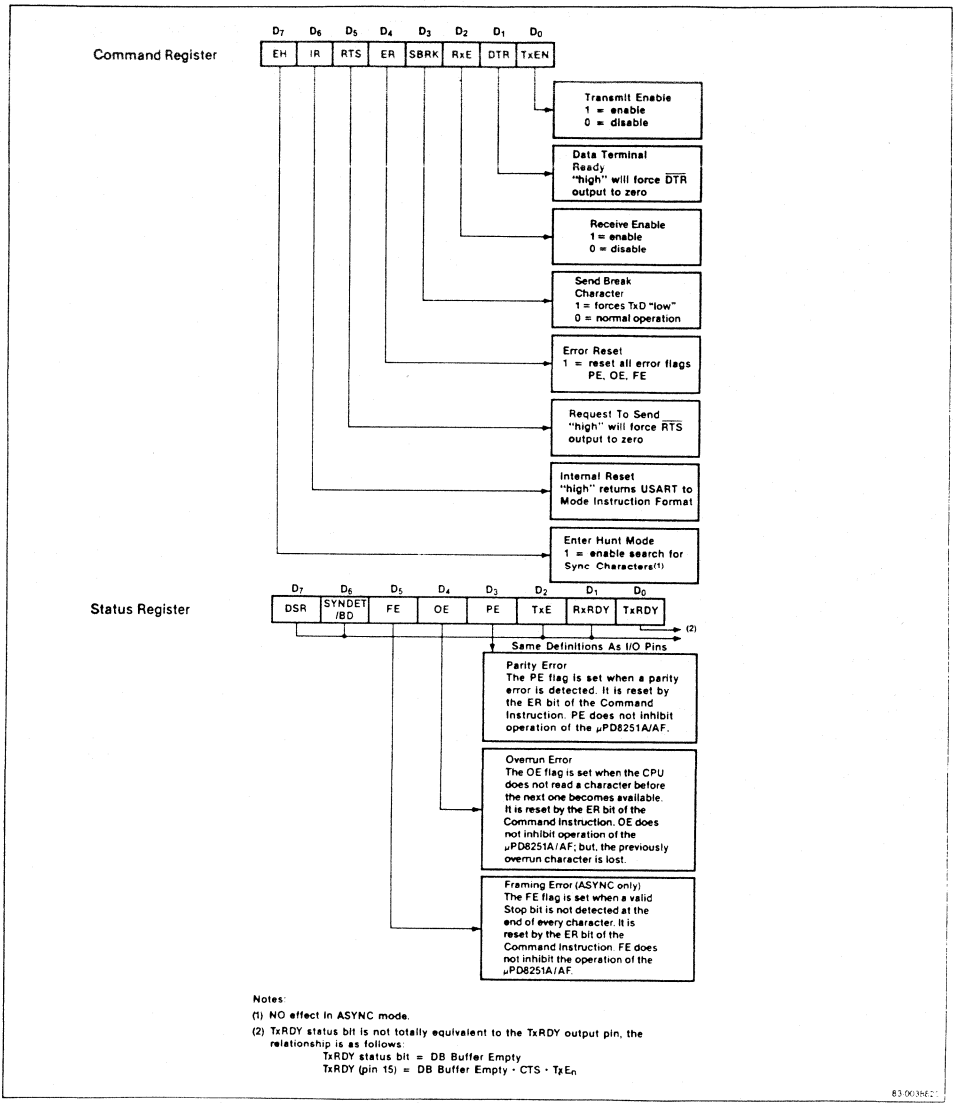
Overrun Error

If the processor fails to read a data character before the one following is available, the OE flag is set. It is cleared by setting the ER bit in a subsequent command instruction. Although OE being set does not inhibit USART operation, the previously received character is overwritten and lost.

Framing Error

If a valid STOP bit is not detected at the end of a character, the FE flag is set (ASYUNC mode only). It is cleared by setting the ER bit in a subsequent command instruction. FE being set does not inhibit USART operation.

Command and Status Register Formats



Notes:

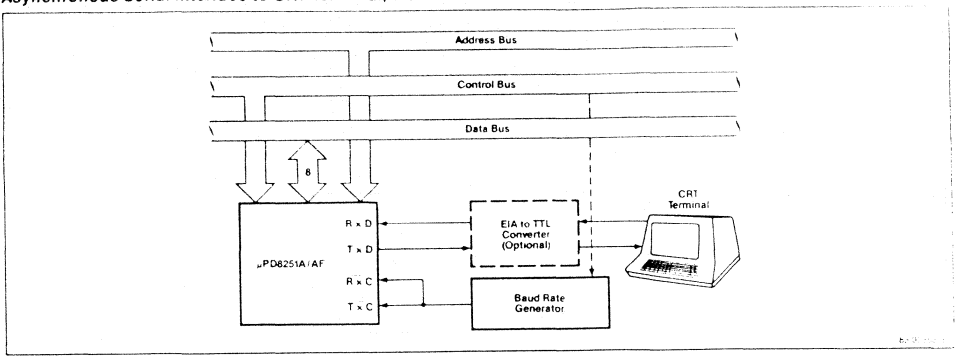
(1) NO effect in ASYNC mode.

(2) TxRDY status bit is not totally equivalent to the TxRDY output pin, the relationship is as follows:

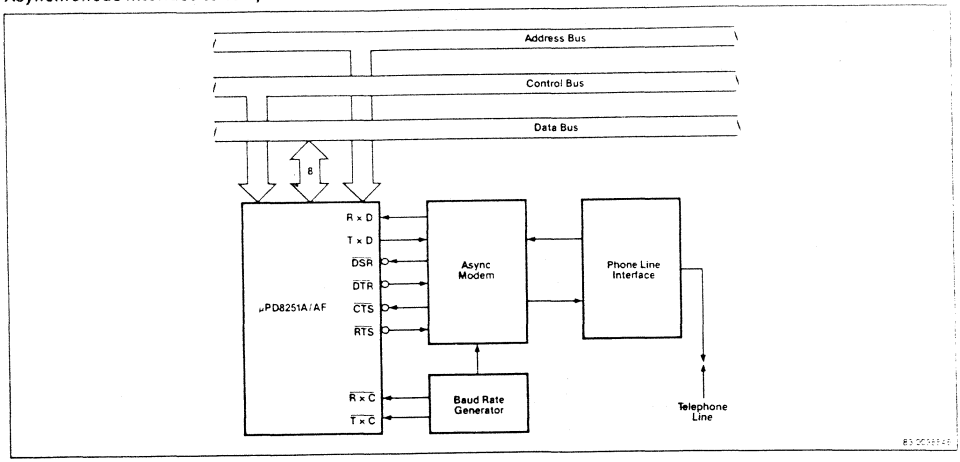
TxRDY status bit = DB Buffer Empty

TxRDY (pin 15) = DB Buffer Empty · CTS · T_xE_n

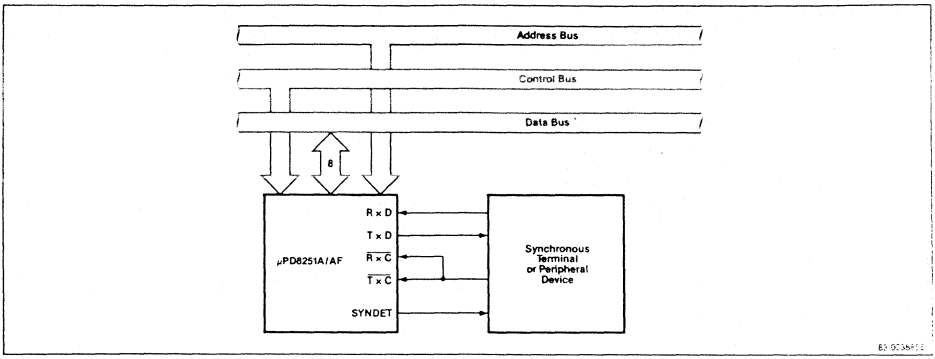
Asynchronous Serial Interface to CRT Terminal, DC to 9600 Baud



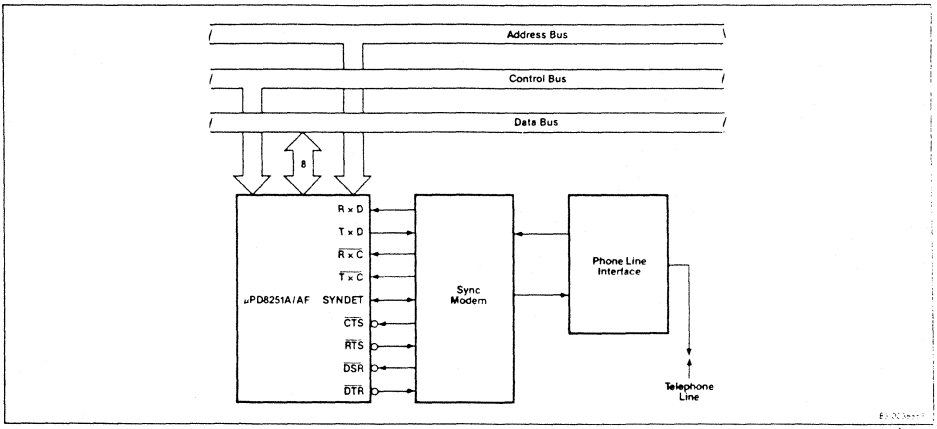
Asynchronous Interface to Telephone Lines



Synchronous Interface to Terminal or Peripheral Device



Synchronous Interface to Telephone Lines



Description

The NEC μPD8253 contains three independent, programmable, multi-model 16-bit counter/timers. It is designed as a general purpose device, fully compatible with the 8080 family. The μPD8253 interfaces directly to the buses of the processor as an array of I/O ports.

The μPD8253 can generate accurate time delays under the control of system software. The three independent 16-bit counters can be clocked at rates from DC to 5 MHz. The system software controls the loading and starting of the counters to provide accurate multiple time delays. The counter output flags the processor at the completion of the time-out cycles.

System overhead is greatly improved by relieving the software from the maintenance of timing loops. Some other common uses for the μPD8253 in microprocessor based systems are:

- Programmable baud rate generator
- Event counter
- Binary rate multiplier
- Real time clock
- Digital one-shot
- Complex motor controller

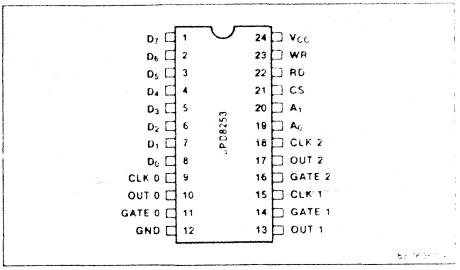
Features

- ☐ Three independent 16-bit counters
- ☐ Clock rate: DC to 5 MHz
- ☐ Binary count or BCD
- ☐ Single +5 V power supply, ± 10%

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD8253C-2	24-pin plastic DIP	5 MHz
μPD8253C-5	24-pin plastic DIP	4 MHz

Pin Configuration



Pin Identification

No.	Symbol	Function
1-8	D_7-D_0	Three-state data bus
9,15,18	CLK 0,1,2	Counter clock inputs 0-2
10,13,17	OUT 0,1,2	Counter outputs 0-2
11,14,16	GATE 0,1,2	Counter gate inputs 0-2
12	GND	Ground
19,20	A0,A1	Counter select
21	$\overline{CS}$	Chip select
22	$\overline{RD}$	Read counter
23	$\overline{WR}$	Write command or data
24	V_{CC}	+5 V power supply

Pin Functions

D_7-D_0 (Data Bus)

These pins form a three-state, bidirectional data bus that interfaces with the 8080AF/8085 microprocessor system.

CLK 0,1,2 (Counter Clock Inputs 0-2)

CLK 0, CLK 1, and CLK 2 input the clock signal for counter 0, counter 1, and counter 2, respectively.

OUT 0,1,2 (Counter Outputs 0-2)

OUT 1, OUT 2, and OUT 3 are outputs signals for counter 0, counter 1, and counter 2, respectively.

GATE 0,1,2 (Counter Gate Inputs 0-2)

The GATE 0, GATE 1, and GATE 2 inputs gate counter 0, counter 1, and counter 2, respectively.

GND (Ground)

Connection to ground.

A_0, A_1 (Counter Select)

These inputs are normally connected to the processor's address bus. Their function is to select which of the three counters will be operated on, and to address the control word register for mode selection.

$\overline{CS}$ (Chip Select)

A low level input to this pin enables the μPD8253. Reading and writing will not occur unless the device is selected. This input has no effect on the actual operation of the counters.

$\overline{RD}$ (Read Counter)

A low level input to this pin instructs the μPD8253 to send the selected counter value to the processor.

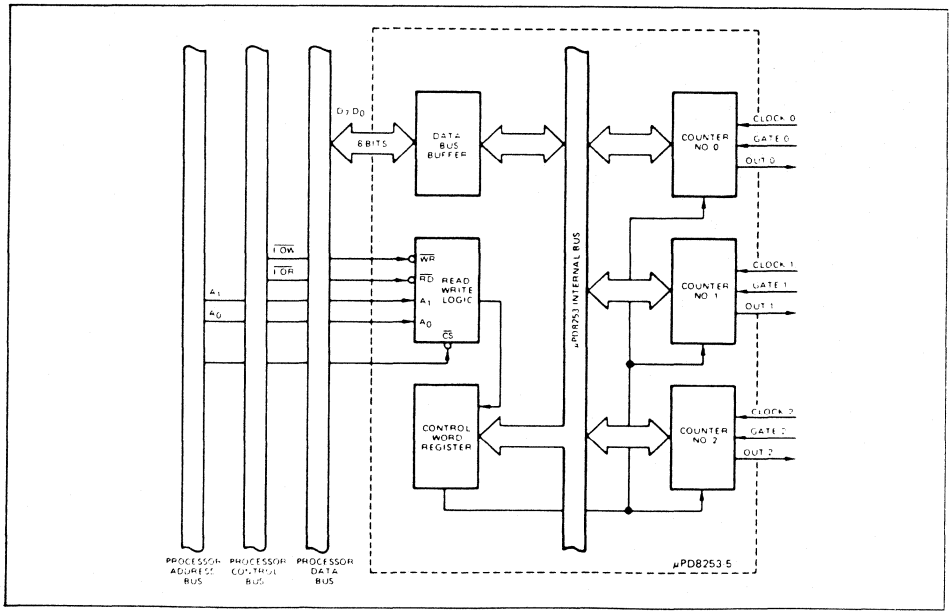
$\overline{WR}$ (Write Command or Data)

A low level input to this pin instructs the μPD8253 to receive mode information or counter input data from the processor.

V_{CC}

+5 V power supply.

Block Diagram



Functional Description

The three-state, bidirectional data bus buffer interfaces the μPD8253 to the 8080AF/8085A microprocessor system. Data transfer is according to the input or output instructions executed by the processor. The data bus buffer has three basic functions:

- Programming the μPD8253 modes
- Loading the count registers
- Reading the count values

The read/write logic controls the overall operation of the μPD8253 and is governed by inputs received from the processor system bus.

When A_0 and A_1 are high level, data from the data bus buffer is stored in the control word register. This data controls the operational mode of the counters, the selection of BCD or binary counting, and the loading of the count registers.

Counters 0, 1, and 2 are identical 16-bit down counters that are functionally independent, allowing for separate mode configurations and counting operations. Each counter can operate in either binary or BCD. Gate, input, and output line configurations are determined by the operational mode data stored in the control word register. System software overhead can be reduced by allowing the control word to govern the loading of the count data.

It is possible to read the contents of a counter when it is operating, without disturbing its operation. The following table shows how the counters are manipulated by input signals to the read/write logic.

$\overline{CS}$	$\overline{RD}$	$\overline{WR}$	A_1	A_0	Function
0	1	0	0	0	Load counter no. 0
0	1	0	0	1	Load counter no. 1
0	1	0	1	0	Load counter no. 2
0	1	0	1	1	Write mode word
0	0	1	0	0	Read counter no. 0
0	0	1	0	1	Read counter no. 1
0	0	1	1	0	Read counter no. 2
0	0	1	1	1	No-operation, 3-state
1	X	X	X	X	Disable, 3-state
0	1	1	X	X	No-operation, 3-state

Absolute Maximum Ratings

Operating temperature	0°C to +70°C
Storage temperature	−65°C to +150°C
Voltage on any pin	−0.5 to +7 volts (1)

Note:

(1) With respect to ground.

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Capacitance

T_A = 25°C; V_{CC} = GND = 0 V

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input capacitance	C_{IN}			10	pF	f_c = 1 MHz
Input/Output capacitance	$C_{I/O}$			20	pF	Unmeasured pins returned to V_{SS}

DC Characteristics

T_A = 0°C to +70°C; V_{CC} = +5 V ± 10%

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input low voltage	V_{IL}	−0.5		0.8	V	
Input high voltage	V_{IH} (1)	2.0		V_{CC} + 0.5	V	
Output low voltage	V_{OL}			0.45	V	I_{OL} = 2.2 mA
Output high voltage	V_{OH}	2.4			V	I_{OH} = −400 μA
Input load current	I_{IL}			±10	μA	$0 \leq V_{IN} \leq V_{CC}$
Output float leakage current	I_{OFL}			±10	μA	$0.45 \leq V_{OUT} \leq V_{CC}$
V_{CC} supply current	I_{CC}			140	mA	

Note:

(1) V_{IH} 2.2 min for μPD8253-2.

AC Characteristics

T_A = 0°C to +70°C; V_{CC} = +5 V ±10%; GND = 0 V

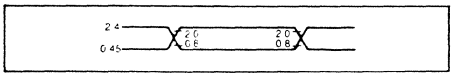
Parameter	Symbol	Limits μPD8253-2 Min	Limits μPD8253-2 Max	Limits μPD8253-5 Min	Limits μPD8253-5 Max	Unit	Test Conditions
Read							
Address stable before READ	t_{AR}	30		0		ns	
Address hold time for READ	t_{RA}	0		0		ns	
READ pulse width	t_{RR}	200		250		ns	
Data delay from READ	t_{RD}		140		170	ns	C_L = 150 pF
READ to data floating	t_{DF}	10	85	25	100	ns	C_L = 150 pF
Recovery time between READS	t_{RV}	200		1000		ns	
Write							
Address stable before WRITE	t_{AW}	0		0		ns	
Address hold time for WRITE	t_{WA}	0		0		ns	
WRITE pulse width	t_{WW}	160		250		ns	
Data set up time for WRITE	t_{DW}	130		150		ns	
Data hold time for WRITE	t_{WD}	0		0		ns	
Recovery time between WRITES	t_{RV}	200		1000		ns	
Clock and Gate Timing							
Clock period	t_{CLK}	200		250	DC	ns	
High pulse width	t_{PWH}	80		160		ns	
Low pulse width	t_{PWL}	80		90		ns	
Gate pulse width high	t_{GW}	120		150		ns	
Gate set up time to clock ↑	t_{GS}	70		100		ns	
Gate hold time after clock ↑	t_{GH}	50		50		ns	
Low gate width	t_{GL}	120		100		ns	
Output delay from Clock ↓	t_{OD}		250		300	ns	C_L = 150 pF
Output delay from gate	t_{ODG}		250		300	ns	C_L = 150 pF

Note:

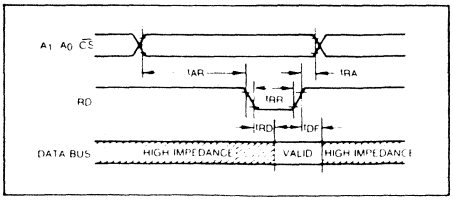
(1) AC timing measured at V_{OH} = 2.0 V; V_{OL} = 0.8 V.

Timing Waveforms

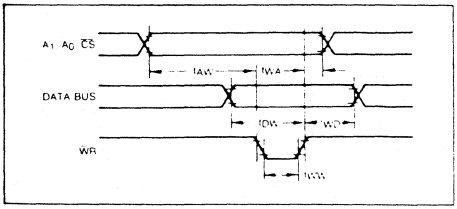
AC Test Conditions



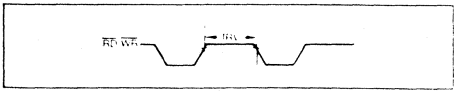
Read Timing



Write Timing

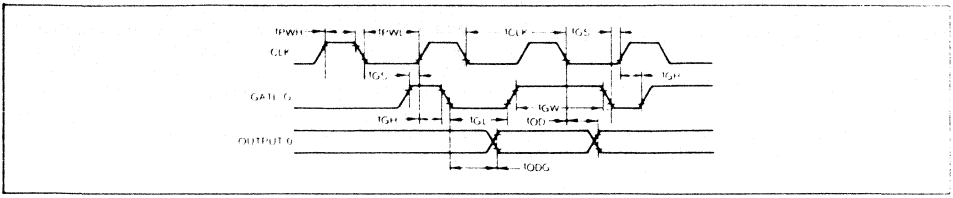


Read and Write Timing



Timing Waveforms (cont)

Clock and Gate Timing



Programming the μPD8253

The programmer can select any of the six operational MODES for the counters using system software. Individual counter programming is accomplished by loading the CONTROL WORD REGISTER with the appropriate control word data (A_0, A_1 = 11).

Control Word Format

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
SC_1	SC_0	RL_1	RL_0	M_2	M_1	M_0	BCD

RL — Read/Load

RL_1	RL_0	
0	0	Counter latching operation
1	0	Read/Load most significant byte only
0	1	Read/Load least significant byte only
1	1	Read/Load least significant byte first, then most significant byte

SC — Select Counter

SC_1	SC_0	
0	0	Select counter 0
0	1	Select counter 1
1	0	Select counter 2
1	1	Invalid

BCD

0	Binary counter, 16-bits
1	BCD counter, 4-decades

M-Mode

M_2	M_1	M_0	
0	0	0	Mode 0
0	0	1	Mode 1
X	1	0	Mode 2
X	1	1	Mode 3
1	0	0	Mode 4
1	0	1	Mode 5

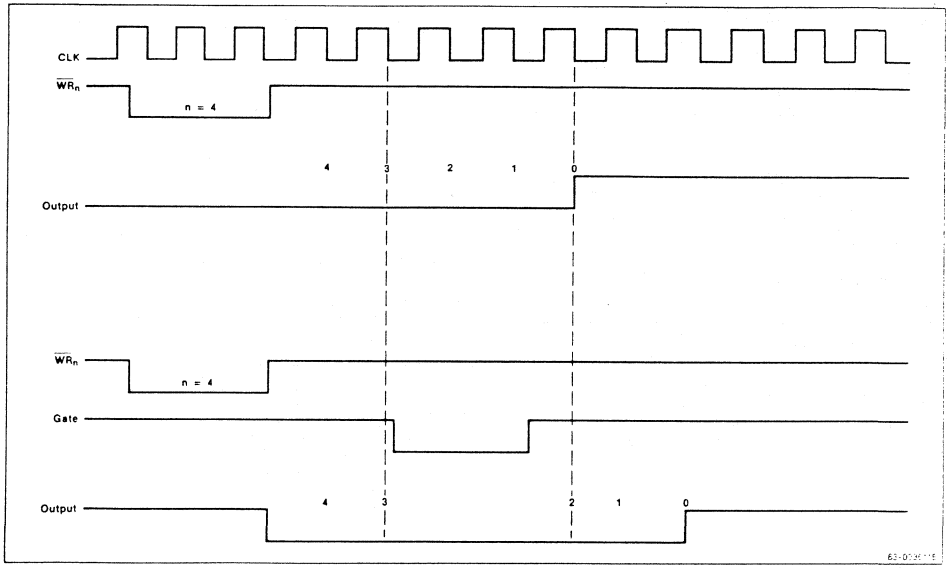
Operational Modes

Each of the three counters can be individually programmed with different operating MODES by appropriately formatted control words. The following is a summary of the MODE operations.

Mode O: Interrupt on Terminal Count

The initial MODE set operation forces the OUTPUT low. When the specified counter is loaded with the count value, it will begin counting. The OUTPUT will remain low until the terminal count sets it high. It will remain in the high state until the trailing edge of the second WR pulse loads in COUNT data. If data is loaded during the counting process, the first WR stops the count. Counting starts with the new count data triggered by the falling clock edge after the second WR. If a GATE pulse is asserted while counting, the count is terminated for the duration of GATE. The falling edge of CLK following the removal of GATE restarts counting from the terminated point.

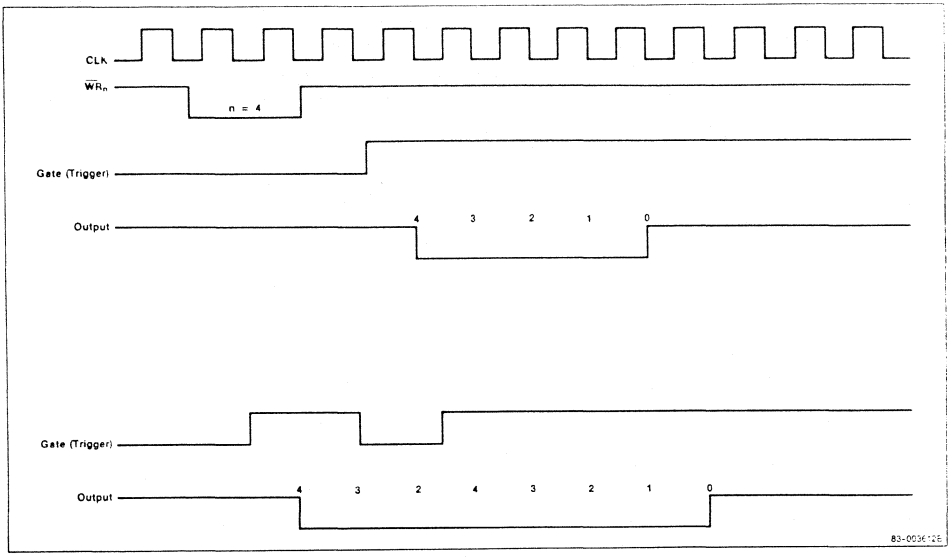
Mode 0: Interrupt on Terminal Count



Mode 1: Programmable One-Shot

The OUTPUT is set low by the falling edge of CLOCK following the trailing edge of GATE. The OUTPUT is set high again at the terminal count. The output pulse is not affected if new count data is loaded while the OUTPUT is low. The new data will be loaded on the rising edge of the next trigger pulse. The assertion of a trigger pulse while OUTPUT is low, resets and retriggers the one-shot. The OUTPUT will remain low for the full count value after the rising edge of TRIGGER.

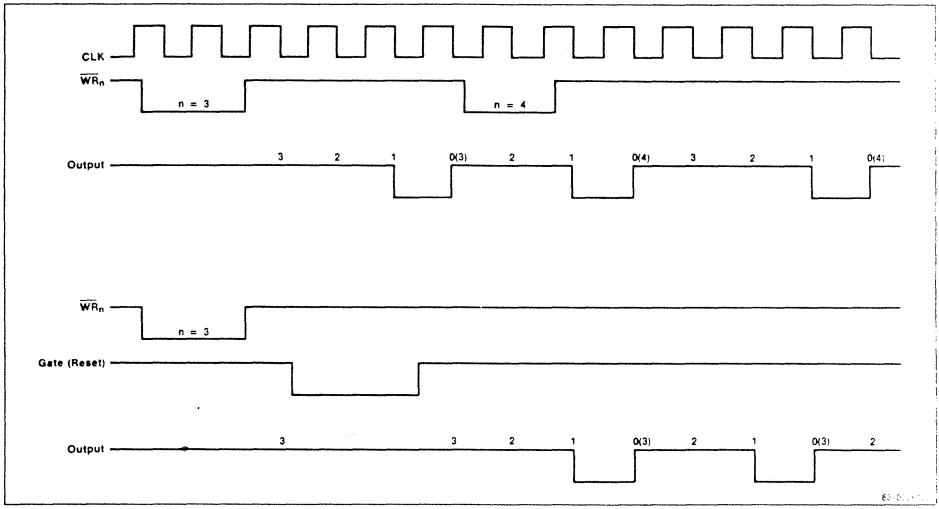
Mode 1: Programmable One-Shot



Mode 2: Rate Generator

The RATE GENERATOR is a variable modulus counter. The OUTPUT goes low for one full CLOCK period as shown in the following timing diagram. The count data sets the time between OUTPUT pulses. If the count register is reloaded between output pulses the present period will not be affected. The subsequent period will reflect the new value. The OUTPUT will remain high for the duration of the asserted GATE input. Normal operation resumes on the falling CLOCK edge following the rising edge of GATE.

Mode 2: Rate Generator

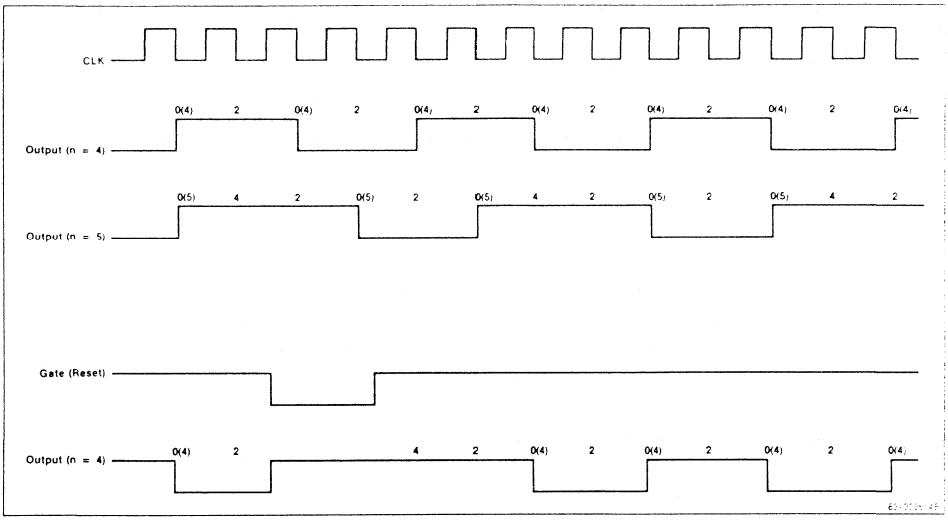


Mode 3: Square Wave Generator

MODE 3 resembles MODE 2 except the OUTPUT will be high for half of the count and low for the other half (for even values of data). For odd values of count data the OUTPUT. Put will be high one clock cycle longer than when it is low (High Period → $\frac{N+1}{2}$ clock cycles; Low Period → $\frac{N-1}{2}$ clock periods, where N is the decimal value of count data). If the count register is reloaded with a new value during counting, the new value will be reflected immediately after the output transition of the current count.

The OUTPUT will be held in the high state while GATE is asserted. Counting will start from the full count data after the GATE has been removed.

Mode 3: Square Wave Generator

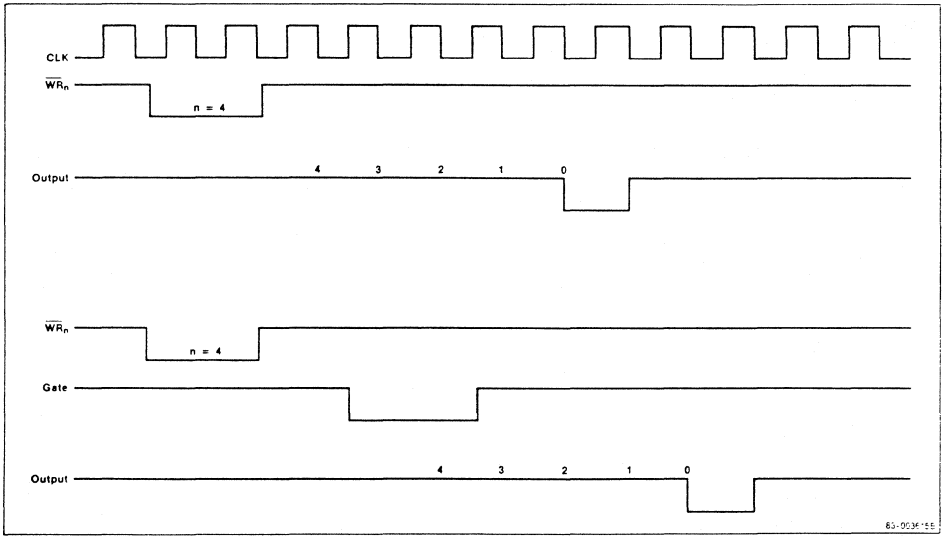


Mode 4: Software Triggered Strobe

The OUTPUT goes high when MODE 4 is set, and counting begins after the second byte of data has been loaded. When the terminal count is reached, the OUTPUT will pulse low for one clock period. Changes in count data are reflected in the OUTPUT as soon as the new data has been loaded into the count registers. During the loading of new data, the OUTPUT is held high and counting is inhibited.

The OUTPUT is held high for the duration of GATE. The counters are reset and counting begins from the full data value after GATE is removed.

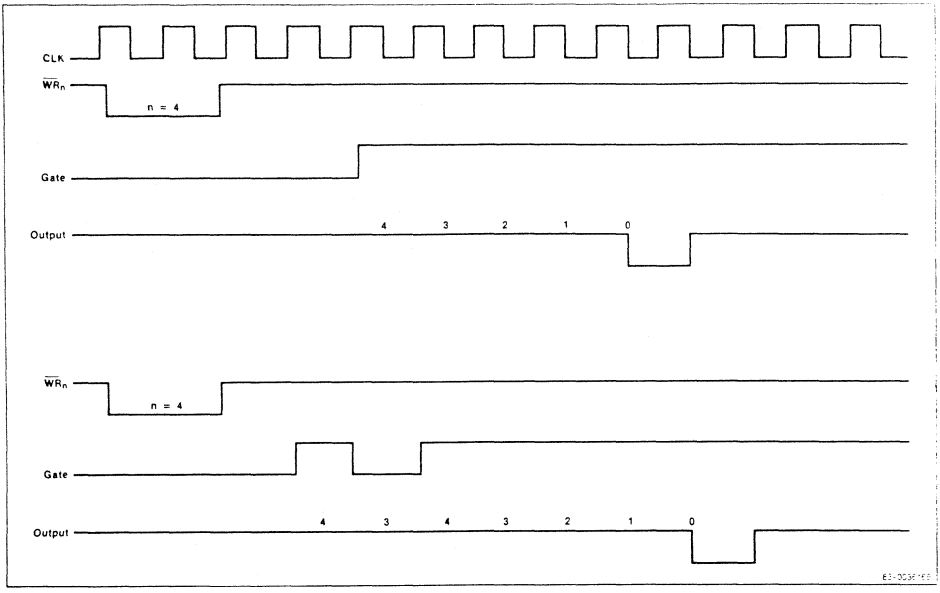
Mode 4: Software Triggered Strobe



Mode 5: Hardware Triggered Strobe

Loading MODE 5 sets OUTPUT high. Counting begins when count data is loaded and GATE goes high. After terminal count is reached, the OUTPUT will pulse low for one clock period. Subsequent trigger pulses will restart the counting sequence with the OUTPUT pulsing low on terminal count following the last rising edge of the trigger input. (Reference the bottom half of the timing diagram.)

Mode 5: Hardware Triggered Strobe



Description

The μPD8255A-2 and μPD8255A-5 are general purpose programmable input/output devices designed for use with the 8080A/8085A microprocessors. Twenty-four I/O lines may be programmed in two groups of twelve (group I and group II) and used in three modes of operation. In the basic mode, (Mode 0), each group of twelve I/O pins may be programmed in sets of 4 to input or output. In the strobed mode, (MODE 1), each group may be programmed to have 8 lines of input or output. Three of the remaining four pins in each group are used for handshaking strobes and interrupt control signals. The bidirectional bus mode, (MODE 2), uses the 8 lines of port A for a bi-directional bus, and five lines from port C for bus control signals.

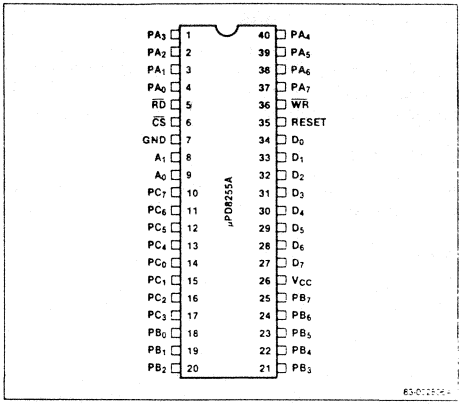
Features

- ☐ Fully compatible with the 8080A/8085 microprocessor families
- ☐ All inputs and outputs TTL compatible
- ☐ 24 programmable I/O pins
- ☐ Direct bit set/reset eases control application interfaces
- ☐ Eight Darlington drive outputs for printers and displays
- ☐ LSI drastically reduces system package count

Ordering Information

Part Number	Package Type	Max System Clock Frequency
μPD8255AC-2	40-pin plastic DIP	5 MHz
μPD8255AC-5	40-pin plastic DIP	4 MHz

Pin Configuration



Pin Identification

No.	Symbol	Function
1-4, 37-40	PA_7-PA_0	Port A (I/O)
5	$\overline{RD}$	Read input
6	$\overline{CS}$	Chip select input
7	GND	Ground
8,9	A_1,A_0	Port address inputs
10-17	PC_7-PC_0	Port C (I/O)
18-25	PB_7-PB_0	Port B (I/O)
26	V_{CC}	+5 V power supply
27-34	D_7-D_0	Bidirectional data bus
35	RESET	Reset input
36	$\overline{WR}$	Write input

Pin Functions

D_7-D_0 (Data Bus Buffer)

These pins form a three-state, bidirectional data bus buffer that is controlled by input and output instructions executed by the processor. Control words and status information are also transmitted via D_7-D_0.

$\overline{CS}$ (Chip Select)

A low input to this pin enables the μPD8255A for communication with the 8080A/8085A.

$\overline{RD}$ (Read)

A low input to this pin enables the μPD8255A for communication with the 8080A/8085A.

$\overline{WR}$ (Write)

A low input to this pin enables the data bus buffer to receive data or control words from the processor.

A_1, A_0 (Port Address)

These inputs are used in conjunction with $\overline{CS}$, $\overline{RD}$, and $\overline{WR}$ to control the selection of one of the three ports on the control word register. A_0 and A_1 are usually connected to A_0 and A_1 of the processor address bus.

RESET (Reset)

A high level input to this pin clears the control register and places ports A, B, and C in input mode. The input latches in ports A, B, and C are not cleared.

PA_7-PA_0, PB_7-PB_0, PC_7-PC_0 (Ports A, B, and C)

These three 8-bit I/O ports can be configured to meet a variety of functional requirements through system software. The effectiveness and flexibility of the μPD8255A are further enhanced by special features unique to each of the ports, as follows:

- Port A has an 8-bit data output latch/buffer, data input latch/buffer, and data input latch.
- Port B has an 8-bit data I/O latch/buffer and an 8-bit data input buffer.
- Port C has an 8-bit output latch/buffer and a data input buffer (input not latched).

Port C may be divided into two independent 4-bit control and status ports for use with ports A and B.

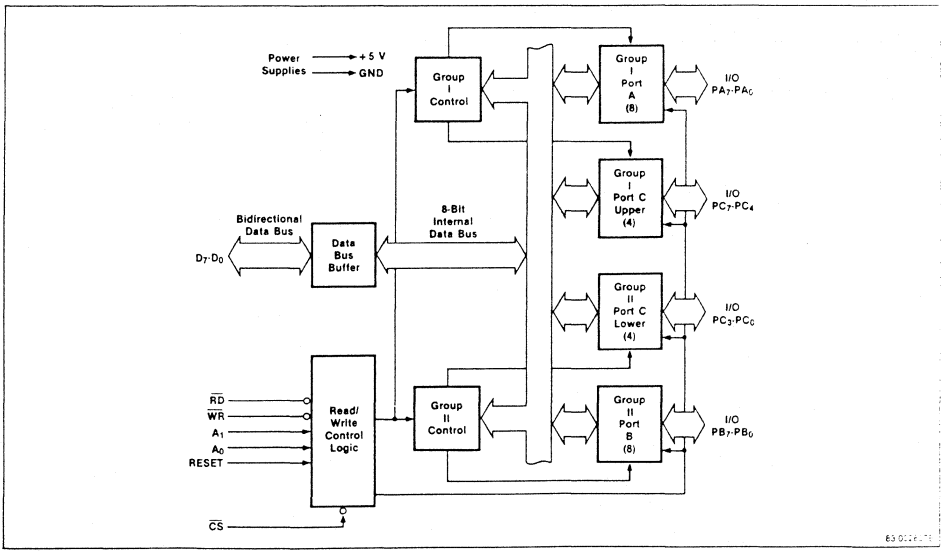
V_{CC}

+5 V power supply.

GND (Ground)

Connection to ground.

Block Diagram



Functional Description

The read/write and control logic manages all internal and external transfers of data, control, and status. It is through this block that the processor address and control buses control the peripheral interfaces.

Through an OUT instruction in system software from the processor, a control word is transmitted to the μPD8255A. Information such as the mode, bit set, and bit reset is used to initialize the functional configuration of each I/O port.

Both group I and group II accept commands from the read/write control logic and control words from the internal data bus and in turn controls its associated I/O ports, as follows:

- Group I: port A and upper port C (PC_7-PC_4)
- Group II: port B and lower port C (PC_3-PC_0)

While the control word register can be written to, the contents cannot be read back to the processor.

Absolute Maximum Ratings

T_A = 25°C

Operating temperature, T_{OPT}	0°C to +70°C
Storage temperature, T_{STG}	−65°C to +150°C
Voltage on any pin with respect to V_{SS}	−0.5 to +7 V

Comment: Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

T_A = 0 to +70°C; V_{CC} = +5 V ±10%; V_{SS} = 0 V

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Input low voltage	V_{IL}	−0.5	0.8	V	
Input high voltage	V_{IH}	2	V_{CC}	V	
Output low voltage	V_{OL}		0.45	V	(2)
Output high voltage	V_{OH}	2.4		V	(3)
Darlington drive current	I_{OH} (1)	−1	−4	mA	V_{EXT} = 1.5 V R_{EXT} = 750Ω
Power supply current	I_{CC}		120	mA	V_{CC} = +5 V; output open
Input leakage current	I_{LIH}		10	μA	V_{IN} = V = V_{CC}
Input leakage current	I_{LIL}		−10	μA	V_{IN} = 0.4 V
Output leakage current	I_{LOH}		±10	μA	V_{OUT} = V_{CC}; CS = 2.0 V
Output leakage current	I_{LOL}		−10	μA	V_{OUT} = 0.4 V; CS = 2.0 V

Note:

(1) Any set of eight outputs from either port A, B, C can source 4 mA into 1.5 V.

(2) I_{OL} = 2.5 mA for DB port; 1.7 mA for peripheral ports.

(3) I_{OH} = −400μA for DB port; −200 μA for peripheral ports.

Capacitance

T_A = 25°C; V_{CC} = 0V

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Input capacitance	C_I		10	pF	f_c = 1 MHz Unmeasured pins returned to V_{SS}
I/O capacitance	C_{IO}		20	pF	

AC Characteristics

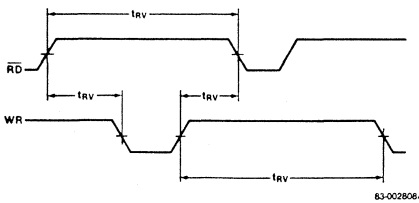
T_A = 0°C to +70°C; V_{CC} = +5 V ±5%; V_{SS} = 0 V

Parameter	Symbol	8255A-2 Limits Min	8255A-2 Limits Max	8255A-5 Limits Min	8255A-5 Limits Max	Unit	Test Conditions
Address stable before $\overline{READ}$	t_{AR}	0		0		ns	
Address stable after $\overline{READ}$	t_{RA}	0		0		ns	
$\overline{READ}$ pulse width	t_{RR}	200		250		ns	
Data valid from $\overline{READ}$	t_{RD}		140		170	ns	C_L = 150 pF
Data float after $\overline{READ}$	t_{DF}		100		100	ns	C_L = 100 pF
		10		10		ns	C_L = 15 pF
Time between $\overline{READ}$s and /$\overline{WRITE}$s	t_{RV}	200		850		ns	(Note 2)
Write							
Address stable before $\overline{WRITE}$	t_{AW}	0		0		ns	
Address stable after $\overline{WRITE}$	t_{WA}	20		20		ns	
$\overline{WRITE}$ pulse width	t_{WW}	200		250		ns	
Data valid to $\overline{WRITE}$ (T.E.)	t_{DW}	100		100		ns	
Data valid after $\overline{WRITE}$	t_{WD}	0		0		ns	
Other Timing							
$\overline{WR}$ = 0 to output	t_{WB}		350		350	ns	C_L = 150 pF
Peripheral data before $\overline{RD}$	t_{IR}	0		0		ns	
Peripheral data after $\overline{RD}$	t_{HR}	0		0		ns	
$\overline{ACK}$ pulse width	t_{AK}	300		300		ns	
$\overline{STB}$ pulse width	t_{ST}	350		350		ns	
Per. data before T.E. of $\overline{STB}$	t_{PS}	0		0		ns	
Per. data after T.E. of $\overline{STB}$	t_{PH}	150		150		ns	
$\overline{ACK}$ = 0 to output	t_{AD}		300		300	ns	C_L = 150 pF
$\overline{ACK}$ = 0 to output float	t_{KD}		250		250	ns	C_L = 50 pF
		20		20			C_L = 15 pF
$\overline{WR}$ = 1 to OBF = 0	t_{WOB}		300		650	ns	
$\overline{ACK}$ = 0 to OBF = 1	t_{AOB}		350		350	ns	
$\overline{STB}$ = 0 to IBF = 1	t_{SIB}		300		300	ns	
$\overline{RD}$ = 1 to IBF = 0	t_{RIB}		300		300	ns	
$\overline{RD}$ = 0 to INTR = 0	t_{RIT}		400		400	ns	
$\overline{STB}$ = 1 to INTR = 1	t_{SIT}		300		300	ns	C_L = 150 pF
$\overline{ACK}$ = 1 to INTR = 1	t_{AIT}		350		350	ns	
$\overline{WR}$ = 0 to INTR = 0	t_{WIT}		450		850	ns	C_L = 150 pF (Note 3)

Note:

(1) Period of reset pulse must be at least 50 μs during or after power on. Subsequent reset pulse can be 500 ns min.

(2)



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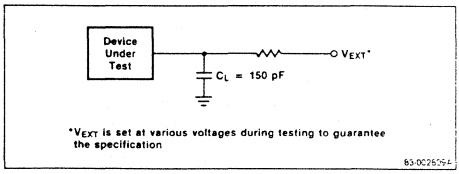
(3) INTRt may occur as early as $\overline{WR}$↓.

AC Testing Load Circuit



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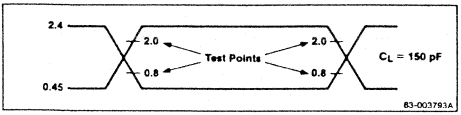
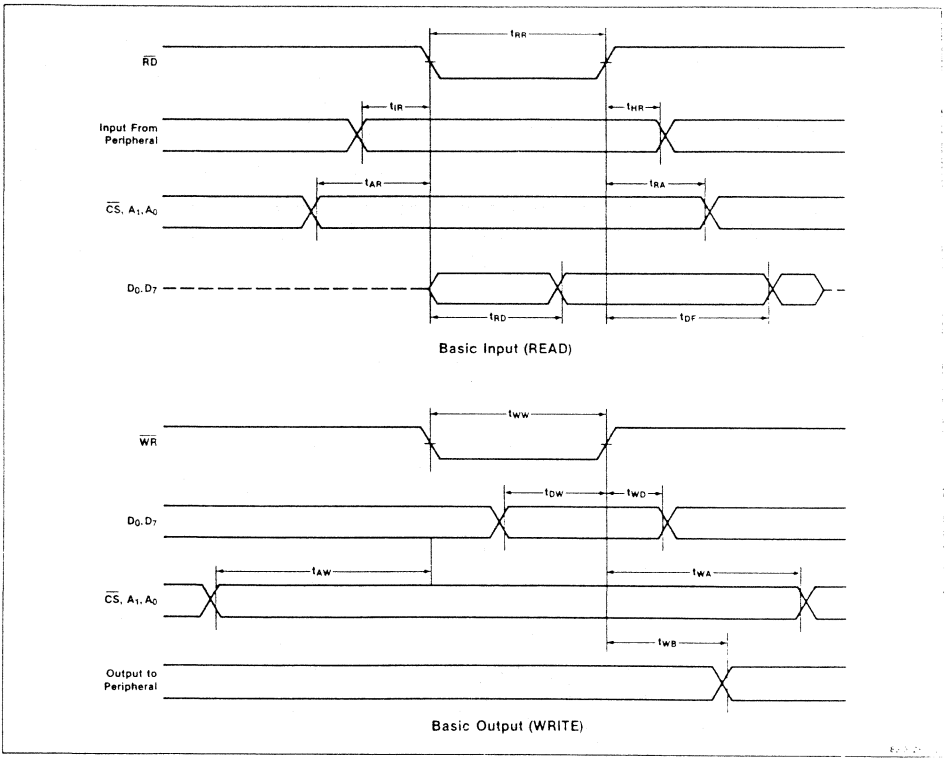
Timing Waveforms

AC Testing Input, Output Waveform

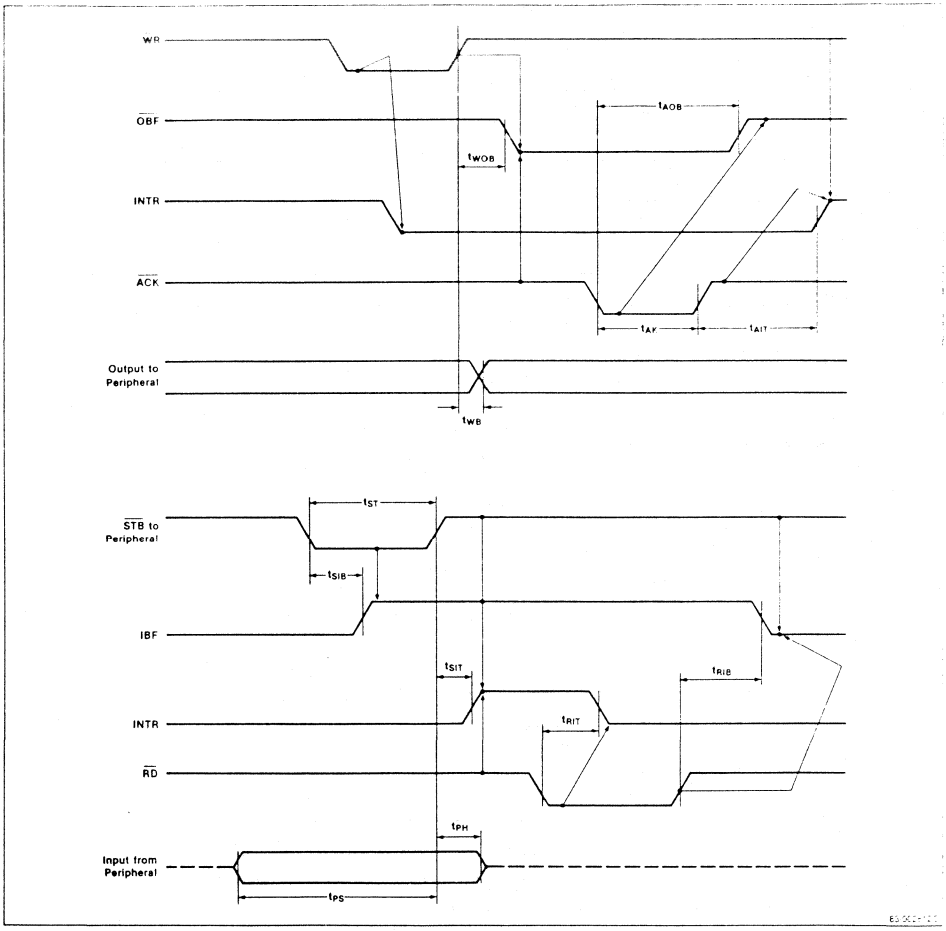


Mode 0



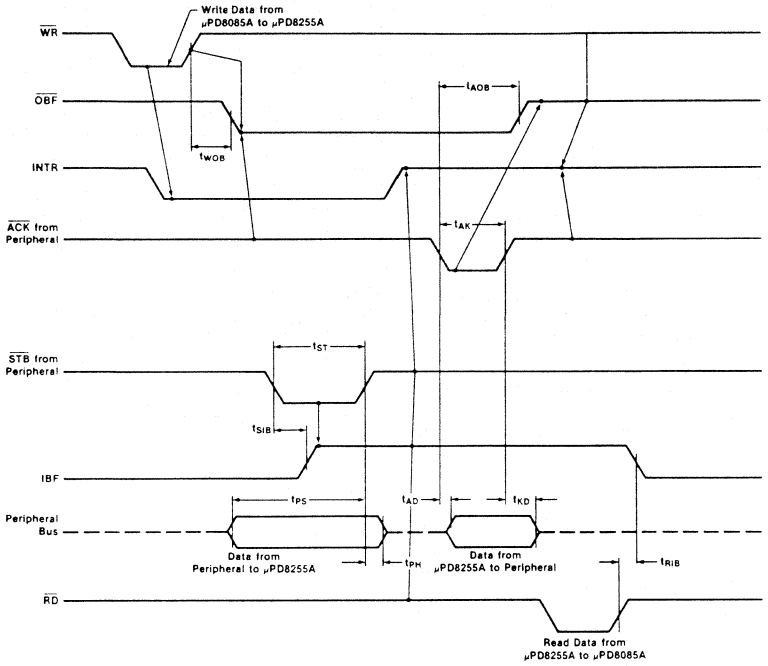
Timing Waveforms (cont)

Mode 1



Timing Waveforms (cont)

Mode 2



Note:

(1) Any sequence where $\overline{WR}$ occurs before $\overline{ACK}$ and $\overline{STB}$ occurs before $\overline{RD}$ is permissible (INTR = IBF • MASK • STB • RD + OBF • MASK • ACK • WR).

(2) When the μPD8255A is set to Mode 1 or 2, $\overline{OBF}$ is reset to be high (logic 1).

Modes

The μPD8255A can be operated in modes 0, 1 or 2 which are selected by appropriate control words and are detailed below.

Mode 0

Mode 0 provides basic input and output operations through each of the ports A, B, and C. Output data is latched and input data follows the peripheral. No "handshaking" strobes are needed.

- 16 different configurations in mode 0
- Two 8-bit ports and two 4-bit ports
- Inputs are not latched
- Outputs are latched

Mode 1

Mode 1 provides for strobed input and output operations with data transferred through port A or B and handshaking through port C.

- Two I/O groups (I and II)
- Both groups contain an 8-bit data port and a 4-bit control/data port
- Both 8-bit data ports can be either latched input or latched output

Mode 2

Mode 2 provides for strobed bidirectional operation using PA_0PA_{-7} as the bidirectional latched data bus. PC_3PC_7 is used for interrupts and "handshaking" bus flow control similar to mode 1. Note that PB_0PB_7 and PC_0PC_2 may be defined as mode 0 or 1, input or output in conjunction with port A in mode 2.

- An 8-bit latched bidirectional bus port (PA_0-PA_7) and a 5-bit control port (PC_3PC_7)
- Both inputs and outputs are latched
- An additional 8-bit input or output port with a 3-bit control port.

Basic Operation

Input Operation (Read)

A_1	A_0	RD	WR	CS	
0	0	0	1	0	PORT A → DATA BUS
0	1	0	1	0	PORT B → DATA BUS
1	0	0	1	0	PORT C → DATA BUS

Output Operation (Write)

A_1	A_0	RD	WR	CS	
0	0	1	0	0	DATA BUS → PORT A
0	1	1	0	0	DATA BUS → PORT B
1	0	1	0	0	DATA BUS → PORT C
1	1	1	0	0	DATA BUS → CONTROL

Disable Function

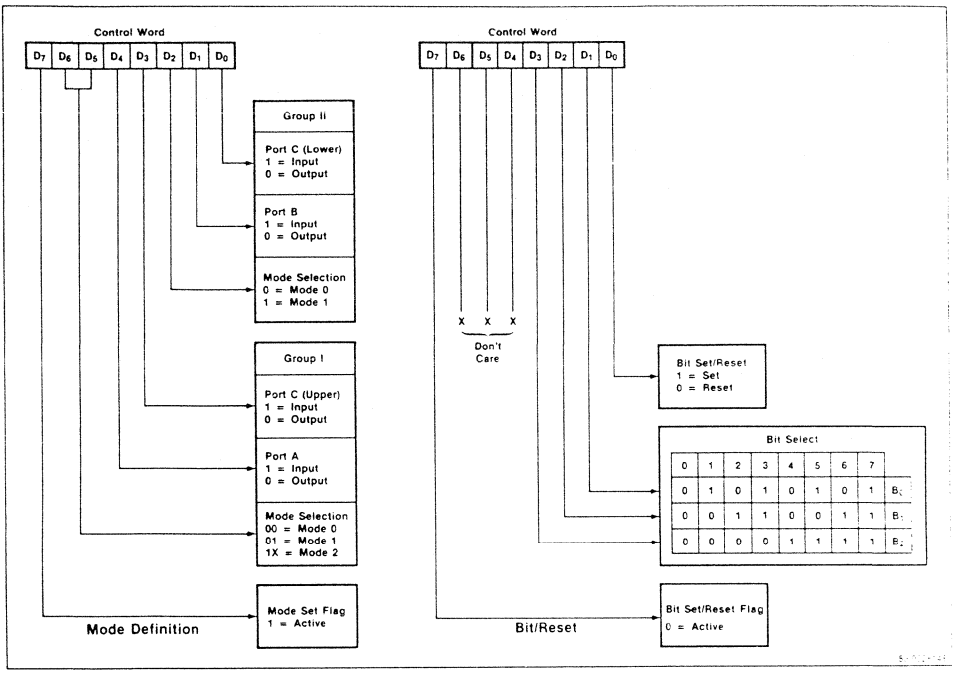
A_1	A_0	RD	WR	CS	
X	X	X	X	1	DATA BUS → HIGH Z STATE
X	X	1	1	0	DATA BUS → HIGH Z STATE

Note:

(1) X means "DO NOT CARE"
(2) All conditions not listed are illegal and should be avoided.

Formats

Mode Definition, Bit/Rest Format



Description

The μPD8257 is a programmable four-channel direct memory access (DMA) controller. It is designed to simplify high-speed transfers between peripheral devices and memories. Upon a peripheral request, the μPD8257 generates a sequential memory address, thus allowing the peripheral to read or write data directly to or from memory. Peripheral requests are prioritized within the μPD8257 so that the system bus may be acquired by the generation of a single HOLD command to the 8080A. DMA cycle counts are maintained for each of the four channels, and a control signal notifies the peripheral when the preprogrammed member of DMA cycles has occurred. Output control signals are also provided which allow simplified sectored data transfers and expansion to other μPD8257 devices for systems requiring more than four DMA channels.

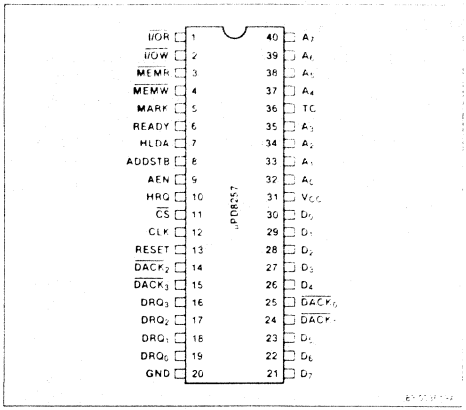
Features

- ☐ Four-channel DMA controller
- ☐ Priority DMA request logic
- ☐ Channel inhibit logic
- ☐ Terminal count and modulo 128 outputs
- ☐ Automatic load mode
- ☐ Single TTL clock
- ☐ Single +5 V ± 10% power supply
- ☐ Expandable
- ☐ Available in extended temperature range

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD8257C-2	40-pin plastic DIP	5 MHz
μPD8257C-5	40-pin plastic DIP	3 MHz

Pin Configuration



Pin Identification

No.	Symbol	Function
1	$\overline{I/OR}$	I/O read, control signal
2	$\overline{I/OW}$	I/O write, control signal
3	$\overline{MEMR}$	Memory read output
4	$\overline{MEMW}$	Memory write output
5	MARK	Modulo 128 mark
6	READY	Ready input
7	HLDA	Hold acknowledge input (from 8080A)
8	ADDSTB	Address strobe output
9	AEN	Address enable output
10	HRQ	Hold request (to 8080A)
11	$\overline{CS}$	Chip select input
12	CLK	Clock input
13	RESET	Reset input
14, 15, 24, 25	$\overline{DACK_2}$, $\overline{DACK_3}$, $\overline{DACK_1}$, $\overline{DACK_0}$	DMA acknowledge output
16-19	DRQ_3-DRQ_0	DMA request input
20	GND	Ground
21-23, 26-30	D_7-D_5, D_4-D_0	I/O data bus
31	V_{CC}	+5 V power supply
32-35	A_0-A_3	I/O address bus
36	TC	Terminal count output
37-40	A_4-A_7	Output address bus

Pin Functions

D_0-D_7 (I/O Data Bus)

During an I/O read, the CPU enables these lines as inputs, allowing it to read an address register, a word count register, or the status or temporary register. During an I/O write, these lines are enabled as outputs, allowing the CPU to program the μPD8257-2/-5 control registers. During DMA cycles, the eight MSBs of the address are output to the data bus to be strobed to an external latch via ADDSTB.

A_4-A_7 (Output Address Bus)

These lines, active only during DMA service, are outputs that provide the four MSBs of the address.

A_0-A_3 (I/O Address Bus)

During DMA active states, these lines are outputs that provide the 4 LSBs of the output address bus. During DMA idle states, these lines are inputs, allowing the CPU to load or examine control registers.

DRQ_0-DRQ_3 (DMA Request Input)

These are asynchronous channel request inputs used by peripherals to request DMA service. In a fixed priority scheme, DRQ_0 has the highest priority and DRQ_3 has the lowest. The polarity of these lines is programmable; however, reset initializes them to active high.

HLDA (Hold Acknowledge)

Indicates that the CPU has relinquished control of the system busses.

HRQ (Hold Request)

Requests control of the system bus. The μPD8257-2/-5 issues this signal in response to software requests or DRQ inputs from peripherals.

$\overline{DACK_0}$-$\overline{DACK_3}$ (DMA Acknowledge Output)

These lines indicate an active channel. They are sometimes used to select a peripheral. Only one DACK may be active at any time. All DACK lines are inactive unless DMA has control of the bus. The polarity of these lines is programmable; however, reset initializes them to active low.

TC (Terminal Count)

When the terminal count occurs, TC goes high, informing the CPU that the data transfer is complete.

RESET

Clears the command, status, request, and temporary registers, the first/last flip flop, and sets the mask register. The μPD8257-2/-5 is in idle state after a reset.

$\overline{CS}$ (Chip Select)

The CPU uses $\overline{CS}$ to select the μPD8257-2/-5 as an I/O device during an I/O read or write by the CPU. This provides CPU communication on the data bus. $\overline{CS}$ may be held low during multiple transfers to or from the μPD8257-2/-5 as long as $\overline{I/OR}$ or $\overline{I/OW}$ is toggled following each transfer.

READY

This signal can extend memory read and write pulses for slow memories or I/O peripherals.

CLK (Clock)

Controls internal operations and data transfer rate.

AEN (Address Enable)

This signal allows the external latch to output the upper address byte by disabling the system bus during DMA cycles. Use HLDA and AEN to deselect I/O peripherals that may be erroneously accessed during DMA transfers. The μPD8257-2/-5 deselects itself during DMA transfers.

ADDSTB (Address Strobe)

This signal strobes the upper address byte form D_0-D_7 into an external latch.

$\overline{MEMR}$ (Memory Read)

This signal accesses data from a specified memory location during memory-to-peripheral or memory-to-memory transfers.

$\overline{MEMW}$ (Memory Write)

This signal writes data to a specified memory location during peripheral-to-memory or memory-to-memory transfers.

$\overline{I/OR}$ (I/O Read)

In the idle state, this signal is an input control line used by the CPU to read control registers. In the active state, the μPD8257-2/-5 uses I/OR as an output control signal to access data from a peripheral during a DMA write.

$\overline{I/OW}$ (I/O Write)

In the idle state, the CPU uses I/OW as an input control signal to load information to the μPD8257-2/-5. In the active state, the μPD8257-2/-5 uses I/OW as an output control signal to load data to a peripheral during a DMA read.

The rising edge of $\overline{WR}$ must follow each data byte transfer in order for the CPU to write to the μPD8257-2/-5. Holding I/OW low while toggling CS does not produce the same effect.

MARK (Modulo 128 Mark)

This output notifies the selected peripheral that the current DMA cycle is the 128th cycle since the previous MARK output. MARK always occurs at 128 (and all multiples of 128) cycles from the end of the data block.

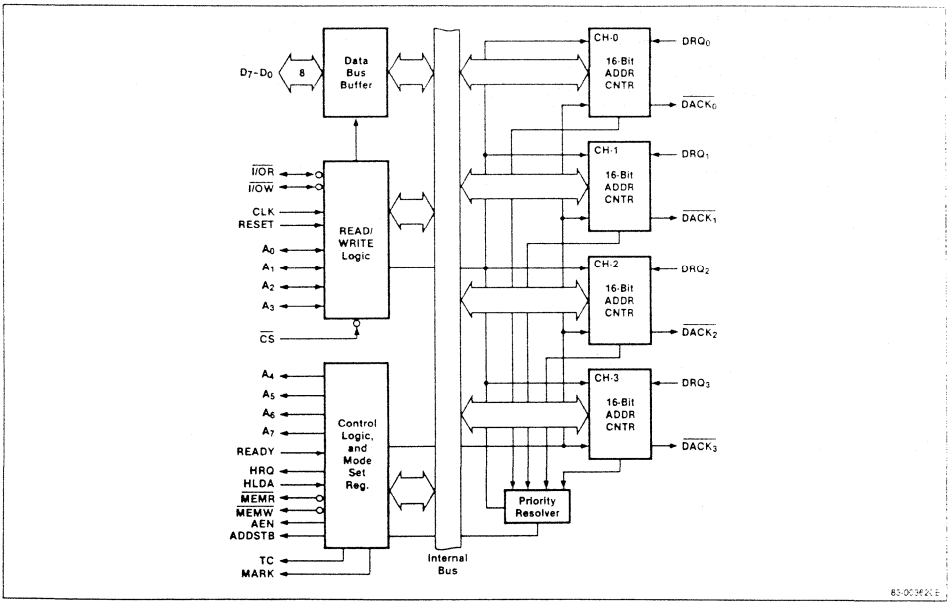
V_{CC}

Power supply.

GND

Ground.

Block Diagram



Absolute Maximum Ratings

T_A = 25°C

Operating temperature, T_{OPT}	0°C to 70°C
Storage temperature, T_{STG}	−65°C to +150°C
Power supply voltage, V_{CC}	−0.5 V to +7 V (1)
Power dissipation	1 Watt

Comment: Stress above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note:

(1) With respect to Ground

DC Characteristics

T_A = 0°C to +70°C; V_{CC} = +5 V ±10% GND = 0 V

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Input low voltage	V_{IL}	−0.5	0.8	V	
Input high voltage	V_{IH}	2.0	V_{CC} +0.5	V	
Output low voltage	V_{OL}		0.45	V	I_{OL} = 1.6 mA
Output high voltage	V_{OH}	2.4	V_{CC}	V	I_{OH} = −150 μA for AB, DB and AEN I_{OH} = −80 μA for others
HRQ output high voltage	V_{HH}	3.3	V_{CC}	V	I_{OH} = −80 μA
Power supply current	I_{CC}		100	mA	8257-2
			120	mA	8257-5
Input leakage	I_{IL}	−10	10	μA	$0 \leq V_{IN} \leq V_{CC}$
Output leakage during float	I_{OFL}	−10	10	μA	$0.45 \leq V_{OUT} \leq V_{CC}$

Capacitance

T_A = 25°C; V_{CC} = GND = 0 V

Parameter	Symbol	Limits Min	Limits Typ	Limits Max	Unit	Test Conditions
Input capacitance	C_I			10	pF	f_c = 1 MHz
I/O capacitance	$C_{I/O}$			20	pF	Unmeasured pins returned to GND

AC Characteristics

T_A = 0°C to +70°C, V_{CC} = 5 V ±10%; GND = 0 V

Parameter	Symbol	Limits μPD8257-2 Min	Limits μPD8257-2 Max	Limits μPD8257-5 Min	Limits μPD8257-5 Max	Unit	Test Conditions
Read							
ADR or $\overline{CS}$↓ Setup to $\overline{RD}$↓	t_{AR}	0				ns	
ADR or $\overline{CS}$ → hold from $\overline{RD}$↑	t_{RA}	0				ns	
Data Access from $\overline{RD}$↓	t_{RDE}	0	140	0	170	ns	C_L = 100 pF
DB → float delay from $\overline{RD}$↑	t_{RDF}	10	85	20	100	ns	C_L = 100 pF
$\overline{RD}$ width	t_{RW}	200		250		ns	
Write							
ADR setup to $\overline{WR}$↓	t_{AW}	20				ns	
ADR hold from $\overline{WR}$↑	t_{WA}	0				ns	
Data setup to $\overline{WR}$↓	t_{DW}	100		200		ns	
Data hold from $\overline{WR}$↑	t_{WD}	0				ns	
$\overline{WR}$ width	t_{WWS}	100		200		ns	
Other timing							
Reset pulse width	t_{RSTW}	300		300		ns	
Power supply ↑(V_{CC}) setup to reset↓	t_{RSTD}	500		500		μs	
Signal rise & fall times	t_r, t_f		20		20		
Reset to first $\overline{IOWR}$	t_{RSTS}	2		2		t_{CY}	

Note:

(1) All timing measurements are made at the following reference voltages unless specified otherwise: input "1" at 2.0 V, "0" at 0.8 V, output "1" at 2.0 V, "0" at 0.8 V.

AC Characteristics

T_A = 0°C to +70°C; V_{CC} = +5 V ±10%; GND = 0 V

Parameter	Symbol	Limits μPD8257-2 Min	Limits μPD8257-2 Max	Limits μPD8257-5 Min	Limits μPD8257-5 Max	Unit	Test Conditions
Cycle time (period)	t_{CY}	0.200	4	0.320	4	μs	
Clock active (high)	t_θ	80		80	.8t_{CY}	ns	
DRQ↑ setup to θ↓ (SI, S4)	t_{DS}	50		120			
DRQ↓ hold from HLDA↑	t_{DH}	0		0			(4)
HRQ↑ or ↓ delay from θ↑ (SI, S4) (measured at 2.0 V)	t_{DQ}		160		160	ns	
HRQ↑ or ↓delay from θ↑ (SI, S4)	t_{HS}		200	100	250	ns	(3)
HLDA↑ or ↓setup to θ↓ (SI, S4)	t_{HS}	50		100		ns	
AEN↑ delay from θ↓ (S1)	t_{AEL}		150		300	ns	
AEN↓ delay from θ↑ (SI)	t_{AET}		150		200	ns	
ADR (AB) (active) delay from AEN↑ (S1)	t_{AEA}	20		20		ns	(4)
ADR (AB) (active) delay from θ↑ (S1)	t_{FAAB}		200		250	ns	(2)
ADR (AB) (float) delay from θ↑ (SI)	t_{AFAB}		150		150	ns	(2)
ADR (AB) (stable) delay from θ↑ (S1)	t_{ASM}		200		250	ns	(2)
ADR (AB) (stable) hold from θ↑ (S1)	t_{AH}	$t_{ASM}-50$		$t_{ASM}-50$			(2)
ADR (AB) (valid) hold from RD↑ (S2, SI)	t_{AHR}	60		60		ns	(4)

AC Characteristics (cont)

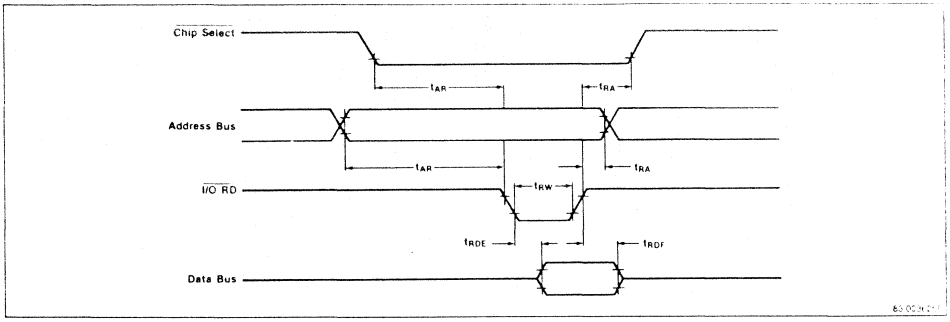
Parameter	Symbol	Limits μPD8257-2 Min	Limits μPD8257-2 Max	Limits μPD8257-5 Min	Limits μPD8257-5 Max	Unit	Test Conditions
ADR (AB) (valid) hold from WR↑ (S1, SI)	t_{AHW}	100		300		ns	(4)
ADR (DB) (active) delay from θ↑ (S1)	t_{FADB}		150		300	ns	(2)
ADR (DB) (float) delay from θ↑ (S2)	t_{AFDB}	t_{STT}	140	$t_{STT}+20$	170	ns	(2)
ADR (DB) setup to ADR STB↓ (S1-S2)	t_{ASS}	100		100		ns	(4)
ADR (DB) (valid) hold from ADR STB↓ (S2)	t_{AHS}	20		50		ns	(4)
ADR STB↑ delay from θ↑ (S1)	t_{STL}		150		200	ns	
ADR STB↓ delay from θ↑ (S2)	t_{STT}		140		140	ns	
ADR STB width (S1-S2)	T_{SW}	$t_{CY}-100$		$t_{CY}-100$		ns	(4)
$\overline{RD}$↓ or $\overline{WR}$ (ext)↓ delay from ADR STB↓ (S2)	t_{ASC}	20		70		ns	(4)
RD↓ or WR (ext)↓ delay from ADR (DB) (float) (S2)	t_{DBC}	0		20		ns	(4)
DACK↑ or ↓delay from θ↓ (S2, S1) and TC/Mark↑ delay from θ↑ (S3) and TC/Mark↓ delay from θ↑ (S4)	t_{AK}		200		250	ns	(5)
$\overline{RD}$↓ or $\overline{WR}$ (ext) ↓ delay from θ↑ (S2) and $\overline{WR}$↓ delay from θ↑ (S3)	t_{DCL}		150		200	ns	(2) (6)
$\overline{RD}$↑ delay from θ↓ (S1, SI) and $\overline{WR}$↑ delay from θ↑ (S4)	t_{DCT}		150		200	ns	(2) (7)
$\overline{RD}$ or $\overline{WR}$ (active) from θ↑ (S1)	t_{FAC}		200		300	ns	(2)
$\overline{RD}$ or $\overline{WR}$ (float) from θ↑ (SI)	t_{AFC}		150		150	ns	(2)
$\overline{RD}$ width (S2-S1 or SI)	T_{RWM}	$2t_{CY}+t_{\theta}-50$		$2t_{CY}+t_{\theta}-50$		ns	(4)
$\overline{WR}$ width (S3-S4)	t_{WWM}	$t_{CY}-50$		$t_{CY}-50$		ns	(4)
$\overline{WR}$ (ext) width (S2-S4)	t_{WWME}	$2t_{CY}-50$		$2t_{CY}-50$		ns	(4)
READY set up time to θ↑ (S3, Sw)	t_{RS}	30		30		ns	
READY hold time from θ↑ (S3, Sw)	t_{RH}	30		30		ns	

Note:

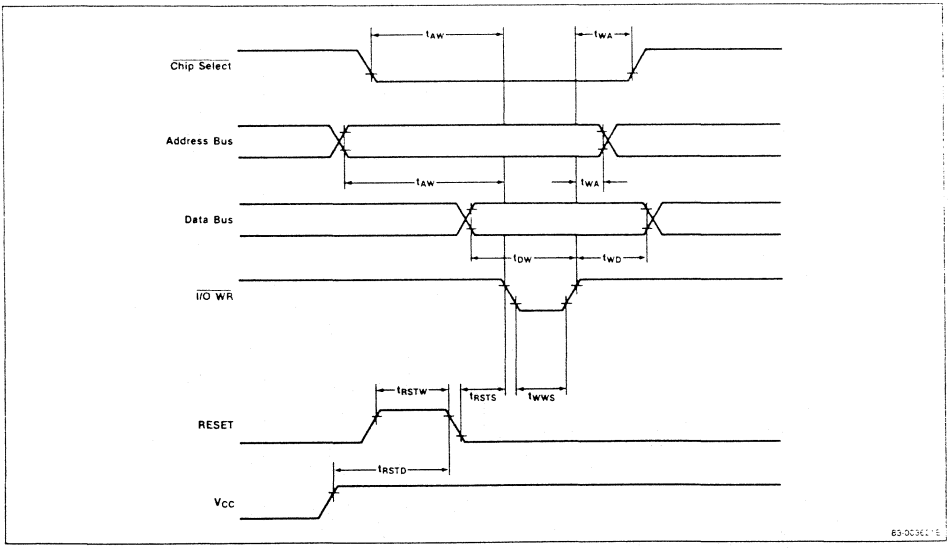
(1) Load = 1 TTL
(2) Load = 50 pF
(3) Load = V_{OH} = 3.3 V
(4) Tracking specification
(5) $\triangle t_{TAK} \leq 50$ ns
(6) $\triangle t_{DCL} \leq 50$ ns
(7) $\triangle t_{DCT} \leq 50$ ns

Timing Waveforms

Read Timing

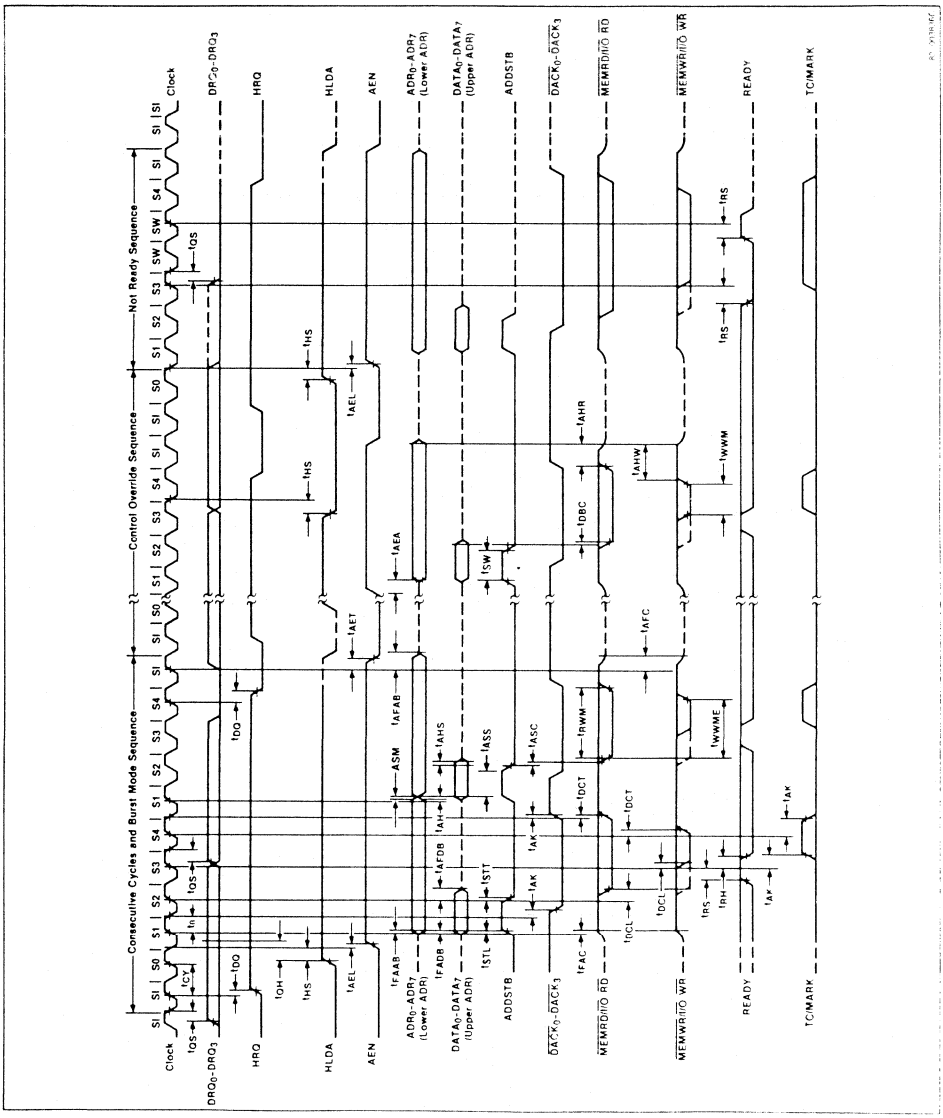


Write/Reset Timing



Timing Waveforms (cont)

DMA (Master) Mode



Functional Description

The μPD8257 is a programmable, direct memory Access (DMA) device. When used with an 8212 I/O port device, it provides a complete four-channel DMA controller for use in 8080A/8085A based systems. Once Initialized by an 8080A/8085A CPU, the μPD8257 will block transfer up to 16,364 bytes of data between memory and a peripheral device without any attention from the CPU. It will do this on all 4-DMA channels. After receiving a DMA transfer request from a peripheral, the following sequence of events occurs within the μPD8257.

(1) It acquires control of the system bus (placing 8080A/8085A in hold mode).

(2) Resolves priority conflicts if multiple DMA requests are made.

(3) A 16-bit memory address word is generated with the aid of an 8212 in the following manner:

  (a) The μPD8257 outputs the least significant eight bits (A_0-A_7) which go directly onto the address bus.

  (b) The μPD8257 outputs the most significant eight bits (A_8-A_{15}) onto the data bus where they are latched into an 8212 and then sent to the high order bits on the address bus.

(4) The appropriate memory and I/O read/write control signals are generated allowing the peripheral to receive or deposit a data byte directly from or to the appropriate memory location.

Block transfer of data (e.g., a sector of data on a floppy disk) either to or from a peripheral may be accomplished as long as the peripheral maintains its DMA request (DRQ_n). The μPD8257 retains control of the system bus as long as DRQ_n remains high or until the terminal count (TC) is reached. When the terminal count occurs, TC goes high, informing the CPU that the operation is complete.

There are three different modes of operation:

(1) DMA read, which causes data to be transferred from memory to a peripheral;

(2) DMA write, which causes data to be transferred from a peripheral to memory; and

(3) DMA verify, which does not actually involve the transfer of data.

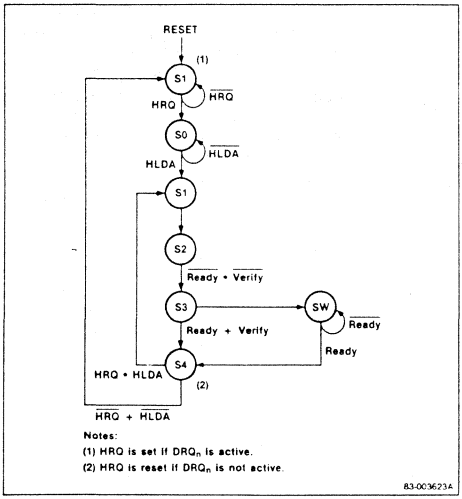
The DMA read and write modes are the normal operating conditions for the μPD8257. The DMA verify mode responds in the same manner as read/write except no memory or I/O read/write control signals are generated, thus preventing the transfer of data. The peripheral gains control of the system bus and obtains DMA acknowledgements for its requests, thus allowing it to access each byte of a data block for check purposes or accumulation of a CRC (cycle redundancy code) checkword. In some applications it is necessary for a block of DMA read or write cycles to be followed by a block of DMA verify cycles to allow the peripheral to verify its newly acquired data.

DMA Operation

As shown in figure 1, internally the μPD8257 contains six different states (S0, S1, S2, S3, S4 and SW). The duration of each state is determined by the input clock. In the idle state, (S1), no DMA operation is being executed. A DMA cycle is started upon receipt of one or more DMA requests (DRQ_n). Then the μPD8257 enters the S0 state, during which a hold request (HRQ) is sent to the 8080A/8085A and the μPD8257 waits in S0 until the 8080A/8085A issues a hold acknowledge (HLDA) back. During S0, DMA requests are sampled and DMA priority is resolved (based upon either the fixed or priority scheme).

After receipt of HLDA, the DMA acknowledge line ($DACK_n$) with the highest priority is driven low, selecting that particular peripheral for the DMA cycle. The DMA request line (DRQ_n) must remain high until either a DMA acknowledge ($DACK_n$) or both $DACK_n$ and TC (terminal count) occur, indicating the end of a block or sector transfer (burst model).

Figure 1. DMA Operation State Diagram



The DMA cycle consists of four internal states; S1, S2, S3, and S4. If the access time of the memory or I/O device is not fast enough to return a ready command to the μPD8257 after it reaches state S3, then a wait state is initiated (SW). One or more than one wait state occurs until a ready signal is received, and the μPD8257 is allowed to go into state S4. Either the extended write option or the DMA verify mode may eliminate any wait state.

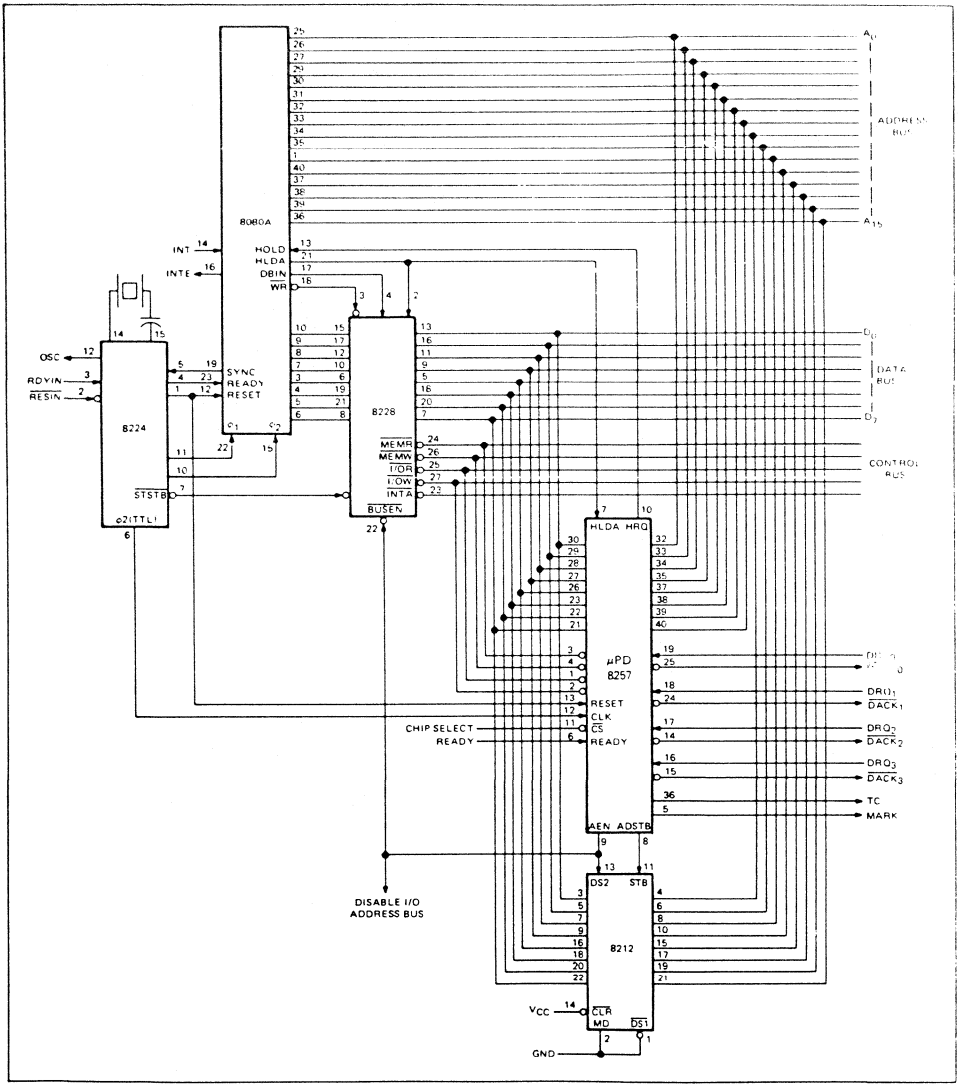
If the μPD8257 should lose control of the system bus, (i.e., HLDA goes low) then the current DMA cycle is completed; the device goes into the S1 state, and no more DMA cycles occur until the bus is reacquired. Ready setup time (t_{RS}), write setup time (t_{DW}), read data access time (t_{RD}), and HLDA setup time (t_{QS}) should all be carefully observed during the handshaking mode between the μPD8257 and the 8080A/8085A.

During DMA write cycles, the I/O Read (I/O R) output is generated at the beginning of state S2 and the memory write (MEMW) output is generated at the beginning of S3. During DMA read cycles, the memory read (MEMR) output is generated at the beginning of state S2 and the I/O write (I/O W) goes low at the beginning of state S3. No read or write control signals are generated during DMA verify cycles.

System Interface

Figure 2 is the schematic diagram of a μPD8257 system interface with the 8080A CPU, 8212 I/O Port, 8224 Clock Generator, and 8228 System Controller and Bus Driver.

Figure 2. Typical μPD8257 System Interface Schematic



μPD8259A PROGRAMMABLE INTERRUPT CONTROLLER

Description

The μPD8259A is a programmable interrupt controller directly compatible with the 8080A/8085A/8086/8088 microprocessors. It can service eight levels of interrupts and contains on-chip logic to expand interrupt capabilities up to 64 levels with the addition of other μPD8259A's. The user can choose a selection of priority algorithms to tailor the priority processing to meet his system requirements. These algorithms can be dynamically modified during operation, which expands the versatility of the system. The μPD8259A is completely upward compatible with the μPD8259-5, allowing software written for the μPD8259-5 to run on the μPD8259A/-2.

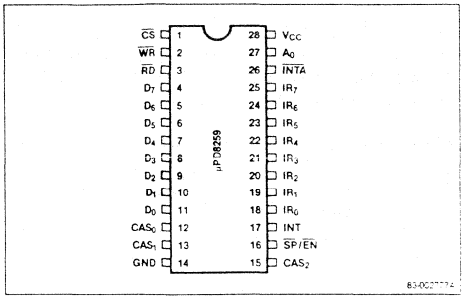
Features

- ☐ Eight-level priority controller
- ☐ Programmable base vector address
- ☐ Expandable to 64 levels
- ☐ Programmable interrupt modes (algorithms)
- ☐ Individual request mask capability
- ☐ Single +5 V power supply (no clocks)
- ☐ Full compatibility with 8080A/8085A/8086/8088

Ordering Information

Part Number	Package Type
μPD8259AC	28-pin plastic DIP
μPD8259AC-2	28-pin plastic DIP

Pin Configuration



Pin Identification

No.	Symbol	Function
1	$\overline{CS}$	Chip select input
2	$\overline{WR}$	Write input
3	$\overline{RD}$	Read input
4-11	D_7-D_0	Bidirectional data bus
12, 13, 15	CAS_0-CAS_2	Cascade lines
14	GND	Ground
16	$\overline{SP}/\overline{EN}$	Slave program input / enable buffer output
17	INT	Interrupt output
18-25	IR_0-IR_7	Interrupt request inputs
26	$\overline{INTA}$	Interrupt acknowledge input
27	A_0	Command select address input
28	V_{CC}	+5 V power supply

Pin Functions

Bidirectional Data Bus (D_7-D_0)

Three-state data bus used for interfacing to the system data bus. This bus carries control words, status information, and interrupt vector information.

Interrupt Request Inputs (IR_0-IR_7)

These are eight asynchronous inputs that operate in two modes. In the edge-triggered mode, the IR input must be raised from low to high and held high until it is acknowledged. In the level-triggered mode, the IR input requires only a high.

Cascade Lines (CAS_0-CAS_2)

These lines are used as a bus which controls multiple μPD8259As in a master/slave configuration. When an μPD8259A is a master, these lines are outputs. When a μPD8259A is used as a slave, the lines are inputs.

Chip Select ($\overline{CS}$)

When $\overline{CS}$ is low, the CPU can read and write to the μPD8259A. The INTA input operates independently of $\overline{CS}$.

Command Select Address Input (A_0)

The μPD8259A uses this input with $\overline{CS}$ and $\overline{WR}$ to decode command words written by the CPU. A_0 is used with $\overline{CS}$ and $\overline{RD}$ to decode controller status information for the CPU to read. Typically, A_0 is connected to the A_0 address lines on the CPU.

Interrupt (INT)

When the μPD8259A receives a valid interrupt request, the INT output goes high to interrupt the CPU. This pin should be connected directly to the interrupt pin on the CPU.

Interrupt Acknowledge ($\overline{INTA}$)

This input line goes active low to indicate that the CPU has received an interrupt request from the μPD8259A. $\overline{INTA}$ enables interrupt vector data onto the data bus.

Read Input ($\overline{RD}$)

When both $\overline{RD}$ and $\overline{CS}$ are low, the μPD8259A sends its status information to the data bus so the CPU can read it.

Write Input ($\overline{WR}$)

The μPD8259A can receive command words from the CPU when both $\overline{WR}$ and $\overline{CS}$ are low.

Slave Program Input / Enable Buffer Output ($\overline{SP}$ / $\overline{EN}$)

This is a dual function pin. In the buffered mode, the enable buffer output is used to enable the buffer transceivers. In the non-buffered mode, when the $\overline{SP}$ input is high, the μPD8259A operates as a master and when the $\overline{SP}$ input is low, the μPD8259A operates as a slave.

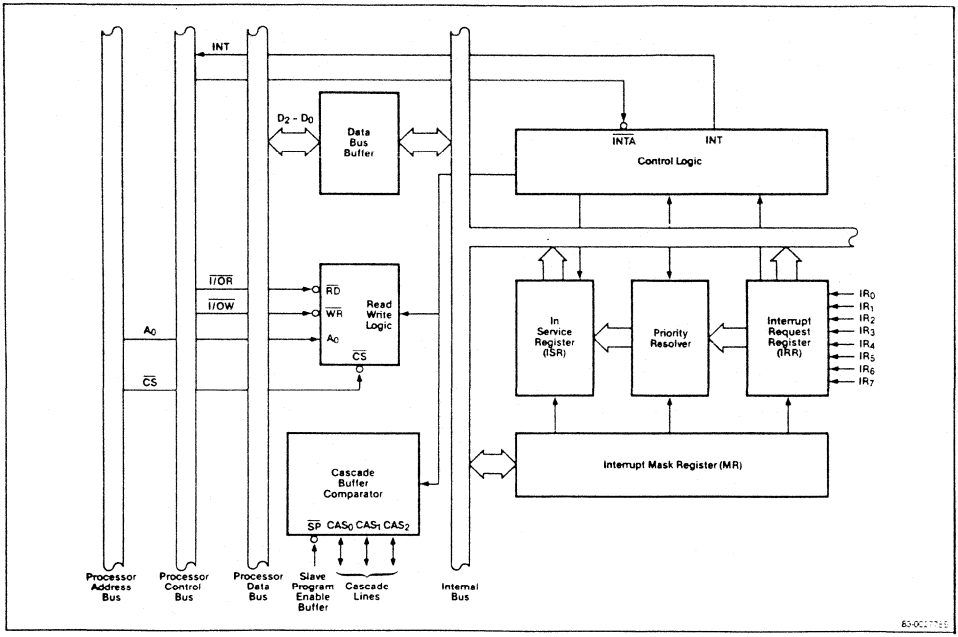
Ground (GND)

Ground

Power Supply (V_{CC})

Power supply input, +5 volts.

Block Diagram



Block Diagram Description

Interrupt Request Register (IRR) and In-Service Register (ISR)

The interrupt request and in-service registers store the incoming interrupt request signals appearing on the IR_0-IR_7 lines. The inputs requesting service are stored in the IRR while the interrupts actually being serviced are stored in the ISR. Refer to functional block diagram.

A positive transition on an IR input sets the corresponding bit in the interrupt request register. At the same time, the INT output of the μPD8259A is set high. The IR input line must remain high until the first $\overline{INTA}$ input has been received. Multiple non-masked interrupts occurring simultaneously can be stored in the IRR. The incoming $\overline{INTA}$ sets the appropriate ISR bit, which is determined by the programmed interrupt algorithm, and resets the corresponding IRR bit. The ISR bit stays active high during the interrupt service subroutine until it is reset by the programmed end of interrupt command (EOI).

Priority Resolver

The priority resolver decides the priority of the interrupt levels in the IRR. When the highest priority interrupt is determined, it is loaded into the appropriate bit of the ISR by the first $\overline{INTA}$ pulse.

Data Bus Buffer

The three state 8-bit bidirectional data bus buffer interfaces the μPD8259A to the systems data bus. It buffers the control word and status information being transferred between the μPD8259A and the processor.

Read/Write Logic

The read/write logic accepts processor commands and stores them in its initialization command word (ICW) and operation command word (OCW) registers. This logic also controls the transfer of status information to the processor.

Chip Select ($\overline{CS}$)

The μPD8259A is enabled when this input receives an active low signal. When the $\overline{CS}$ input is high, reading or writing of the μPD8259A is inhibited.

Write ($\overline{WR}$)

This active low signal instructs the μPD8259A to receive command data from the processor.

Read ($\overline{RD}$)

When the $\overline{RD}$ input receives an active low signal, the status of the interrupt request register, in-service register, interrupt mask register or binary code of the interrupt level is placed on the data bus.

Interrupt (INT)

The interrupt output from the μPD8259A is directly connected to the processor's INT input. The voltage levels of this output are compatible with the 8080A/8085A/8086/8088.

Interrupt Mask Register (IMR)

The interrupt mask register stores the bits which will mask the individual interrupt lines. The IMR masks the data in the ISR. Lower priority lines are not affected by masking a higher priority line.

Interrupt Acknowledge ($\overline{INTA}$)

$\overline{INTA}$ pulses cause the μPD8259A to put vectoring information on the bus. The number of pulses depend upon whether the μPD8259A is in the μPD8085A mode or 8086/8088 mode.

Command Select Address Input (A_0)

A_0 is usually connected to the processor's data bus. Together with $\overline{RD}$ and $\overline{WR}$, it signals the loading of data into the command register or the reading of status data. Table 1 illustrates the basic operations performed. Note that it is divided into three functions: input, output, and bus disable distinguished by the $\overline{RD}$, $\overline{WR}$, and $\overline{CS}$ inputs.

Table 1. μPD8259A Basic Operation

A_0	D_4	D_3	$\overline{RD}$	$\overline{WR}$	$\overline{CS}$	Operation
						Processor Input (Read)
0			0	1	0	IRR, ISR or IR → data bus (Note 1)
1			0	1	0	IMR → data bus
						Processor Output (Write)
0	0	0	1	0	0	Data bus → OCW2
0	0	1	1	0	0	Data bus → OCW3
0	1	X	1	0	0	Data bus → ICW1
1	X	X	1	0	0	Data bus → OCW1, ICW2, ICW3, ICW4 (Note 2)
						Disable Function
X	X	X	1	1	0	Data bus → high impedance state
X	X	X	X	X	1	Data bus → high impedance state

Note:

(1) The contents of OCW3 written prior to the read operation governs the selection of IRR, ISR or the interrupt level.

(2) The sequencer logic on the μPD8259A aligns these commands in the proper order.

Cascade Buffer/Comparator

The IDs of all μPD8259As are buffered and compared in the cascade buffer/comparator. See figure 4. The master μPD8259A sends the ID of the interrupting slave device along the CAS_0, CAS_1 and CAS_2 lines to all slave devices. The cascade buffer/comparator compares its preprogrammed ID to the CAS_0, CAS_1 and CAS_2 lines. The next two $\overline{INTA}$ pulses strobe the preprogrammed 2 byte call routine address onto the data bus from the slave whose ID matches the code on the CAS_0, CAS_1 and CAS_2 lines.

Slave Program ($\overline{SP}$)

The interrupt capability can be expanded to 64 levels by cascading multiple μPD8259As in a master plus slaves array. See figure 4. The master controls the slaves through the CAS_0, CAS_1 and CAS_2 lines. The $\overline{SP}$ input to the device selects the CAS_0, CAS_1 and CAS_2 lines as either outputs ($\overline{SP} = 1$) for the master or as inputs ($\overline{SP} = 0$) for the slaves. If only one μPD8259A is used, the SP input must be set to a logic 1, since it is functioning as a master.

Absolute Maximum Ratings

$T_A = 25°C$

Power supply voltage, V_{CC}	−0.5 to +7.0 V(Note 1)
Input voltage, V_I	−1.0 V to V_{CC} + 1.0 V
Output voltage, V_O	−0.5 V to V_{CC} + 0.5 V
Operating temperature, T_{OPT}	0 to +70°C
Storage temperature, T_{STG}	−65 to +150°C
Power dissipation, P_D	1.0 W

Note:
(1) With respect to ground.

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

$T_A = 0$ to +70°C, $V_{CC} = +5\,V \pm 10\%$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage low	V_{IL}	−0.5		0.8	V	
Input voltage high	V_{IH}	2.0		V_{CC} +0.5	V	
Output voltage low	V_{OL}			0.45	V	$I_{OL} = 2.2$ mA
Output voltage high	V_{OH}	2.4			V	$I_{OH} = -400\,\mu A$
Interrupt output	V_{OH-INT}	2.4			V	$I_{OH} = -400\,\mu A$
High voltage		3.5			V	$I_{OH} = -100\,\mu A$
Input leakage current (Note 1)	I_{LI}	−10		10	μA	$0\,V \leq V_I \leq V_{CC}$
Output leakage current	I_{LO}	−10		10	μA	$0.45\,V \leq V_O \leq V_{CC}$
V_{CC} power supply current	I_{CC}			85	mA	

Note:
(1) For other inputs.

AC Characteristics

Timing Requirements

$T_A = 0°C$ to +70°C, $V_{CC} = +5\,V \pm 10\%$

Parameter	Symbol	Limits μPD8259A Min	Max	μPD8259A-2 Min	Max	Unit	Test Conditions
A0 / $\overline{CS}$ setup to $\overline{RD}$ / $\overline{INTA}$ ↓	t_{AHRL}	0		0		ns	
A0 / $\overline{CS}$ hold after $\overline{RD}$ / $\overline{INTA}$ ↑	t_{RHAX}	0		0		ns	
$\overline{RD}$ pulse width	t_{RLRH}	235		160		ns	
A0 / $\overline{CS}$ setup to $\overline{WR}$ ↓	t_{AHWL}	0		0		ns	
A0 / $\overline{CS}$ hold after $\overline{WR}$ ↑	t_{WHAX}	0		0		ns	
$\overline{WR}$ pulse width	t_{WLWH}	290		190		ns	
Data setup to $\overline{WR}$ ↑	t_{DVWH}	240		160		ns	
Data hold after $\overline{WR}$ ↑	t_{WHDX}	0		0		ns	
Interrupt request width low	t_{JLJH}	100		100		ns	(Note 1)
Cascade setup to second or third $\overline{INTA}$ ↓ (slave only)	t_{CVIAL}	55		40		ns	
End of $\overline{RD}$ to next command	t_{RHRL}	160		160		ns	
End of $\overline{WR}$ to next command	t_{WHRL}	190		190		ns	
End of command to next command (different type)	t_{CHCL}	500		500		ns	(Note 2)
End of $\overline{INTA}$ sequence to next $\overline{INTA}$ sequence	t_{CHCL}	500		500		ns	(Note 2)

Note:
(1) This is the low time required to clear the input latch in the edge-triggered mode.

(2) Worst case timing for t_{CHCL} in an actual microprocessor system is typically much greater than 500 ns (8085A = 1 μs, 8085-2 = 1 μs, 8086 = 1 μs, 8086-2 = 625 ns).

AC Characteristics (cont)

Timing Responses

T_A = 0°C to +70°C, V_{CC} = +5 V ± 10%

Parameter	Symbol	Limits μPD8259A Min	Limits μPD8259A Max	Limits μPD8259A-2 Min	Limits μPD8259A-2 Max	Unit	Test Conditions
Data valid from $\overline{RD}$ / $\overline{INTA}$ ↓	t_{RLDV}		200		120	ns	(Notes 1-5)
Data float after $\overline{RD}$/$\overline{INTA}$ ↑	t_{RHDZ}	10	100	10	85	ns	(Notes 1-5)
Interrupt output delay	t_{JHIH}		350		300	ns	(Notes 1-5)
Cascade valid from first $\overline{INTA}$ ↓ (master only)	t_{IALCV}		565		360	ns	(Notes 1-5)
Enable active from $\overline{RD}$ ↓ or $\overline{INTA}$ ↑	t_{RLEL}		125		100	ns	(Notes 1-5)
Enable inactive from $\overline{RD}$ ↑ or $\overline{INTA}$ ↑	t_{RHEH}		150		150	ns	(Notes 1-5)
Data valid from stable address	t_{AHDV}		200		200	ns	(Notes 1-5)
Cascade valid to valid data	t_{CVDV}		300		200	ns	(Notes 1-5)

Note:

(1) C of data bus = 100 pF

(2) Max test C = 100 pF

(3) Min test C = 15 pF

(4) C_{INT} = 100 pF

(5) $C_{CASCADE}$ = 100 pF

Capacitance

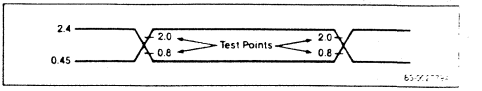
T_A = 25°C, V_{CC} = GND = 0 V, fc = 1.0 MHz

Parameter	Symbol	Limits Min	Limits Typ	Limits Max	Unit	Test Conditions
Input capacitance	C_I			10	pF	(Note 1)
I/O capacitance	$C_{I/O}$			20	pF	(Note 1)

Note:

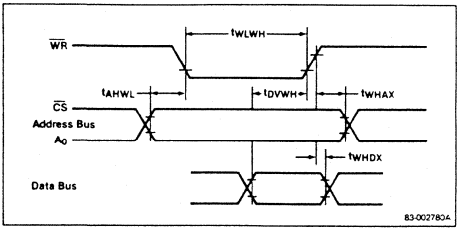
(1) Unmeasured pins returned to V_{SS}

AC Test Input

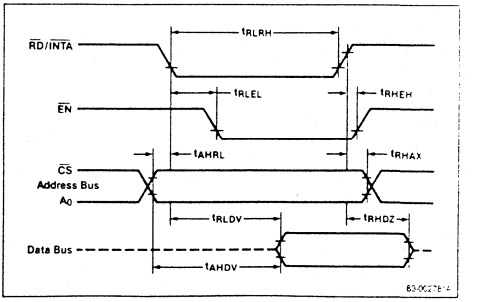


Timing Waveforms

Write Mode

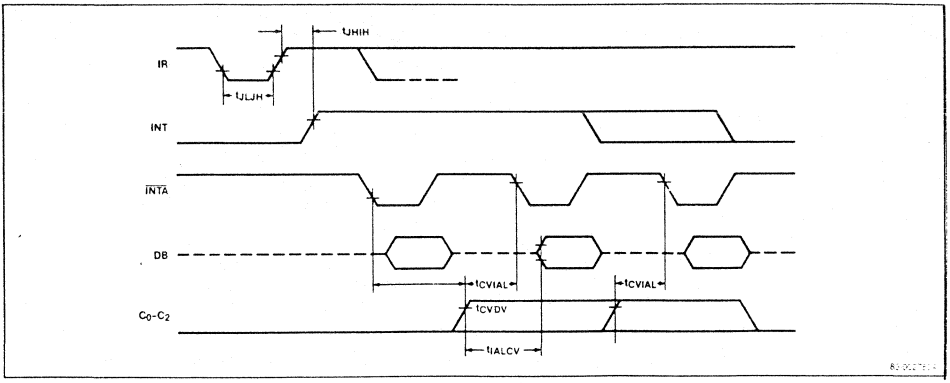


Read/$\overline{INTA}$ Mode

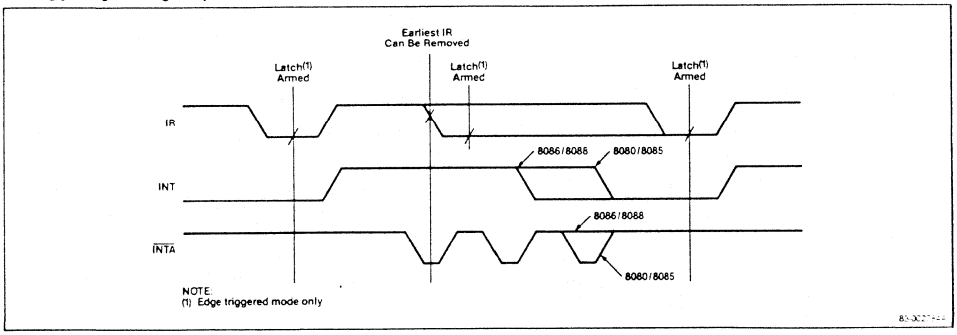


Timing Waveforms (cont)

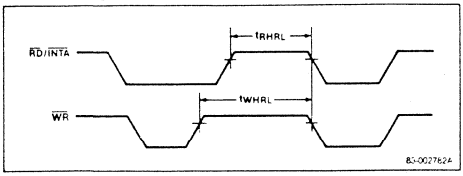
$\overline{INTA}$ Sequence



IR Triggering Timing Requirements



Other Timing



Functional Description

The μPD8259A functions are described in following paragraphs under these major headings:

- Interrupt Sequence
- 8080/8085A Mode
- 8086/8088 Mode
- Initialization Command Words
- Operational Command Words
- Reading μPD8259A Status

Interrupt Sequence

The μPD8259A derives its versatility from programmable interrupt modes and the ability to jump to any memory address through programmable CALL instructions.

The sequence used by the μPD8259A to handle an interrupt depends upon whether an 8080A/8085A or 8080/8088 CPU is being used.

The following sequence demonstrates how the μPD8259A interacts with the 8080A/8085A systems.

(1) An interrupt(s) appearing on IR_0-IR_7 sets the corresponding IR bit(s) high. This in turn sets the corresponding IRR bit(s) high.

(2) Once the IRR bit(s) has been set, the μPD8259A will resolve priorities according to the preprogrammed interrupt algorithm. It then issues an INT signal to the processor.

(3) When the processor receives an INT, it issues an $\overline{INTA}$ to the μPD8259A.

(4) The $\overline{INTA}$ input to the μPD8259A from the processor group sets the highest priority ISR bit and resets the corresponding IRR bit. The $\overline{INTA}$ also signals the μPD8259A to place an 8-bit CALL instruction opcode (11001101) onto its data bus lines.

(5) The CALL instruction code instructs the processor group to issue two more $\overline{INTA}$ pulses to the μPD8259A.

(6) The two $\overline{INTA}$ pulses signal the μPD8259A to place its preprogrammed interrupt vector address onto the data bus. The first $\overline{INTA}$ releases the low order 8 bits of the address and the second $\overline{INTA}$ releases the high order 8 bits.

(7) The μPD8259As CALL instruction sequence is complete. A preprogrammed EOI command is issued to the μPD8259A at the end of the interrupt service routine. This resets the ISR bit and allows the μPD8259A to service the next interrupt.

The following sequence demonstrates how the μPD8259A interacts with the 8086/8088 systems.

(1), (2), (3) Same as for 8080A/8085A.

(4) During the first $\overline{INTA}$ from the processor, the μPD8259A does not drive the data bus. The highest priority ISR bit is set and the corresponding IRR bit is reset.

(5) The μPD8259A puts vector information onto the data bus on the second $\overline{INTA}$ pulse from the 8086/8088.

(6) There is no third $\overline{INTA}$ pulse in this mode. In the AEOI mode the ISR bit is reset at the end of the second $\overline{INTA}$ pulse, or it remains set until an EOI command is issued.

8080/8085A Mode

For these processors, the μPD8259A is controlled by three $\overline{INTA}$ pulses. The first $\overline{INTA}$ pulse will cause the μPD8259A to put the CALL opcode onto the data bus. See table 2. The second and third $\overline{INTA}$ pulses will cause the upper and lower address of the interrupt vector to be released on the bus. See tables 3 and 4.

Table 2. Contents of First Interrupt Vector Byte

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
1	1	0	0	1	1	0	1

Table 3. Contents of Second Interrupt Vector Byte

IR	Interval = 4							
	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
7	A_7	A_6	A_5	1	1	1	0	0
6	A_7	A_6	A_5	1	1	0	0	0
5	A_7	A_6	A_5	1	0	1	0	0
4	A_7	A_6	A_5	1	0	0	0	0
3	A_7	A_6	A_5	0	1	1	0	0
2	A_7	A_6	A_5	0	1	0	0	0
1	A_7	A_6	A_5	0	0	1	0	0
0	A_7	A_6	A_5	0	0	0	0	0

IR	Interval = 8							
	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
7	A_7	A_6	1	1	1	0	0	0
6	A_7	A_6	1	1	0	0	0	0
5	A_7	A_6	1	0	1	0	0	0
4	A_7	A_6	1	0	0	0	0	0
3	A_7	A_6	0	1	1	0	0	0
2	A_7	A_6	0	1	0	0	0	0
1	A_7	A_6	0	0	1	0	0	0
0	A_7	A_6	0	0	0	0	0	0

Table 4. Contents of Third Interrupt Vector Byte

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
A_{15}	A_{14}	A_{13}	A_{12}	A_{11}	A_{10}	A_9	A_8

Table 5. Contents of Interrupt Vector Byte, 8086/8088 Mode

IR	Interval = 4							
	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
7	T_7	T_6	T_5	T_4	T_3	1	1	1
6	T_7	T_6	T_5	T_4	T_3	1	1	0
5	T_7	T_6	T_5	T_4	T_3	1	0	1
4	T_7	T_6	T_5	T_4	T_3	1	0	0
3	T_7	T_6	T_5	T_4	T_3	0	1	1
2	T_7	T_6	T_5	T_4	T_3	0	1	0
1	T_7	T_6	T_5	T_4	T_3	0	0	1
0	T_7	T_6	T_5	T_4	T_3	0	0	0

8086/8088 Mode

In this mode only two $\overline{INTA}$ pulses are sent to the μPD8259A. After the first $\overline{INTA}$ pulse, the μPD8259A does not output a CALL but internally sets priority resolution. If it is a master, it sets the cascade lines. The interrupt vector is output to the data bus on the second $\overline{INTA}$ pulse. See table 5.

Initialization Command Words

ICW1 and ICW2

LTIM — If LTIM = 1, then the μPD8259A operates in the level interrupt mode. Edge detect logic on the interrupt inputs is disabled.

ADI — CALL address interval. If ADI = 1 then the interval is four; if ADI = 0 then the interval is eight.

SNGL — (Single) Indicates that there is only one μPD8259A in the system. If SNGL = 1, no ICW3 is issued.

IC4 — If this bit is set, ICW4 has to be read. If ICW4 is not needed, set IC4 to logic 0.

A_5-A_{15} — Defines the page starting address of the service routines. In an 8085A system, the eight request levels generate CALLs to eight locations equally spaced in memory. These can be programmed to be spaced at intervals of four or eight memory locations, allowing eight routines to occupy a page of 32 or 64 bytes, respectively.

The address form is two bytes long (A_0-A_{15}). When the routine interval is four, A_0-A_4 are automatically inserted by the μPD8259A, while A_5-A_{15} are programmed externally. When the routine interval is eight, A_0-A_5 are automatically inserted by the μPD8259A, while A_6-A_{15} are programmed externally.

The eight-byte interval maintains compatibility with current software, while the four-byte interval is best for a compact jump table.

In an 8086/8088 system, T_7-T_3 are inserted in the five most significant bits of the vectoring byte. The μPD8259A sets the three least significant bits according to the interrupt level.

ICW3

This word is read only when there is more than one μPD8259A in the system and cascading will be used. SNGL of ICW1 is programmed for logic 0. ICW3 will load the 8-bit slave register. The functions of this register are, in the master mode, when $\overline{SP}$ = 1 or BUF = 1 and M/S = 1 in ICW4, a 1 is set for each slave in the system. The master then releases byte 1 of the call sequence (for 8080A/8085A system) and enables the corresponding slave via the cascade lines to release vector bytes 2 and 3 (byte 2 only for 8086/8088).

In the slave mode, when $\overline{SP}$ = 0 or BUF = 1 and M/S = 0 in ICW4, bits ID_2-ID_0 identify the slave. The slave compares its cascade input with these bits and if they are equal, vector bytes 2 and 3 of the call sequence (byte 2 only for 8086/8088) are released by the slave on the data bus.

ICW4

SNFM — If SNFM = 1, the special fully nested mode is programmed.

BUF — If BUF = 1, the buffered mode is programmed. In the buffered mode, $\overline{SP}/\overline{EN}$ becomes an enable output and the master/slave determination is by M/S.

M/S — If the buffered mode is selected, M/S = 1 means the μPD8259A is programmed to be a master, M/S = 0 means the μPD8259A is programmed to be a slave. If BUF = 0, M/S has no function.

AEOI — If AEOI = 1, the automatic end of interrupt mode is programmed.

μPM — Microprocessor mode: μPM = 0 sets the μPD8259A for 8085A system operation; μPM = 1 sets the μPD8259A for 8086 system operation.

Figure 1 illustrates the command word initialization sequence.

Figure 1. Initialization Sequence

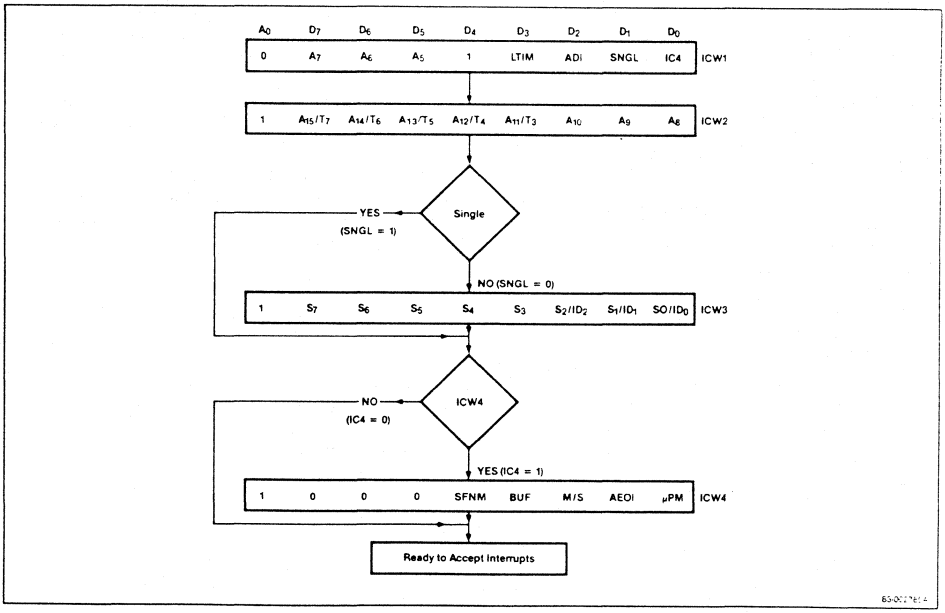
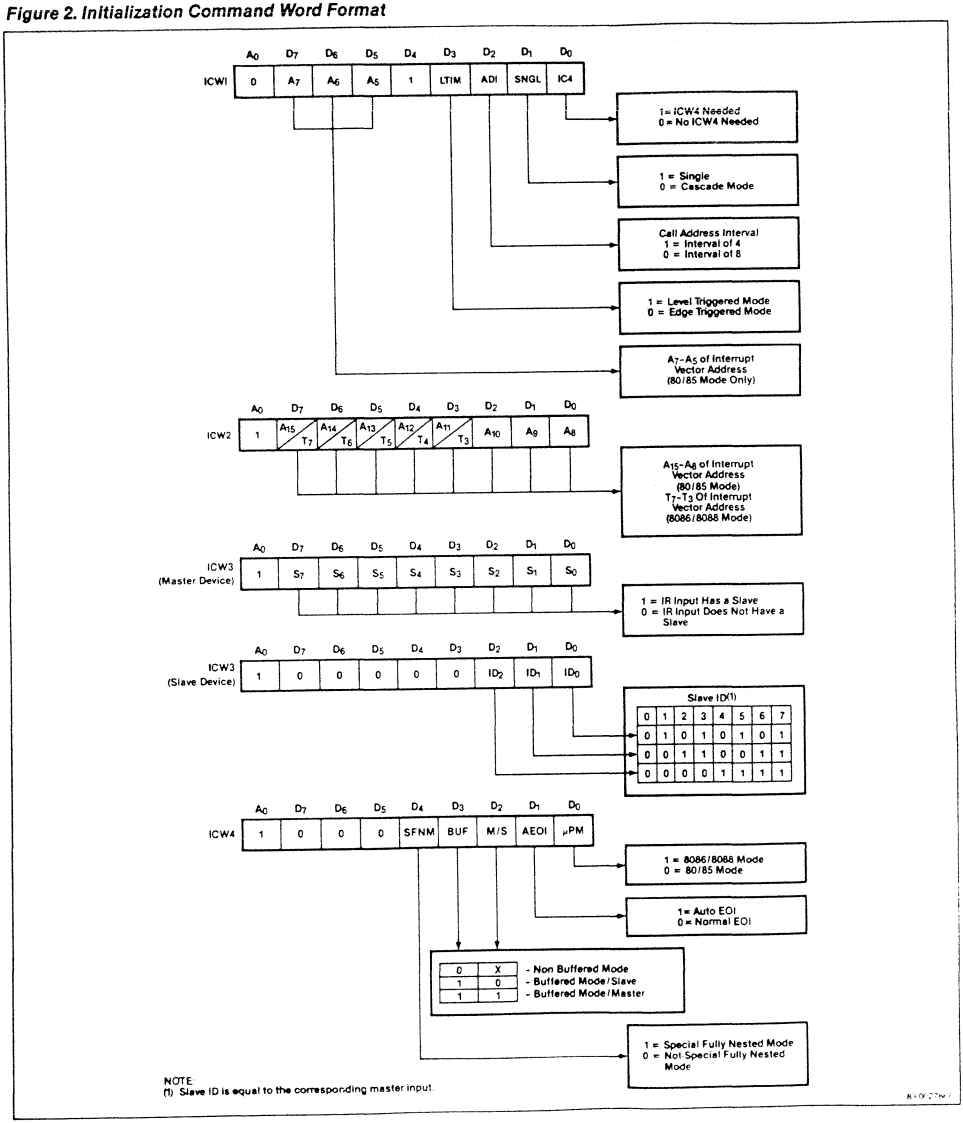


Figure 2 illustrates the initialization command word format.

Figure 2. Initialization Command Word Format



Operational Command Words

Once the μPD8259A has been programmed with initialization command words, it can be programmed for the appropriate interrupt algorithm by the operation command words (OCW). See figure 3. Interrupt algorithms in the μPD8259A can be changed at any time during program operation by issuing another set of operation command words. The following sections describe the various algorithms available and their associated OCWs.

Interrupt Masks

The individual interrupt request input lines are maskable by setting the corresponding bits in the interrupt mask register to a logic 1 through OCW1. The actual masking is performed upon the contents of the in-service register. For example, if interrupt request line 3 is to be masked, then only bit 3 of the IMR is set to logic 1. The IMR in turn acts upon the contents of the ISR to mask bit 3.

Once the μPD8259A has acknowledged an interrrupt, the masked interrupt input inhibits lower priority requests from being acknowledged. There are two means of enabling these lower priority interrupt lines. The first is by issuing an end of interrupt (EOI) through operation command word 2 (OCW2), thereby resetting the appropriate ISR bit. The second approach is to select the special mask mode through OCW3. The special mask mode (SMM) and end of interrupt (EOI) are described later.

Fully Nested Mode

The fully nested mode is the μPD8259A's basic operating mode. It will operate in this mode after the initialization sequence without requiring operation command words for formatting. The order of priority is determined by IR_0-IR_7. IR_0 has the highest priority. After the interrupt has been acknowledged by the processor and system controller, only higher priorities will be serviced. Upon receiving an $\overline{INTA}$, the priority resolver determines the priority of the interrupt, sets the corresponding IR bit, and outputs the vector address to the data bus. The EOI command resets the corresponding ISR bits at the end of its service routines.

Rotating Priority Mode Commands

The two variations of rotating priorities are the auto rotate and specific rotate modes. These two modes are typically used to service interrupting devices of equivalent priorities.

Auto Rotate Mode. Programming the auto rotate mode through OCW2 assigns priorities 0-7 to the interrupt request inputs. Interrupt line IR_0 is set to the highest priority and IR_7 to the lowest. Once an interrupt has been serviced, it is automatically assigned the lowest priority. That same input must then wait for the devices ahead of it to be serviced before it can be acknowledged again. The auto rotate mode is selected by programming OCW2 in the following way: set rotate priority bit R to a logic 1, program EOI to a logic 1 and SEOI to a logic 0. The EOI and SEOI commands are discussed later. The following is an example of the auto rotate mode with devices requesting interrupts on line IR_2 and IR_5.

(1) Before interrupts are serviced:

In-service register

IS_7	IS_6	IS_5	IS_4	IS_3	IS_2	IS_1	IS_0
0	0	1	0	0	1	0	0

Priority status register — highest priority

IR_7	IR_6	IR_5	IR_4	IR_3	IR_2	IR_1	IR_0

According to the priority status register, IR_2 has a higher priority than IR_5 and will be serviced first.

(2) After interrupts are serviced:

In-service register

IS_7	IS_6	IS_5	IS_4	IS_3	IS_2	IS_1	IS_0
0	0	1	0	0	0	0	0

Priority status register — highest priority

IR_2	IR_1	IR_0	IR_7	IR_6	IR_5	IR_4	IR_3

At the completion of IR_2's service routine, the corresponding in-service register bit (IS_2) is reset to logic 0 by the preprogrammed EOI command. IR_2 is then assigned the lowest priority level in the priority status register. The μPD8259A is now ready to service the next highest interrupt, which, in this case, happens to be IR_5.

Specific Rotate Mode. The priorities are set by programming the lowest level via OCW2. Then, the μPD8259A automatically assigns the highest priority. If, for example, IR_3 is set to the lowest priority (bits L_2, L_1, L_0 form the binary code of the bottom priority level), then IR_4 will be set to the highest priority. The specific rotate mode is selected by programming OCW2 in the following manner: set rotate priority bit R to a logic 1, program EOI to a logic 0, SEOI to a logic 1 and L_2, L_1, L_0 to the lowest priority level. If EOI is set to a logic 1, the ISR bit defined by L_2, L_1, L_0 is reset.

End of Interrupt (EOI) and Specific End of Interrupt (SEOI)

The end of interrupt (EOI) or specific end of interrupt (SEOI) command must be issued to reset the appropriate in-service register bit before the completion of a service routine. Once the ISR bit has been reset to logic 0, the μPD8259A is ready to service the next interrupt.

Two types of EOI's are available to clear the appropriate ISR bit depending on the μPD8259A's operating mode.

Non-Specific End of Interrupt (EOI). When operating in interrupt modes where the priority order of the interrupt inputs is preserved, such as the fully nested mode, the particular ISR bit to be reset at the completion of the service routine can be determined. A non-specific EOI command automatically resets the highest priority ISR bit of those set. The highest priority ISR bit must necessarily be the interrupt being serviced and must necessarily be the service subroutine returned from.

Specific End of Interrupt (SEOI). When operating in interrupt modes where the priority order of the interrupt inputs is not preserved, such as the rotating priority mode, the last serviced interrupt level may not be known. In these modes, a specific end of interrupt must be issued to clear the ISR bit at the completion of the interrupt service routine. The SEOI is programmed by setting the appropriate bits in OCW2 to logic 1's. See figure 3. Both the EOI and SEOI bits of OCW2 must be set to a logic 1 with L_2, L_1, L_0 forming the binary code of the ISR bit to be reset.

Special Mask Mode

Setting up an interrupt mask through the interrupt mask register by setting the appropriate bits in OCW1 to a logic 1 inhibits lower priority interrupts being acknowledged. In applications requiring that the lower priorities be enabled while the IMR is set, the special mask mode can be used. The SMM is programmed in OCW3 by setting the appropriate bits to a logic 1. Once the SMM is set, the μPD8259A remains in this mode until it is reset. The special mask mode does not affect the higher priority interrupts.

Poll Mode

In poll mode, the processor must be instructed to disable its interrupt input (INT). Interrupt service is initiated through software by a poll command. Poll mode is programmed by setting the poll mode bit in OCW3 to logic 1 during a WR Pulse. The following RD pulse is then considered as an interrupt acknowledge. If an interrupt input is present, the $\overline{RD}$ pulse sets the appropriate ISR bit and reads the interrupt priority level. Poll mode is a one time operation and must be programmed through OCW3 before every read. The word format which is strobed onto the data bus during the poll mode follows:

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
I	X	X	X	X	W_2	W_1	W_0

where:
I = 1 if there is an interrupt requesting service
I = 0 if there are no interrupts
W_2-W_0 forms the binary code of the highest priority level of the interrupts requesting service.

Poll mode can be used when an interrupt service routine is common to several interrupt inputs. The $\overline{INTA}$ sequence is no longer required; this saves ROM space. Poll mode can also be used to expand the number of interrupts beyond 64.

Reading μPD8259A Status

The following major registers' status is available to the processor by appropriately formatting OCW3 and issuing $\overline{RD}$ command.

Interrupt Request Register

The 8-bit interrupt request register stores the interrupt levels awaiting acknowledgement. The highest priority in-service bit is reset once it has been acknowledged. Note that the interrupt mask register has no effect on the IRR. Prior to the issuing of the $\overline{RD}$ command, a $\overline{WR}$ command must be issued with OCW3. Programmable logic bits RIS and ERIS of OCW3 determine whether the IRR or ISR register is to be read. To read the contents of the IRR, ERIS must be a logic 1, and RIS a logic 0.

In-Service Register

The 8-bit in-service register stores the priorities of the interrupt levels being serviced. Assertion of an end of interrupt (EOI) updates the ISR to the next priority level. A $\overline{WR}$ command must be issued with OCW3 prior to issuing the $\overline{RD}$ command. both ERIS and RIS should be set to logic 1.

Interrupt Mask Register

The 8-bit interrupt mask register holds mask data modifying interrupt levels. A $\overline{WR}$ pulse preceding the $\overline{RD}$ is not necessary to read the IMR status. The IMR data is available to the data bus when $\overline{RD}$ is asserted with A_0 at logic 1.

A single OCW3 is sufficient to enable succesive status reads providing it is of the same register. A status read is overridden by the poll mode when bits P and ERIS of OCW3 are set to logic 1.

Figure 3. Operation Command Word Format

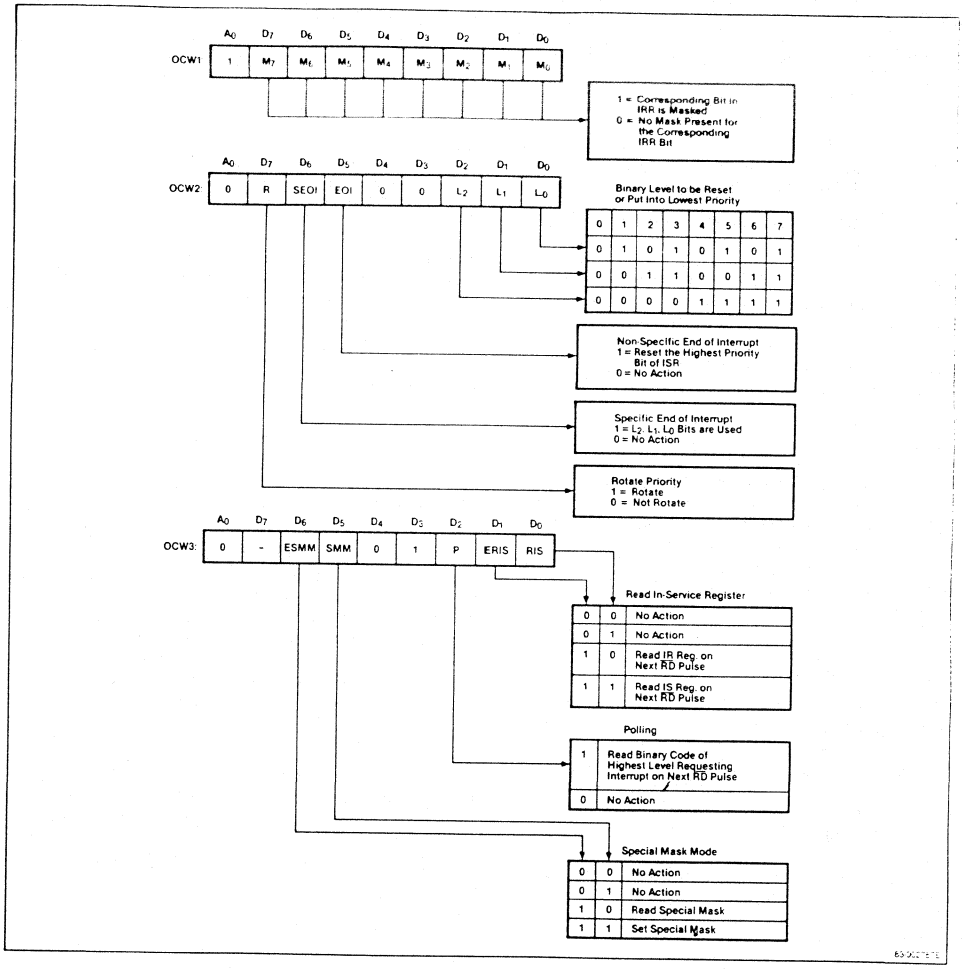
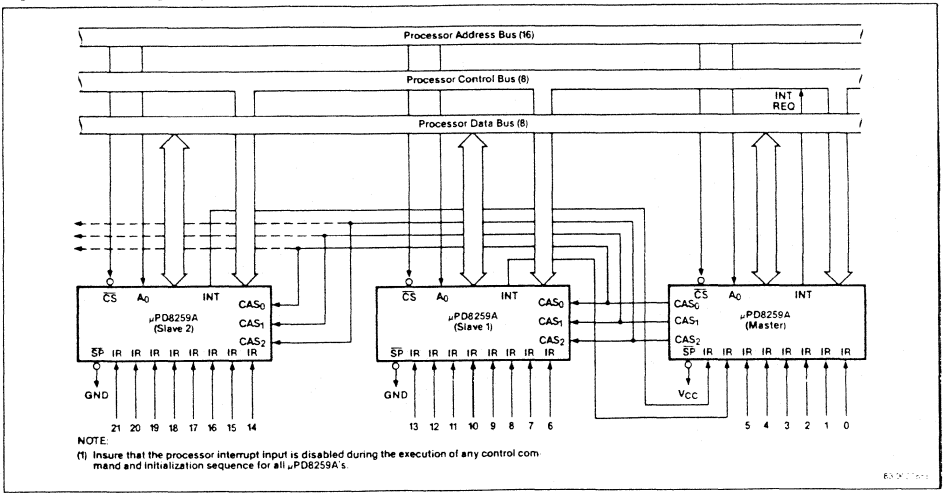


Table 6. Summary of Operation Command Word Programming

	A_0	D_4	D_3				
OCW1	1	X	X	M_7–M_0			IMR (interrupt mask register) $\overline{WR}$ loads IMR data while $\overline{RD}$ reads status
OCW2	0	0	0	R	SEOI	EOI	
				0	0	0	No action
				0	0	1	Non-specific end of interrupt
				0	1	0	No action
				0	1	1	Specific end of interrupt L_2, L_1, L_0 forms binary representation of level to be reset
				1	0	0	No action
				1	0	1	Rotate priority at end of interrupt (auto mode)
				1	1	0	Rotate priority, L_2, L_1, L_0 specifies bottom priority without end of interrupt
				1	1	1	Rotate priority at end of interrupt (specific mode). L_2, L_1, L_0 specifies bottom priority, and it is in-service register bit is reset

	A_0	D_4	D_3			
OCW3	0	0	1	ESMM	SMM	
				0	0	} Special mask not affected
				0	1	Special mask not affected
				1	0	Reset special mask
				1	1	Set special mask
				ERIS	RIS	
				0	0	} No action
				0	1	No action
				1	0	Read IR register status
				1	1	Read IS register status

Figure 4. Cascading the μPD8259A



NOTE:
(1) Insure that the processor interrupt input is disabled during the execution of any control command and initialization sequence for all μPD8259A's.

Instruction Set

#	Mnemonic	Operation Description	Operation Code D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	A_0	Format
(Byte 1 Initialization, No ICW4 Required)												
1	ICW1 A	Single, edge triggered	A_7	A_6	A_5	1	0	1	1	0	0	4
2	ICW1 B	Single, level triggered	A_7	A_6	A_5	1	1	1	1	0	0	4
3	ICW1 C	Not single, edge triggered	A_7	A_6	A_5	1	0	1	0	0	0	4
4	ICW1 D	Not single, level triggered	A_7	A_6	A_5	1	1	1	0	0	0	4
5	ICW1 E	Single, edge triggered	A_7	A_6	0	1	0	0	1	0	0	8
6	ICW1 F	Single, level triggered	A_7	A_6	0	1	1	0	1	0	0	8
7	ICW1 G	Not single, edge triggered	A_7	A_6	0	1	0	0	0	0	0	8
8	ICW1 H	Not single, level triggered	A_7	A_6	0	1	1	0	0	0	0	8
(Byte 1 Initialization, ICW4 Required)												
9	ICW1 I	Single, edge triggered	A_7	A_6	A_5	1	0	1	1	1	0	4
10	ICW1 J	Single, level triggered	A_7	A_6	A_5	1	1	1	1	1	0	4
11	ICW1 K	Not single, edge triggered	A_7	A_6	A_5	1	0	1	0	1	0	4
12	ICW1 L	Not single, level triggered	A_7	A_6	A_5	1	1	1	0	1	0	4
13	ICW1 M	Single, edge triggered	A_7	A_6	0	1	0	0	1	1	0	8
14	ICW1 N	Single, level triggered	A_7	A_6	0	1	1	0	1	1	0	8
15	ICW1 O	Not single, edge triggered	A_7	A_6	0	1	0	0	0	1	0	8
16	ICW1 P	Not single, level triggered	A_7	A_6	0	1	1	0	0	1	0	8
(Byte 2 Initialization)												
17	ICW2	Initialize byte 2	A_{15}	A_{14}	A_{13}	A_{12}	A_{11}	A_{10}	A_9	A_8	1	
(Byte 3 Initialization)												
18	ICW3 M	Initialize byte 3 (master)	S_7	S_6	S_5	S_4	S_3	S_2	S_1	S_0	1	
19	ICW3 S	Initialize byte 3 (slave)	0	0	0	0	0	S2	S_1	S_0	1	
(Byte 4 Initialization)												
20	ICW4 A	No action, redundant	0	0	0	0	0	0	0	0	1	
21	ICW4 B	Non-buffered, no AEOI, 8086 / 8088	0	0	0	0	0	0	0	1	1	
22	ICW4 C	Non-buffered, AEOI, 80 / 85	0	0	0	0	0	0	1	0	1	
23	ICW4 D	Non-buffered, AEOI, 8086 / 8088	0	0	0	0	0	0	1	1	1	
24	ICW4 E	No action, redundant	0	0	0	0	0	1	0	0	1	
25	ICW4 F	Non-buffered, no AEOI, 8086 / 8088	0	0	0	0	0	1	0	1	1	
26	ICW4 G	Non-buffered AEOI, 80 / 85	0	0	0	0	0	1	1	0	1	
27	ICW4 H	Non-buffered, AEOI, 8086 / 8088	0	0	0	0	0	1	1	1	1	
28	ICW4 I	Buffered, slave, no AEOI, 80 / 85	0	0	0	0	1	0	0	0	1	
29	ICW4 J	Buffered, slave, no AEOI, 8086 / 8088	0	0	0	0	1	0	0	1	1	
30	ICW4 K	Buffered, slave, AEOI, 80 / 85	0	0	0	0	1	0	1	0	1	
31	ICW4 L	Buffered, slave, AEOI, 8086 / 8088	0	0	0	0	1	0	1	1	1	
32	ICW4 M	Buffered, master, no AEOI, 80 / 85	0	0	0	0	1	1	0	0	1	
33	ICW4 N	Buffered, master, no AEOI, 8086 / 8088	0	0	0	0	1	1	0	1	1	

Instruction Set (cont)

#	Mnemonic	Operation Description	Operation Code									Format
			D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	A_0	
(Byte 4 Initialization) (cont)												
34	ICW4 O	Buffered, master, AEOI, 80/85	0	0	0	0	1	1	1	0	1	
35	ICW4 P	Buffered, master, AEOI, 8086/8088	0	0	0	0	1	1	1	1	1	
36	ICW4 NA	Fully nested, non-buffered, no AEOI, 8085A	0	0	0	1	0	0	0	0	1	
37	ICW4 NB	ICW4 NB-ICW4 ND are identical to ICW4 B-ICW4 D with the addition of fully nested mode	0	0	0	1	0	0	0	1	1	
38	ICW4 NC	ICW4 NB-ICW4 ND are identical to ICW4 B-ICW4 D with the addition of fully nested mode	0	0	0	1	0	0	1	0	1	
39	ICW4 ND	ICW4 NB-ICW4 ND are identical to ICW4 B-ICW4 D with the addition of fully nested mode	0	0	0	1	0	0	1	1	1	
40	ICW4 NE	Fully nested, non-buffered, no AEOI, 80/85	0	0	0	1	0	1	0	0	1	
41	ICW4 NF	ICW4 NF-ICW4 NP are identical to ICW4 F-ICW4 P with the addition of fully nested mode	0	0	0	1	0	1	0	1	1	
42	ICW4 NG	ICW4 NF-ICW4 NP are identical to ICW4 F-ICW4 P with the addition of fully nested mode	0	0	0	1	0	1	1	0	1	
43	ICW4 NH	ICW4 NF-ICW4 NP are identical to ICW4 F-ICW4 P with the addition of fully nested mode	0	0	0	1	0	1	1	1	1	
44	ICW4 NI	ICW4 NF-ICW4 NP are identical to ICW4 F-ICW4 P with the addition of fully nested mode	0	0	0	1	1	0	0	0	1	
45	ICW4 NJ	ICW4 NF-ICW4 NP are identical to ICW4 F-ICW4 P with the addition of fully nested mode	0	0	0	1	1	0	0	1	1	
46	ICW4 NK	ICW4 NF-ICW4 NP are identical to ICW4 F-ICW4 P with the addition of fully nested mode	0	0	0	1	1	0	1	0	1	
47	ICW4 NL	ICW4 NF-ICW4 NP are identical to ICW4 F-ICW4 P with the addition of fully nested mode	0	0	0	1	1	0	1	1	1	
48	ICW4 NM	ICW4 NF-ICW4 NP are identical to ICW4 F-ICW4 P with the addition of fully nested mode	0	0	0	1	1	1	0	0	1	
49	ICW4 NN	ICW4 NF-ICW4 NP are identical to ICW4 F-ICW4 P with the addition of fully nested mode	0	0	0	1	1	1	0	1	1	
50	ICW4 NO	ICW4 NF-ICW4 NP are identical to ICW4 F-ICW4 P with the addition of fully nested mode	0	0	0	1	1	1	1	0	1	
51	ICW4 NP	ICW4 NF-ICW4 NP are identical to ICW4 F-ICW4 P with the addition of fully nested mode	0	0	0	1	1	1	1	1	1	
52	OCW1	Load mask and read mark registers	M_7	M_6	M_5	M_4	M_3	M_2	M_1	M_0	1	
53	OCW2 E	Non-specific EOI	0	0	1	0	0	0	0	0	0	
54	OCW2 SE	Specific EOI, L_0-L_2 code of IS FF to be reset	0	1	1	0	0	L_2	L_1	L_0	0	
55	OCW2 RE	Rotate on non-specific EOI	1	0	1	0	0	0	0	0	0	
56	OCW2 RSE	Rotate on specific EOI L_0-L_2 code of line	1	1	1	0	0	L_2	L_1	L_0	0	
57	OCW2 R	Rotate in auto EOI (set)	1	0	0	0	0	0	0	0	0	
58	OCW2 CR	Rotate in auto EOI (clear)	0	0	0	0	0	0	0	0	0	
59	OCW2 RS	Set priority command	1	1	0	0	0	L_2	L_1	L_0	0	
60	OCW3 P	Poll mode	0	0	0	0	1	1	0	0	0	
61	OCW3 RIS	Read IS register	0	0	0	0	1	0	1	1	0	

Description

The μPD8279 is a programmable keyboard and display input/output device providing the user with the ability to display data on alphanumeric segment displays or simple indicators. The display RAM can be programmed to function as a 16 x 8-bit or dual 16 x 4-bit memory and can be loaded or read by the host processor. The display can be loaded with right or left entry with an auto-increment of the display RAM address.

The keyboard interface provides a scanned signal to a 64 contact key matrix expandable to 128. General sensors or strobed keys may also be used. Keystrokes are stored in an 8 character FIFO and can be either 2 key lockout or N key rollover. Keyboard entries generate an interrupt to the processor.

Features

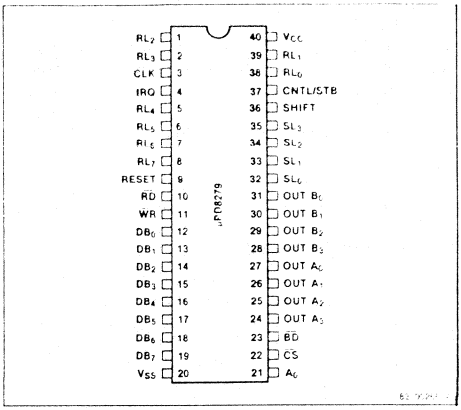
- ☐ Programmable by processor
- ☐ 32 hex or 16 alphanumeric displays
- ☐ 64 expandable to 128 keyboard
- ☐ Simultaneous keyboard and display
- ☐ 8 character keyboard—FIFO
- ☐ 2 key lockout or N key rollover
- ☐ Contact debounce
- ☐ Programmable scan timer
- ☐ Interrupt on key entry
- ☐ Single +5 V ±10% power supply
- ☐ Fully compatible with 8080A, 8085A, μPD780 (Z80®)

® Z80 is a registered trademark of Zilog, Inc.

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD8279C-2	40-pin plastic DIP	5 MHz
μPD8279C-5	40-pin plastic DIP	3 MHz

Pin Configuration



Pin Identification

No.	Symbol	Function
1,2,5,6,7,8,38,39	RL_0-RL_7	Return lines
3	CLK	Clock input
4	IRQ	Interrupt request
9	RESET	Reset input
10	$\overline{RD}$	Read input
11	$\overline{WR}$	Write input
12-19	DB_0-DB_7	Data bus
20	V_{SS}	Ground reference
21	A_0	Buffer address
22	$\overline{CS}$	Chip select
23	$\overline{BD}$	Blank display output
24-27	OUT A_0-OUT A_3	Display A outputs
28-31	OUT B_0-OUT B_3	Display B outputs
32-35	SL_0-SL_3	Scan lines
36	Shift	Shift input
37	CNTL/STB	Control/strobe input
40	V_{CC}	+5 V input

Pin Functions

RL_0-RL_7 (Return Lines)

Return line inputs which are connected to the scan lines through the keys or sensor switches. They have active internal pullups to keep them high until a switch closure pulls one low. They also serve as an 8-bit input in the strobed input mode.

CLK (Clock)

Clock from system used to generate internal timing.

IRQ (Interrupt Request)

In a keyboard mode, the interrupt line is high when there is data in the FIFO/sensor RAM. The interrupt line goes low with each FIFO/sensor RAM read and returns high if there is still information in the RAM. In the sensor mode, the interrupt line goes high whenever a change in a sensor is detected.

RESET (Reset)

A high signal on this pin resets the μPD8279.

$\overline{RD}$ (Read Input)

Input read allows the data buffers to send data to the external bus.

$\overline{WR}$ (Write Input)

Input write allows the data buffers to receive data from the external bus.

DB_0-DB_7 (Data Bus)

Bidirectional data bus. All data and commands between the processor and the μPD8279 are transmitted on these lines.

OUT A_0-OUT A_3 (Display A Outputs)

Output port for the 16 x 4 display refresh registers. The output data is synchronized to the scan lines (SL_0-SL_3) for multiplexed digit displays. Ports A and B may be blanked independently and may also be considered as one 8-bit port.

OUT B_0-OUT B_3 (Display B Outputs)

Output port for the 16 x 4 display refresh registers. The output data is synchronized to the scan lines (SL_0-SL_3) for multiplexed digit displays. Ports A and B may be blanked independently and may also be considered as one 8-bit port.

SL_0-SL_3 (Scan Lines)

Scan lines which are used to scan the key switch or sensor matrix and the display digits. These lines can be either encoded (1 of 16) or decoded (1 of 4).

A_0 (Buffer Address)

A high on this line indicates the signals in or out are interpreted as a command or status. A low indicates that they are data.

$\overline{CS}$ (Chip Select)

A low on this pin enables the interface functions to receive or transmit.

$\overline{BD}$ (Blank Display Output)

This output is used to blank the display during digit switching or by a display blanking command.

SHIFT (Shift)

The shift input status is stored along with the key position on key closure in the scanned keyboard modes. It has an active internal pullup to keep it high until a switch closure pulls it low.

CNTL/STB (Control/Strobe Input)

For keyboard modes this line is used as a control input and stored like status on a key closure. The line is also the strobe line that enters the data into the FIFO in strobed input mode (rising edge). It has an active internal pullup to keep it high until a switch closure pulls it low.

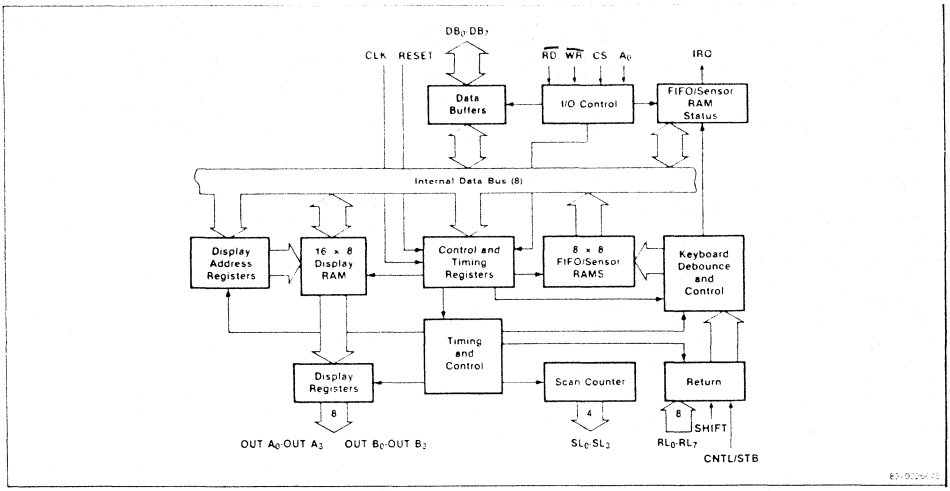
V_{SS} (Ground Reference)

Ground.

V_{CC} (Power Supply)

+5 V power supply input.

Block Diagram



Functional Description

The μPD8279 has two basic functions: 1) to control displays to output and 2) to control a keyboard for input. Its specific purpose is to unburden the host processor from monitoring keys and refreshing displays. The μPD8279 is designed to directly interface with the microprocessor bus. The microprocessor must program the operating mode to the μPD8279 as follows:

Output Modes

- 8 or 16 character display
- Right or left entry display formats

Input Modes

- Scanned keyboard with encoded (8 x 8 key keyboard) or decoded (4 x 8 key keyboard) scan lines.
- Scanned sensor matrix with encoded (8 x 8 matrix switches) or decoded (4 x 8 matrix switches) scan lines.
- Strobed input with data on return lines during control line strobe being transferred to FIFO.

Block Diagram

Following is a description of each section of the μPD8279. See the block diagram for functional reference.

I/O Control and Data Buffers

Communication to and from the μPD8279 is performed by selecting $\overline{CS}$, A_0, $\overline{RD}$ and $\overline{WR}$. The type of information written or read by the processor is selected by A_0. A logic 0 states that information is data while a 1 selects command or status. $\overline{RD}$ and $\overline{WR}$ select the direction by which the transfer occurs through the data buffers. When the chip is deselected ($\overline{CS}$ = 1) the bidirectional data buffers are in a high impedance state. This enables the μPD8279 to be tied directly to the processor bus.

Timing Registers and Timing Control

The timing registers store the display and keyboard modes and other conditions programmed by the processor. The timing control contains the timing counter chain. One counter is a divide-by-N scaler, which may be programmed to match the processor cycle time. The scaler is programmed with a value between 2 and 31 to divide the external clock input by N to yield the internal clock frequency. A value which scales the internal frequency to 100 kHz gives a 5.1 ms scan time and 10.3 ms switch debounce. The other counters divide down to make key, row matrix, and display scans.

Scan Counter

The scan counter can operate in either the encoded or decoded mode. In the encoded mode, the counter provides a count which must be decoded to provide the scan lines. In the decoded mode, the counter provides a 1 out of 4 decoded scan. In the encoded mode, the scan lines are active high, and in the decoded mode, they are active low.

Return Buffers, Keyboard Debounce and Control

The eight return lines are buffered and latched by the return buffers. In the keyboard mode these lines are scanned to sample for key closures in each row. If the debounce circuit senses a closure, about 10 ms are timed out and a check is performed again. If the switch is still pressed, the address of the switch matrix plus the status of shift and control are written into the FIFO. In the scanned sensor mode, the contents of return lines are sent directly to the sensor RAM (FIFO) each key scan. In the strobed mode, the transfer takes place on the rising edge of CNTL/STB.

FIFO/Sensor RAM and Status

This section is a dual purpose 8 x 8 RAM. In strobe or keyboard mode it is a FIFO. Each entry is pushed into the FIFO and read in order. Status keeps track of the number of entries in the FIFO. Too many reads or writes to the FIFO will be treated as an error condition. The status logic generates an IRQ whenever the FIFO has an entry. In the sensor mode the memory is a sensor RAM which detects changes in the status of a sensor. If a change occurs, the IRQ is generated until the change is acknowledged.

Display Address Registers and Display RAM

The display address register contains the address of the word being read or written by the processor, as well as the word being displayed. This address may be programmed to autoincrement after each read or write. The display RAM may be read by the processor any time after the mode and address is set. Data entry to the display RAM may be set to either right or left entry.

Command Operation

The commands programmable to the μPD8279 via the data bus with $\overline{CS}$ active (0) and A_0 high are as follows:

Keyboard/Display Mode Set

0	0	0	D	D	K	K	K

Display Mode:

D	D	
0	0	Eight 8-bit character display—left entry
0	1 (1)	Sixteen 8-bit character display—left entry
1	0	Eight 8-bit character display—right entry
1	1	Sixteen 8-bit character display—right entry

Note:

(1) Power on default condition.

Keyboard Mode:

K	K	K	
0	0	0	Encoded scan—2 key lockout
0	0	0	Decoded scan—2 key lockout
0	1	0	Encoded scan—N key rollover
0	1	1	Decoded scan—N key rollover
1	0	0	Encoded scan—sensor matrix
1	0	1	Decoded scan—sensor matrix
1	1	0	Strobed input, encoded display scan
1	1	1	Strobed input, decoded display scan

Program Clock

0	0	1	P	P	P	P	P

Where PPPPP is the prescaler value between 2 and 31. This prescaler divides the external clock by PPPPP to develop its internal frequency. After reset, a default value of 31 is generated.

Read FIFO/Sensor RAM

0	1	0	A_1	X	A	A	A	$A_0 = 0$

A_1 is the autoincrement flag. AAA is the row to be read by the processor. The read command is accomplished with ($\overline{CS} \cdot RD \cdot \overline{A0}$) by the processor. If A_1 is 1, the row select counter will be incremented after each read. Note that autoincrementing has no effect on the display.

Read Display RAM

0	1	1	A_1	X	A	A	A	$A_0 = 0$

Where A_1 is the autoincrement flagg and AAAA is the character which the processor is about to read.

Write Display RAM

1	0	0	A_1	A	A	A	A

Where AAAA is the character the processor is about to write.

Display Write Inhibit Blanking

1	0	1	X	IW	IW	BL	BL
				A	B	A	B

Where IWA and IWB are inhibit writing nibble A and B respectively, while BLA and BLB are used for blanking. When using the display as a dual 4-bit, it is necessary to mask one of the 4-bit halves to eliminate interaction between the two halves. This in accomplished with the IW flags. The BL flags allow the programmer to blank either half of the display independently. To blank a display formatted as a single 8-bit, it is necessary to set both BLA and BLB. Default after a reset is all zeros. All signals are active high (logic 1).

Clear

1	1	0	C_D	C_D	C_D	C_F	C_A

Where:

C_D	C_D	C_D	
1	0	X	All zeros
1	1	0	AB = 20H
1	1	1	All ones
0	X	X	Disable clear display

This command is used to clear the display RAM, the FIFO, or both. The C_D options allow the user the ability to clear the display RAM to either all zeros or all ones. Clearing the display takes one complete display scan. During this time the processor can't write to the display RAM.

If the C_F bit is set to logic 1, the FIFO status is cleared, the FIFO empty flag is set, and IRQ is cleared. The sensor matrix mode RAM pointer will then be set to row 0.

C_A, the clear all bit, has the combined effect of C_F and C_D; it uses the C_D clearing code on the display RAM and also clears FIFO status. It also resynchronizes the internal timing chain.

End Interrupt/Error Mode Set

1	1	1	E	X	X	X	X

In the sensor matrix mode, this instruction clears IRQ and allows writing into RAM. In N key rollover, setting the E bit to 1 allow for operating in the special error mode. See description of FIFO status.

FIFO Status

D_U	S/E	O	U	F	N	N	N

Where:

- DU = Display unavailable because a clear display or clear all command is in progress.
- S/E = Sense error flag due to multiple closure of switch matrix.
- O = FIFO overrun since an attempt was made to push too many characters into the FIFO.
- U = FIFO underrun. An indication that the processor tried to read an empty FIFO.
- F = FIFO full flag.
- NNN = The number of characters presently in FIFO.

The FIFO status is read with A_0 high and $\overline{CS}$, $\overline{RD}$ active low.

If the C_D or C_A command has not completed its clearing, the display is not available. The S/E flags are used to show an error in multiple closures has occurred. The O or U, overrun or underrun, flags occur when too many characters are written into the FIFO or the processor tries to read an empty FIFO. F is an indication that the FIFO is full and NNN is the number of characters in the FIFO.

Data Read

Data can be read during A_0 = 0 and when $\overline{CS}$, $\overline{RD}$ are active low. The source of data is determined by the read display or read FIFO commands.

Data Write

Data is written to the chip when A_0, $\overline{CS}$, and $\overline{WR}$ are active low. Data will be written into the display RAM with its address selected by the latest read or write display command.

Data Format

CNTL	SH	SCAN	RET

In the scanned key mode, the characters in the FIFO correspond to the above format where CNTL and SH are the most significant bits and the SCAN and return lines are the scan and column counters.

RL_7	RL_6	RL_5	RL_4	RL_3	RL_2	RL_1	RL_0

In the sensor matrix mode, the data corresponds directly to the row of the sensor RAM being scanned. Shift and control (SH, CNTL) are not used in this mode.

Command Word Summary

0	0	0	D	D	K	K	K	Keyboard display mode set
0	0	1	P	P	P	P	P	Load program clock
0	1	0	A_1	X	A	A	A	Read FIFO/sensor RAM
0	1	1	A_1	A	A	A	A	Read display RAM
1	0	0	A_1	A	A	A	A	Write display RAM
1	0	1	X	IW A	IW B	BL A	BL B	Display write inhibit/blanking
1	1	0	C_D	C_D	C_D	C_F	C_A	Clear
1	1	1	E	X	X	X	X	End interrupt/error mode set
D_U	S/E	0	U	F	N	N	N	FIFO status

Absolute Maximum Ratings

T_A = 25°C

Power supply voltage, V_{DD}	−0.5 V to +7.0 V(1)
Power dissipation, P_D	1.0 W
Operating temperature, T_{OPT}	0°C to +70°C
Storage temperature, T_{STG}	−65°C to +150°C

Note:

(1) With respect to V_{SS}.

Comment: Exposing the device to stresses above those listed in the absolute maximum ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum ratings for extended periods may affect device reliability.

Capacitance

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input capacitance	C_I	5		10	pF	$V_I = V_{CC}$
Output capacitance	C_O	10		20	pF	$V_O = V_{CC}$

DC Characteristics

T_A = 0°C to +70°C; V_{CC} = 5 V ±10%; V_{SS} = 0 V

Parameter	Symbol	Limits Min	Max	Unit	Test Conditions
Input high voltage for return lines	V_{IH1}	2.2		V	
Input high voltage for other lines	V_{IH2}	2.0		V	
Input low voltage for return lines	V_{IL1}	−0.5	1.4	V	
Input low voltage for other lines	V_{IL2}	−0.5	0.8	V	
Output high voltage on interrupt line	IRQ pin	+3.5		V	I_{OH} = −50 μA
	others	+2.4		V	I_{OH} = −400 μA
Output low voltage	V_{OL}		0.45	V	I_{OL} = 2.2 mA
Input current on shift, control and return lines	I_{IL1}		+10	μA	$V_I = V_{CC}$
			−100	μA	V_I = 0 V
Input leakage current for other lines	I_{IL2}		±10	μA	$V_I = V_{CC}$ to 0 V
Output float leakage	I_{OFL}		±10	μA	$V_O = V_{CC}$ to 0 V
Power supply current	I_{CC}		120	mA	

AC Characteristics

T_A = 0°C to +70°C, V_{CC} = 5 V ± 10%, V_{SS} = 0 V

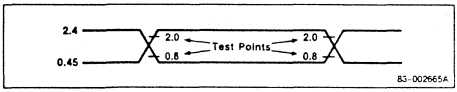
Parameter	Symbol	μPD8279-5 Limits Min	μPD8279-5 Limits Max	μPD8279-2 Limits Min	μPD8279-2 Limits Max	Unit	Test Conditions
Read							
Address stable before $\overline{read}$	t_{AR}	0		0		ns	
Address hold time for $\overline{read}$	t_{RA}	0		0		ns	
$\overline{Read}$ pulse width	t_{RR}	250		200		ns	
Data delay from $\overline{read}$	t_{RD}		150		140	ns	C_L = 150 pF
Address to data valid	t_{AD}		250		250	ns	C_L = 150 pF
$\overline{Read}$ to data floating	t_{DF}	10	100	10	100	ns	
Read cycle time	t_{RCY}	1000		200		ns	
Write							
Address stable before $\overline{write}$	t_{AW}	0		0		ns	
Address hold time for $\overline{write}$	t_{WA}	0		0		ns	
$\overline{Write}$ pulse width	t_{WW}	250		200		ns	
Data set up time for $\overline{write}$	t_{DW}	150		150		ns	
Data hold time for $\overline{write}$	t_{WD}	0		0		ns	
Write cycle time	t_{WCY}	1000		200		ns	
Other							
Clock pulse width	$t_{\phi W}$	120		70		ns	
Clock period	t_{CY}	320		200		ns	

General Timing

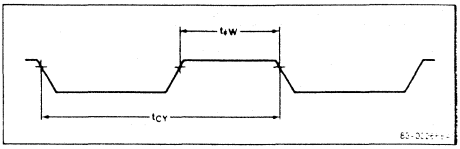
Keyboard scan time	5.1 ms
Keyboard debounce time	10.3 ms
Key scan time	80 μs
Display scan time	10.3 ms
Digit-on time	480 μs
Blanking time	160 μs
Internal clock cycle	10 μs

Timing Waveforms

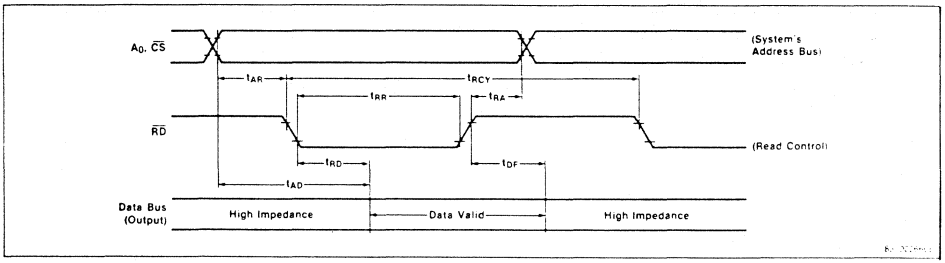
AC Test Input



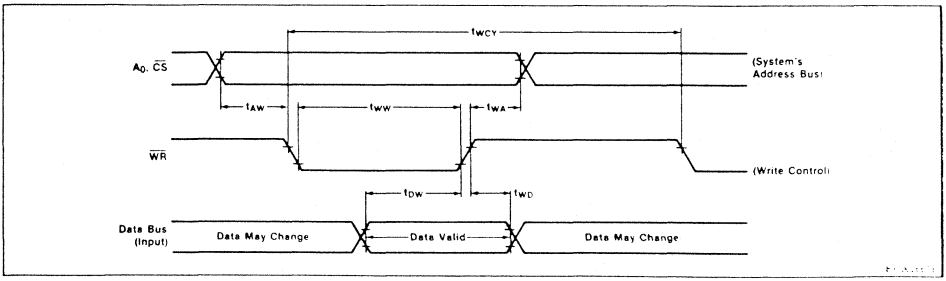
Clock Input



Read



Write



Description

The μPB8282 and μPB8283 are 8-bit latches with three-state output buffers. The μPB8282 is non-inverting and the μPB8283 inverts the input data. These devices are ideal for demultiplexing the address/data buses on the 8085A/8086 microprocessors. The μPB8282/83 are fabricated using NEC's Schottky bipolar process.

Features

- ☐ Support μPB8080, 8085A, 8048, 8086 family systems
- ☐ Transparent during active strobe
- ☐ Fully parallel 8-bit data register and buffer
- ☐ High output drive capability (32 mA) for driving the system data bus
- ☐ Three-state outputs

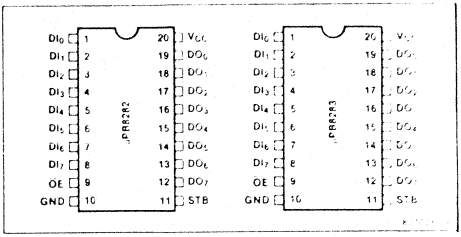
Ordering Information

Part Number	Package Type	Output Drive Capability
μPB8282C	20-pin plastic DIP	32 mA
μPB8283C	20-pin plastic DIP	32 mA

Pin Identification

No.	Symbol	Function
1-8	DI_0-DI_7	Data in
9	$\overline{OE}$	Output enable
10	GND	Ground
11	STB	Strobe
12-19	(μPB8282) DO_7-DO_0 (μPB8283) $\overline{DO_7}$-$\overline{DO_0}$	Data out
20	V_{CC}	Power supply

Pin Configurations



Pin Functions

$\overline{OE}$ (Output Enable)

This active low input control signal enables the contents of the data latches onto the data output pins (B_0-B_7). When $\overline{OE}$ goes high, the output buffers become high impedance.

STB (Strobe)

This input control pulse strobes data at input A_0-A_7 into the data latches. Data is latched at STB's high to low transition. When active high, STB admits input data.

DI_0-DI_7 (Data In)

When data that satisfies the STB strobe setup time requirements is input to these pins, it is latched into the data latches.

DO_0-DO_7 (μPB8282) (Data Out)
$\overline{DO_0}$-$\overline{DO_7}$ (μPB8283)

When $\overline{OE}$ is active (low), it outputs data to the DO_0-DO_7 pins. When $\overline{OE}$ is inactive high, DO_0-DO_7 are high impedance. Enabling or disabling the output buffers will not cause negative-going transients to appear on the data output bus.

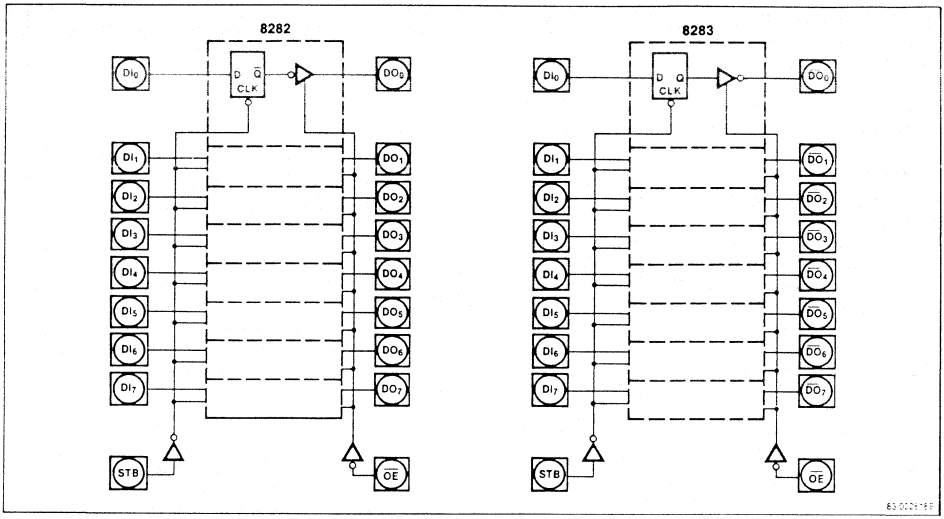
GND (Ground)

This is the ground.

V_{CC} (Power Supply)

This is the +5 V power supply.

Block Diagrams



Functional Description

The μPB8282/83 are 8-bit latches with three-state output buffers. Data on the inputs is latched into the data latches on a high-to-low transition of the STB line. When STB is high, the latches appear transparent. The $\overline{OE}$ input enables the latched data to be transferred to the output pins. When $\overline{OE}$ is high, the outputs are put in the three-state condition. $\overline{OE}$ will not cause transients to appear on the data outputs.

Absolute Maximum Ratings

T_A = 25°C

Operating temperature	0°C to +70°C
Storage temperature	−65°C to +150°C
All output and supply voltages	−0.5 to +7 V
All input voltages	−1.0 V to 5.5 V

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

T_A = 0°C to +70°C; V_{CC} = +5 V ±10%

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Input clamp voltage	V_C		−1	V	I_C = −5 mA
Power supply current	I_{CC}		160	mA	
Forward input current	I_F		−0.2	mA	V_F = 0.45 V
Reverse input current	I_R		50	μA	V_R = 5.25 V
Output low voltage	V_{OL}		0.45	V	I_{OL} = 32 mA
Output high voltage	V_{OH}	2.4		V	I_{OH} = −5 mA
Output off current	I_{OFF}		±50	μA	V_{OFF} = 0.45 to 5.25 V
Input low voltage	V_{IL}		0.8	V	V_{CC} = 5.0 V (1)
Input high voltage	V_{IH}	2.0		V	V_{CC} = 5.0 V (1)
Input capacitance	C_{IN}		12	pF	V_{BIAS} = 2.5 V, V_{CC} = 5 V, T_A = 25°C F = 1 MHz

Note:

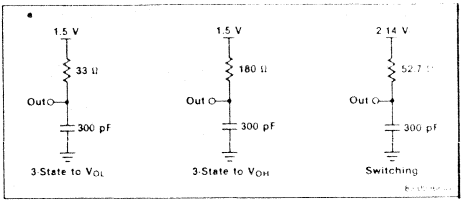
(1) Output loading I_{OL} = 32 mA, I_{OH} = −5 mA, C_L = 300 pF

AC Characteristics

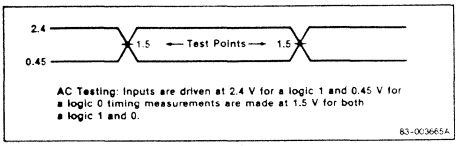
T_A = 0°C to +70°C, V_{CC} = 5 V ± 10%
I_{OL} = 32 mA, I_{OH} = −5 mA, C_L = 300 pF

Parameter	Symbol	Limits Min	Limits Max	Unit
Input to output delay	t_{IVOV}			
—Inverting		5	22	ns
—Non-inverting		5	30	ns
STB to output delay	t_{SHOV}			
—Inverting		10	40	ns
—Non-inverting		10	45	ns
Output disable time	t_{EHOZ}	5	22	ns
Output enable time	t_{ELOV}	10	30	ns
Input to STB setup time	t_{IVSL}	0		ns
Input to STB hold time	t_{SLIX}	25		ns
STB high time	t_{SHSL}	15		ns
Input, output rise time	t_{ILIH}, t_{OLOH}		20	ns
Input, output fall time	t_{IHIL}, t_{OHOL}		12	ns

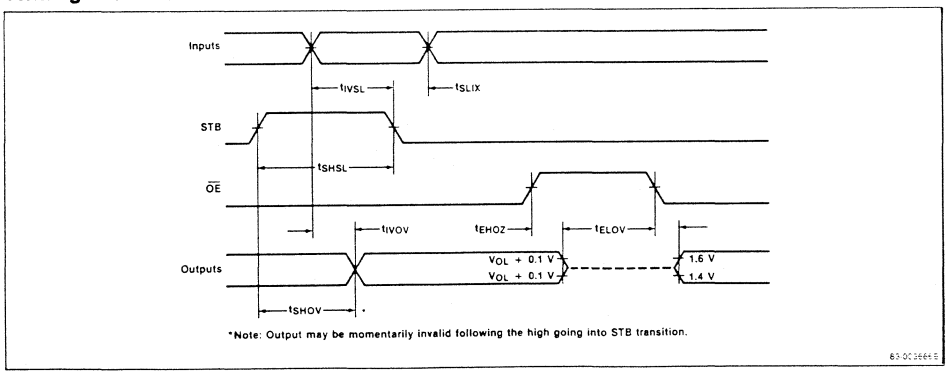
Load Circuits



AC Test Points



Timing Waveform



Description

The μPB8284 is a clock generator and driver for the 8086 and 8088 microprocessors. This bipolar driver provides the microprocessor with a reset signal and also provides properly synchronized READY timing. A TTL clock is also provided for peripheral devices.

Features

- ☐ Generates system clock for the 8086 and 8088
- ☐ Frequency source can be a crystal or a TTL signal
- ☐ MOS level output for the processor
- ☐ TTL level output for the peripheral devices
- ☐ Power-up reset for the processor
- ☐ READY synchronization
- ☐ +5 V supply

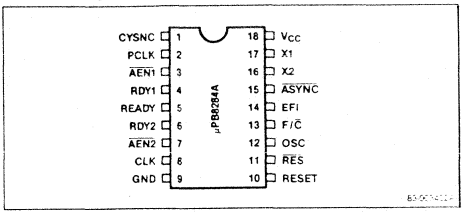
Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPB8284AD	18-Pin cerdip	25 MHz ÷ 3

Pin Identification

No.	Symbol	Function
1	CSYNC	Clock synchronization
2	PCLK	Peripheral clock
3, 7	$\overline{AEN1}$, $\overline{AEN2}$	Address enable
4, 6	RDY1, RDY2	Bus ready
5	READY	Ready
8	CLK	Processor clock
9	GND	Ground
10	RESET	Reset
11	$\overline{RES}$	Reset in
12	OSC	Oscillator output
13	F/C	Frequency crystal select
14	EFI	External frequency in
15	$\overline{ASYNC}$	Asynchronous input
16, 17	X1, X2	Crystal in
18	V_{CC}	V_{CC}

Pin Configuration



Pin Functions

Clock Synchronization

An active high signal which allows multiple 8284s to be synchronized. When CYSNC is low, the internal counters count, and when high, the counters are reset. CYSNC should be grounded when the internal oscillator is used.

Peripheral Clock

A TTL level clock for use with peripheral devices. This clock is one-half the frequency of CLK.

Address Enable

This active low signal is used to qualify its respective RDY inputs. If there is only one bus to interface to, $\overline{AEN}$ inputs are to be grounded.

Bus Ready

This signal is sent to the 8284 from a peripheral device on the bus to indicate that data has been received or data is available to be read.

Ready

The READY signal to the microprocessor is synchronized by the RDY inputs to the processor CLK. READY is cleared after the guaranteed hold time to the processor has been met.

Processor Clock

This is the MOS level clock output of 33% duty cycle to drive the microprocessor and bipolar support devices (8288) connected to the processor. The frequency of CLK is one third of the crystal or EFI frequency.

Ground

Ground.

Reset

This is used to initialize the processor. Its input is derived from an RC connection to a Schmitt trigger input for power up operation.

Reset In

The Schmitt trigger input is used to determine the timing of RESET out via an RC circuit.

Oscillator Output

This TTL level clock is the output of the oscillator circuit running at the crystal frequency.

Frequency Crystal Select

F/$\overline{C}$ is a strapping option used to determine where CLK is generated. A high is for the EFI input, and a low is for the crystal.

External Frequency In

A square wave in at three times the CLK output. A TTL level clock to generate CLK.

Asynchronous Input

Ready Synchronization Select. $\overline{ASYNC}$ is an input which defines the synchronization mode of the READY logic. When $\overline{ASYNC}$ is low, two stages of READY synchronization are provided. When $\overline{ASYNC}$ is left open or HIGH, a single stage of READY synchronization is provided.

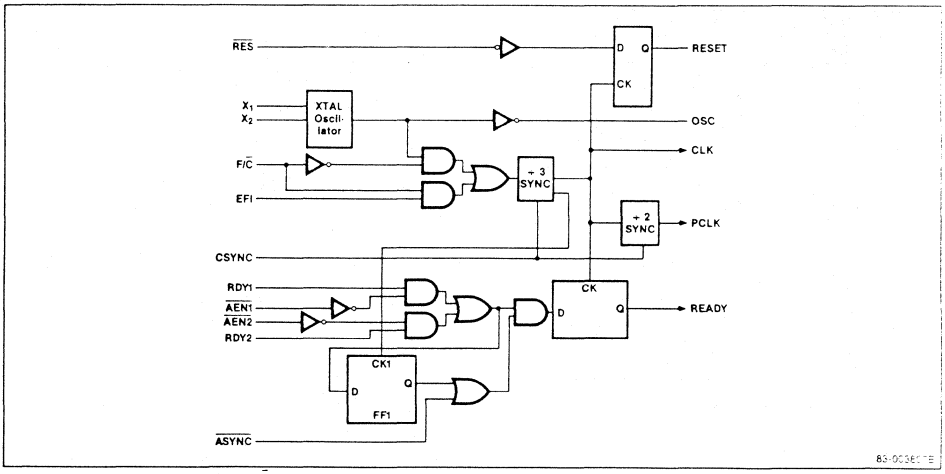
Crystal In

A crystal is connected to these inputs to generate the processor clock. The crystal frequency is three times the desired CLK output.

V_{CC} Supply Voltage

+5 V supply.

Block Diagram



Functional Description

The clock generator can provide the system clock from either a crystal or an external TTL source. There is an internal divide-by-three counter which receives its input from either the crystal or TTL source (EFI pin) depending on the state of the F/$\overline{C}$ input strapping. There is also a clear input (C SYNC) which is used for either inhibiting the clock, or synchronizing it with an external event (or perhaps another clock generator chip). Note that if the TTL input is used, the crystal oscillator section can still be used for an independent clock source, using the OSC output.

For driving the MOS output level, there is a 33% duty cycle MOS output (CLK) for the microprocessor, and a TTL output (PCLK) with a 50% duty cycle for use as a peripheral clock signal. This clock is at one-half of the processor clock speed.

Reset timing is provided by a Schmitt trigger input ($\overline{RES}$) and a flip-flop to synchronize the reset timing to the falling edge of CLK. Power-on reset is provided by a simple RC circuit on the $\overline{RES}$ input.

Absolute Maximum Ratings

$T_A = 25°C$

Power supply voltage, V_{DD}	−0.5 V to +7 V
Input voltage, V_I	−1.0 V to +5.5 V
Output supply voltage, V_O	−0.5 V to +7 V
Operating temperature, T_{OPT}	−0°C to +70°C
Storage temperature, T_{STG}	−65°C to +150°C

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

$T_A = 0°C$ to $+70°C$, $V_{CC} = +5\ V \pm 10\%$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage low	V_{IL}			+0.8	V	$V_{CC} = 5.0$ V
Input voltage high	V_{IH}	2			V	$V_{CC} = 5.0$ V
Output voltage low	V_{OL}			+0.45	V	5 mA = I_{OL}
Output voltage high (CLK)	V_{OH}	4			V	−1 mA = I_{OH}
(Other outputs)		2.4			V	−1 mA = I_{OH}
Forward input current ($\overline{ASYNC}$)	I_F			−1.3	mA	$V_F = 0.45$ V
(Other inputs)				−0.5	mA	$V_F = 0.45$ V
Reverse input current	I_R			50	μA	$V_R = 5.25$ V
Input forward clamp voltage	V_C			−1.0	V	$I_C = -5$ mA
Reset input high voltage	V_{IHR}	2.6			V	$V_{CC} = 5.0$ V
$\overline{RES}$ input hysteresis	$V_{IHR} - V_{ILR}$	0.25			V	$V_{CC} = 5.0$ V
Power supply current	I_{CC}			140	mA	

There are two READY inputs, each with its own qualifier ($\overline{AEN1}$, $\overline{AEN2}$). The unused $\overline{AEN}$ signal should be tied low.

The READY logic in the 8284A synchronizes the RDY1 and RDY2 asynchronous inputs to the processor clock to insure proper set up time, and to guarantee proper hold time before clearing the ready signal.

AC Characteristics

$T_A = 0°C$ to $+70°C$, $V_{CC} = 5\ V \pm 10\%$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Timing Requirements						
External frequency time high	t_{EHEL}	13			ns	90%–90% V_{IN}
External frequency time low	t_{ELEH}	13			ns	10%–10% V_{IN}
EFI period	t_{ELEL}	(5)			ns	(Note 1)
XTAL frequency			12	25	MHz	
RDY1, RDY2 set-up to CLK	t_{R1VCL}	35			ns	
RDY1, RDY2 hold to CLK	t_{CLR1X}	0			ns	
$\overline{AEN1}$, $\overline{AEN2}$ set-up to RDY1, RDY2	t_{A1VR1V}	15			ns	
$\overline{AEN1}$, $\overline{AEN2}$ hold to CLK	t_{CLA1X}	0			ns	
CSYNC set-up to EFI	t_{YHEH}	20			ns	
CSYNC hold to EFI	t_{EHYL}	10			ns	
CSYNC width	t_{YHYL}	$2t_{ELEL}$			ns	
$\overline{RES}$ set-up to CLK	t_{I1HCL}	65			ns	(Note 2)
$\overline{RES}$ hold to CLK	t_{CLI1H}	20			ns	(Note 2)
RDY1, RDY2 active set-up to CLK	t_{R1VCH}	35			ns	$\overline{ASYNC}$ = Low
RDY1, RDY2 inactive set-up to CLK	t_{R1VCL}	35			ns	
$\overline{ASYNC}$ set-up to CLK	t_{AYVCL}	50			ns	
$\overline{ASYNC}$ hold to CLK	t_{CLAYX}	0			ns	
Input rise time	t_{ILIH}			20	ns	From 0.8 V to 2.0 V
Input fall time	t_{IHIL}			12	ns	From 2.0 V to 0.8 V

AC Characteristics (cont)

$T_A = 0°C$ to $+70°C$, $V_{CC} = 5\,V \pm 10\%$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Timing Responses						
CLK cycle period	t_{CLCL}	125			ns	
CLK time high	t_{CHCL}	(6)			ns	Figure 1 and figure 2
CLK time low	t_{CLCH}	(7)			ns	Figure 1 and figure 2
CLK rise and fall time	t_{CH1CH2}, t_{CL2CL1}			10	ns	1.0 V to 3.5 V
PCLK time high	t_{PHPL}	(8)			ns	
PCLK time low	t_{PLPH}	(8)			ns	
Ready inactive to CLK	t_{RYLCL}	−8			ns	Figure 3 and figure 4, (Note 4)
Ready active to CLK	t_{RYHCH}	(7)			ns	Figure 3 and figure 4, (Note 3)
CLK to reset delay	t_{CLIL}			40	ns	
CLK to PCLK high delay	t_{CLPH}			22	ns	
CLK to PCLK low delay	t_{CLPL}			22	ns	
OSC to CLK high delay	t_{OLCH}	−5		12	ns	
OSC to CLK low delay	t_{OLCL}	2		22	ns	
Output rise time (except CLK)	t_{OLOH}			20	ns	From 0.8 V to 2.0 V
Output fall time (except CLK)	t_{OHOL}			12	ns	From 2.0 V to 0.8 V

Note:

(1) d = EFI rise (5 ns max) + EFI fall (5 ns max).

(2) Set-up and hold only necessary to guarantee recognition at next clock.

(3) Applies only to T3 and TW states.

(4) Applies only to T2 states.

(5) $t_{EHEL} + t_{ELEH} + d$

(6) $(1/3\,t_{CLCL}) + 2.0$

(7) $(2/3\,t_{CLCL}) - 15.0$

(8) $t_{CLCL} - 20$

AC Test Circuits

Figure 1. Clock High and Low Time

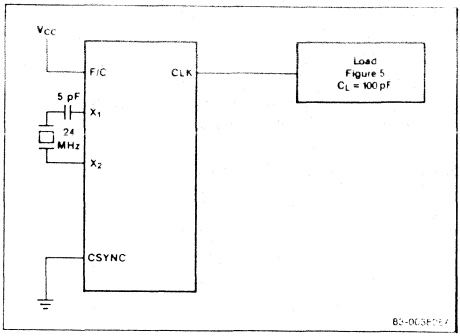


Figure 2. Clock High and Low Time

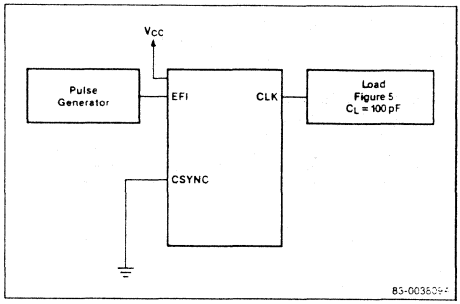


Figure 3. Ready to CLK

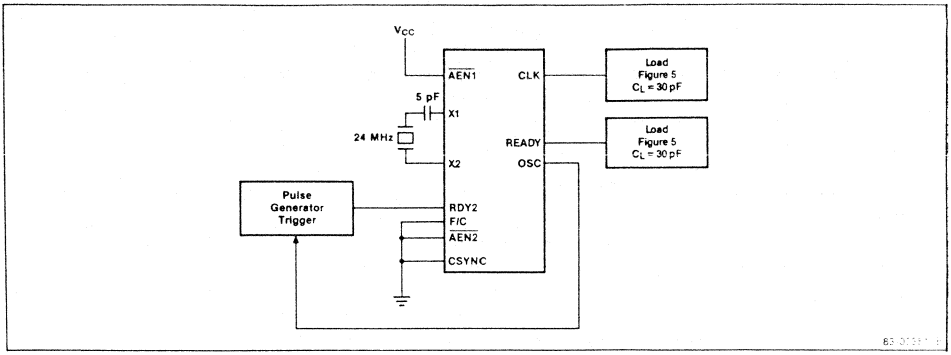


Figure 4. Ready to CLK Output

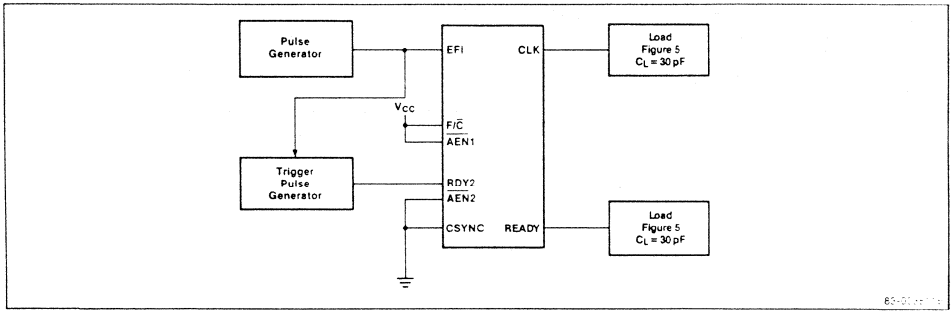


Figure 5. AC Load

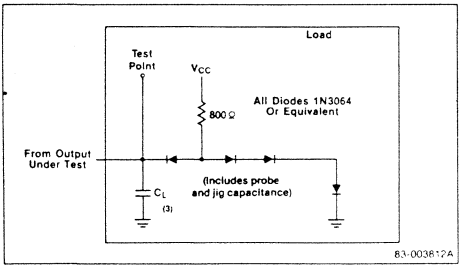
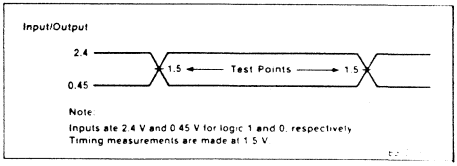
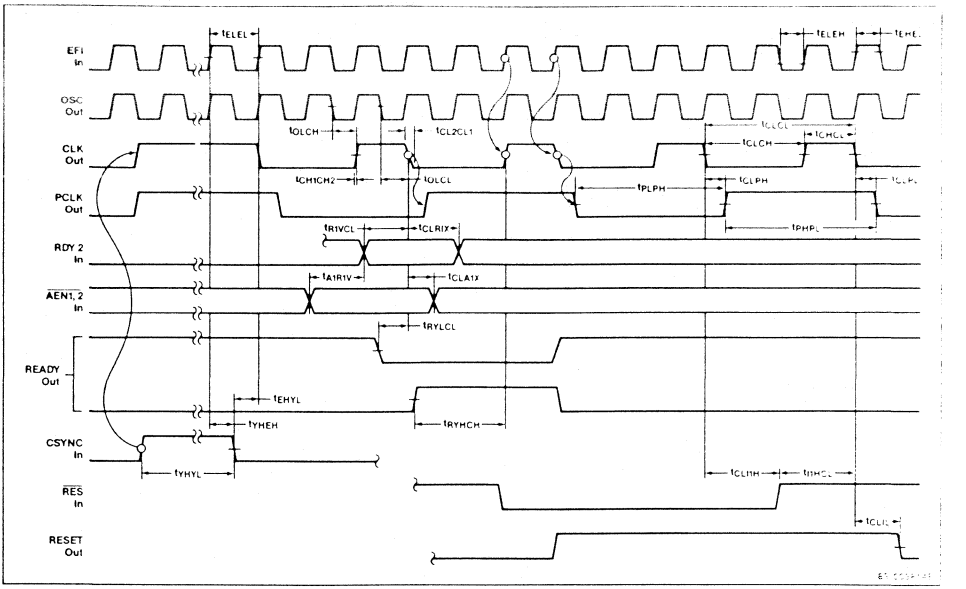


Figure 6. Timing Measurement Points



Timing Waveform



Description

The μPB8286 and μPB8287 are octal bus transceivers used for buffering microprocessor bus lines. Being bi-directional, they are ideal for buffering the data bus lines on 8- or 16-bit microprocessors. Each B output is capable of driving 32 mA low or 5 mA high.

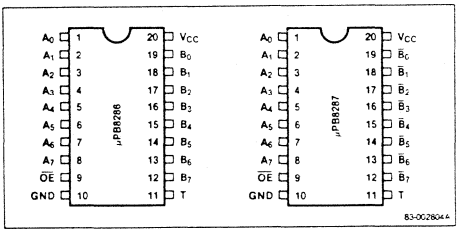
Features

- Data bus buffer driver for μCOM-8 (8080, 8085A, 780) and μCOM-16 (8086) families
- Low input load current – 0.2 mA max
- High output drive capability for driving system data bus
- Three-state outputs

Ordering Information

Part Number	Package Type	I/O Delay, Max
μPB8286C	20-pin plastic DIP	22 ns
μPB8287C	20-pin plastic DIP	30 ns

Pin Configurations



Pin Identification

No.	Symbol	Function
1-8	A_0-A_7	Local data bus
9	$\overline{OE}$	Output enable
10	GND	Ground
11	T	Transmit
12-19	(μPB8286) B_7-B_0 (μPB8287) $\overline{B}_7$-$\overline{B}_0$	System data bus
20	V_{CC}	Power supply

Pin Functions

$\overline{OE}$ (Output Enable)

This active low input control signal enables the output drivers selected by T.

T (Transmit)

This input controls the direction of data through the transceivers. When high, data is transferred from the A_0-A_7 inputs to the B_0-B_7 outputs. When low, data is transferred from the B_0-B_7 inputs to the A_0-A_7 outputs.

A_0-A_7 (Local Data Bus)

A_0-A_7 are bidirectional drivers that, depending on the state of the transmit pin, accept data from or transfer data to the processor's local bus.

B_0-B_7 (System Data Bus)

B_0-B_7 are bidirectional drivers that, depending on the state of the transmit pin, accept data from or transfer data to the system bus.

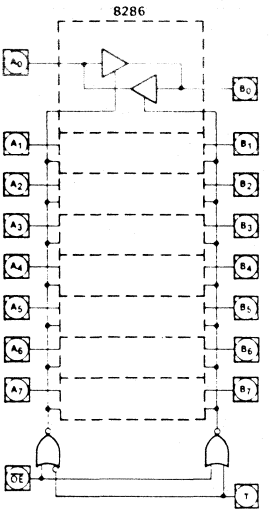
GND (Ground)

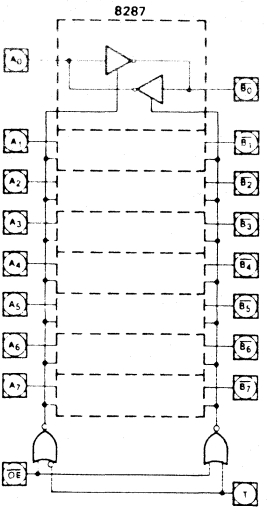
This is the ground.

V_{CC} (Power Supply)

This is the +5 V power supply.

Block Diagram





OE	T	RESULT
0	0	A←B
0	1	A→B
1	0	A and B are high impendace
1	1	

Functional Description

MOS microprocessors like the 8080/8085A/8086 are generally capable of driving a single TTL load. This also applies to MOS memory devices. While sufficient for minimum type small systems on a single PC board, it is usually necessary to buffer the microprocessor and memory signals when a system is expanded or signals go to other PC boards.

These octal bus transceivers are designed to do the necessary buffering.

Bidirectional Driver

Each buffered line of the octal driver consists of two separate three-state buffers. The B side of the driver is designed to drive 32 mA and interface the system side of the bus to I/O, memory, etc. The A side is connected to the microprocessor.

Control Gating, $\overline{OE}$, T

The $\overline{OE}$ (output enable) input is an active low signal used to enable the drivers selected by T on to the respective bus.

T is an input control signal used to select the direction of data through the transceivers. When T is high, data is transferred from the A_0-A_7 inputs to the B_0-B_7 outputs, and when low, data is transferred from B_0-B_7 to the A_0-A_7 outputs.

Absolute Maximum Ratings

$T_A = 25°C$

Power supply voltage, V_{CC}	−0.5 V to +7 V
Input voltage, V_I	−1.0 V to +5.5 V
Output voltage, V_O	−0.5 V to +7 V
Operating temperature, T_{OPT}	0°C to +70°C
Storage temperature, T_{STG}	−65°C to +150°C

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

$T_A = 0°C$ to $+70°C$, $V_{CC} = +5V \pm 10\%$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage low — A side	V_{IL}			+0.8	V	$V_{CC} = 5.0$ V, (Note 1)
— B side				+0.9	V	$V_{CC} = 5.0$ V, (Note 1)
Input voltage high	V_{IH}			2	V	$V_{CC} + 5.0$ V, (Note 1), F = 1 MHz
Output voltage low — B outputs	V_{OL}			+0.45	V	$I_{OL} = 32$ mA
— A outputs				+0.45	V	$I_{OL} = 16$ mA
Output voltage high — B outputs	V_{OH}	2.4			V	$I_{OH} = -5$ mA
— A outputs		2.4			V	$I_{OH} = -1$ mA
Input clamp voltage	V_C			−1	V	$I_C = -5$ mA
Input forward current	I_F			−0.2	μA	$V_F = 0.45$ V
Input reverse current	I_R			50	μA	$V_R = 5.25$ V
Power supply current	I_{CC}					
μPB8287				130	mA	
μPB8286				160	mA	
Output off current	I_{OFF}			I_F		$V_{OFF} = 0.45$ V
Output off current	I_{OFF}			I_R		$V_{OFF} = 5.25$ V

Note:

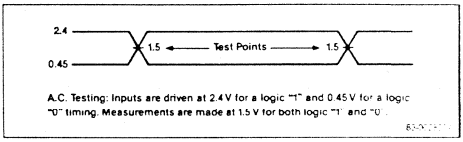
(1) B outputs — $I_{OL} = 32$ mA, $I_{OH} = -5$ mA, $C_L = 300$ pF
A outputs — $I_{OL} = 16$ mA, $I_{OH} = -1$ mA, $C_L = 100$ pF

AC Characteristics

$T_A = 0°C$ to $+70°C$, $V_{CC} = 5V \pm 10\%$

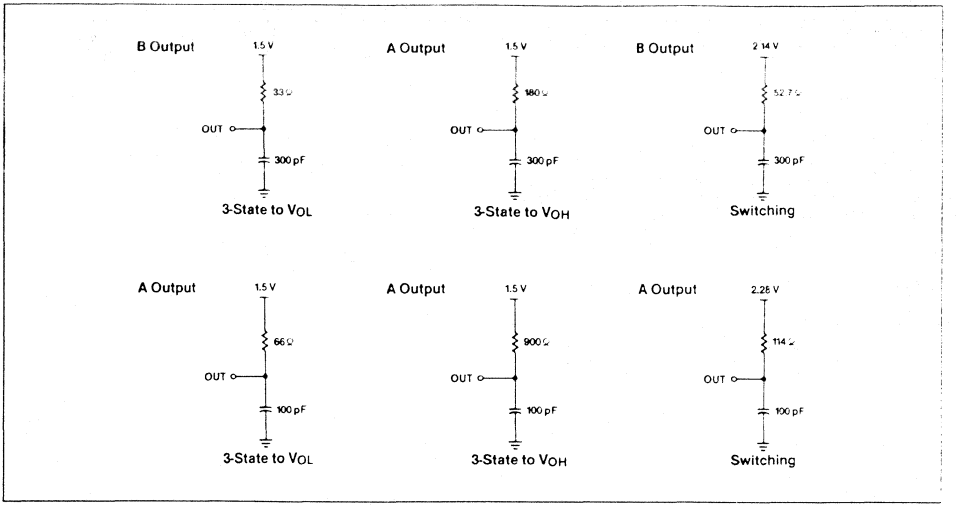
Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input to output delay	t_{IVOV}					
Inverting		5		22	ns	
Non-inverting		5		30	ns	
Transmit / receive hold time	t_{EHTV}	t_{EHOZ}			ns	
Transmit / receive setup	t_{TVEL}	10			ns	
Output disable time	t_{EHOZ}	5		22	ns	
Output enable time	t_{ELOV}	10		30	ns	
I / O rise time	t_{ILIH} t_{OLOH}			20	ns	
I / O fall time	t_{IHIL} t_{OHOL}			12	ns	

AC Test Conditions

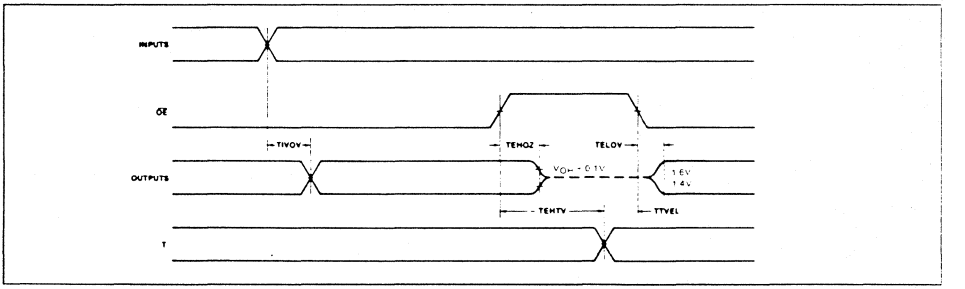


A.C. Testing: Inputs are driven at 2.4 V for a logic "1" and 0.45 V for a logic "0" timing. Measurements are made at 1.5 V for both logic "1" and "0".

Test Load Circuits



Timing Waveform



Description

The μPB8288 bus controller is used in medium to large μPD8086/μPD8088 systems. This 20-pin bipolar component provides command and control timing generation, as well as bipolar drive capability and optimal system performance. It provides both Multibus® command signals and control outputs for the microprocessor system. There is an option to use the controller with a multimaster system bus and separate I/O bus.

Features

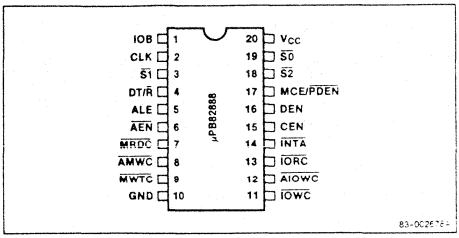
- ☐ System controller for μPD8086/μPD8088 systems
- ☐ Bipolar drive capability
- ☐ Provides advanced commands
- ☐ Three state output drivers
- ☐ Can be used with an I/O bus
- ☐ Enables interface to one or two multimaster buses

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPB8288D	20-pin cerdip	10 MHz

® Multibus is a registered trademark of Intel Corp.

Pin Configuration



Pin Identification

No.	Symbol	Function
1	IOB	I/O bus mode selector input
2	CLK	Clock input
3	$\overline{S1}$	Status input
4	DT/$\overline{R}$	Data transmit/receive
5	ALE	Address latch enable output
6	$\overline{AEN}$	Address enable input
7	$\overline{MRDC}$	Memory read command output
8	$\overline{AMWC}$	Advanced memory write command output
9	$\overline{MWTC}$	Memory write command output
10	GND	Ground
11	$\overline{IOWC}$	I/O write command output
12	$\overline{AIOWC}$	Advanced I/O write command output
13	$\overline{IORC}$	I/O read command output
14	$\overline{INTA}$	Interrupt acknowledge output
15	CEN	Command enable input
16	DEN	Data enable output
17	MCE/$\overline{PDEN}$	Master cascade enable/peripheral data enable output
18	$\overline{S2}$	Status input
19	$\overline{S0}$	Status input
20	V_{CC}	+5 V power supply

Pin Functions

$\overline{AEN}$ (Address Enable)

In the I/O system bus mode, $\overline{AEN}$ enables the command outputs of the μPB8288 105 ns after it becomes active. If $\overline{AEN}$ is inactive, the command outputs become high impedance outputs.

$\overline{AIOWC}$ (Advanced I/O Write Command)

This write command occurs earlier in the machine cycle than the $\overline{IOWC}$ command.

ALE (Address Latch Enable)

This signal is used for controlling transparent D-type latches (μPB8282/μPB8283). It will strobe in the address on a high to low transition.

$\overline{AMWC}$ (Advanced Memory Write Command)

This is an advanced write command which occurs early in the machine cycle, with timing the same as the read command.

CEN (Command Enable)

This signal enables all command and control outputs. If CEN is low, these outputs are inactive.

CLK (Clock)

The clock signal from the μPB8284 clock generator synchronizes the generation of command and control signals.

DEN (Data Enable)

This signal enables the data transceivers onto the bus.

DT/$\overline{R}$ (Data Transmit/Receive)

This signal is used to control the bus transceivers in a system; high for writing to I/O or memory and low for reading data.

$\overline{INTA}$ (Interrupt Acknowledge)

INTA is used to signal an interrupting device to put the vector information on the data bus.

IOB (I/O Bus Mode)

Sets mode of μPB8288; high for the I/O bus mode and low for the system bus mode.

$\overline{IORC}$ (I/O Read Command)

This signal enables the CPU to read data from an I/O device.

$\overline{IOWC}$ (I/O Write Command)

This command is for transferring information to I/O devices.

MCE/$\overline{PDEN}$ (Master Cascade Enable/ Peripheral Data Enable)

Dual function pin system. (MCE) In the bus mode, this signal is active during an interrupt sequence to read the cascade address from the master interrupt controller onto the data bus. ($\overline{PDEN}$) In the I/O bus mode, it enables the transceivers for the I/O bus just as DEN enables bus transceivers in the system bus mode.

$\overline{MRDC}$ (Memory Read Command)

This active low signal is for switching the data from memory to the data bus.

$\overline{MWTC}$ (Memory Write Command)

This signal is used to transfer the data bus to memory, but not as early as $\overline{AMWC}$. (See timing waveforms).

GND (Ground)

Ground.

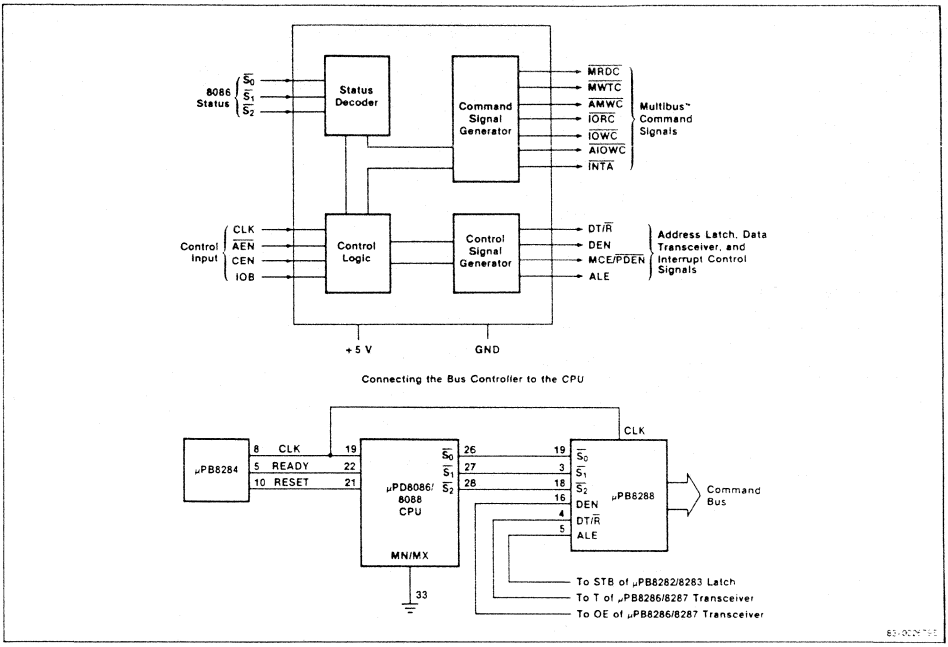
$\overline{S0}$, $\overline{S1}$, $\overline{S2}$ (Status Input Pins)

The μPB8288 decodes these status lines from the μPD8086 to generate command and control signals. When not in use, these pins are high.

V_{CC} (Power Supply)

+5 V power supply.

Block Diagram



Absolute Maximum Ratings

T_A = 25°C

Power supply voltage, V_{DD}	−0.5 to +7.0 V
Input voltage, V_I	−1.0 to +5.5 V
Output voltage, V_O	−0.5 to +7.0 V
Operating temperature, T_{OPT}	0 to +70°C
Storage temperature, T_{STG}	−65 to +150°C

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum ratings for extended periods may affect device reliability.

DC Characteristics

T_A = 0 to +70°C; V_{CC} = 5 V ±10%

Parameter	Symbol	Limits Min	Limits Max	Unit	Test Conditions
Input high voltage	V_{IH}	2.0		V	
Input low voltage	V_{IL}		0.8	V	
Input clamp voltage	V_C		−1	V	I_C = −5 mA
Output high voltage (command)	V_{OH}	2.4		V	I_{OH} = −5 mA
(control)		2.4		V	I_{OH} = −1 mA
Output low voltage (command)	V_{OL}		0.5	V	I_{OL} = 32 mA
(control)			0.5	V	I_{OL} = 16 mA
Forward input current	I_F		−0.7	mA	V_F = 0.45 V
Reverse input current	I_R		50	μA	V_R = V_{CC}
Output off current	I_{OFF}		100	μA	V_{OFF} = 0.4 V to 5.25 V
Power supply current	I_{CC}		230	mA	

AC Characteristics

T_A = 0 to +70°C; V_{CC} = 5 V ±10%

Timing Requirements

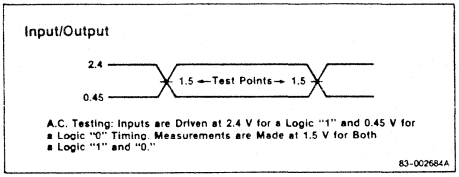
Parameter	Symbol	Limits Min	Limits Max	Unit	Loading
CLK cycle period	t_{CLCL}	100		ns	
CLK low time	t_{CLCH}	50		ns	
CLK high time	t_{CHCL}	30		ns	
Status active setup time	t_{SVCH}	35		ns	
Status active hold time	t_{CHSV}	10		ns	
Status inactive setup time	t_{SHCL}	35		ns	
Status inactive hold time	t_{CLSH}	10		ns	
Input rise time	t_{ILIH}		20	ns	
Input fall time	t_{IHIL}		12	ns	

Timing Responses

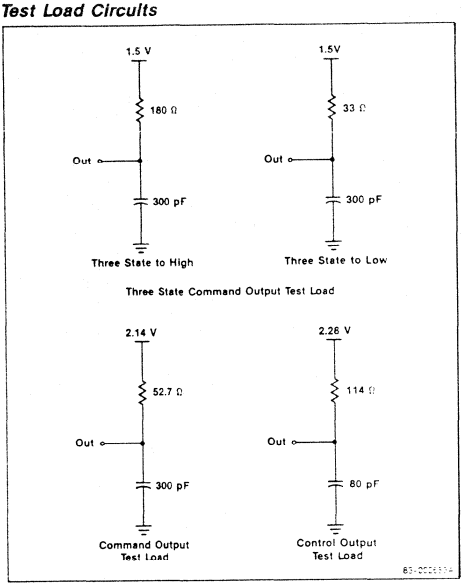
Parameter	Symbol	Limits Min	Limits Max	Unit	Loading
Control active delay	t_{CVNV}	5	45	ns	
Control inactive delay	t_{CVNX}	10	45	ns	
ALE MCE active delay (from CLK)	t_{CLLH} / t_{CLMCH}		20	ns	$\overline{MRDC}$
ALE MCE active delay (from status)	t_{SVLH} / t_{SVMCH}		20	ns	$\overline{IORC}$ / $\overline{MWTC}$ I_{OL} = 32 mA
ALE inactive delay	t_{CHLL}	4	15	ns	$\overline{IOWC}$ I_{OH} = −5 mA
Command active delay	t_{CLML}	10	35	ns	$\overline{INTA}$ C_L = 300 pF
Command inactive delay	t_{CLMH}	10	35	ns	$\overline{AMWC}$
Direction control active delay	t_{CHDTL}		50	ns	$\overline{AIOWC}$
Direction control inactive delay	t_{CHDTH}		30	ns	
Command enable time	t_{AELCH}		40	ns	
Command disable time	t_{AEHCZ}		40	ns	
Enable delay time	t_{AELCV}	115	200	ns	I_{OL} = 16 mA
AEN to DEN	t_{CEVNV}		20	ns	Other: I_{OH} = −1 mA
CEN to DEN, PDEN	t_{CEVNV}		25	ns	C_L = 80 pF
CEN to command	t_{CELRH}		t_{CLML}	ns	
Output rise time	t_{OLOH}		20	ns	
Output fall time	t_{OHOL}		12	ns	

Timing Waveforms

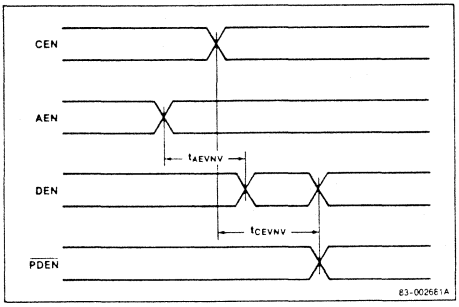
Timing Measurement Points



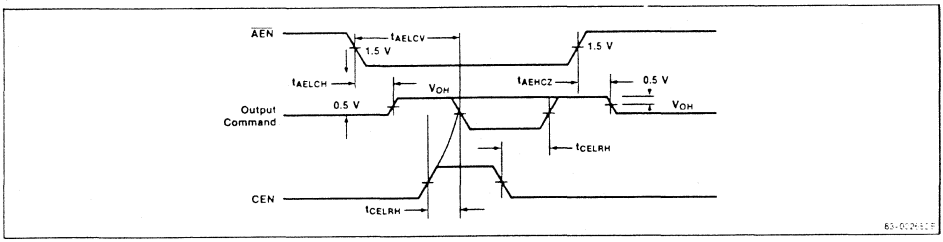
Test Load Circuits



DEN, PDEN Qualification Timing

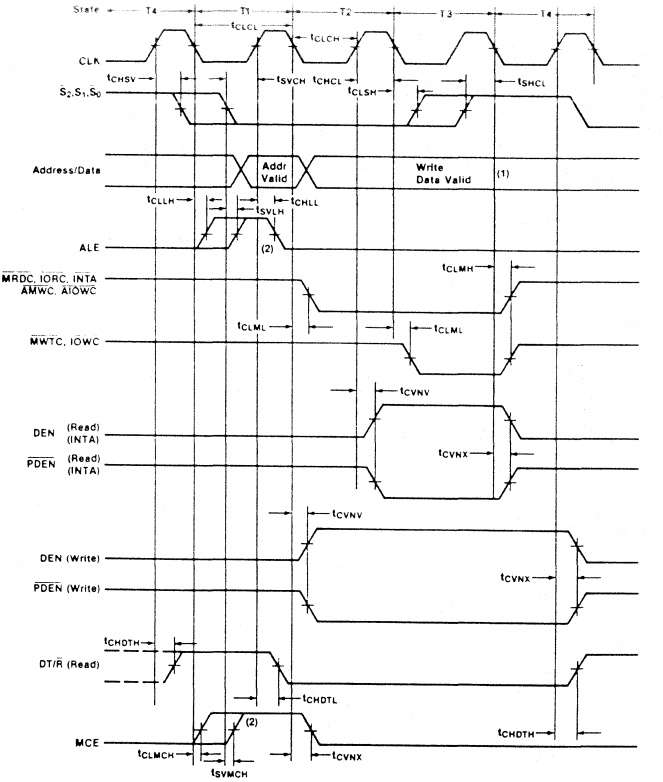


μPD8288 Address Enable (AEN) Timing (Three State Enable/Disable)



Timing Waveforms (cont)

State Timing



Note:

(1) Address/data bus is shown only for reference purposes.

(2) Leading edge of ALE and MCE is determined by the falling edge of CLK or status going active, whichever occurs last.

(3) All timing measurements are made at 1.5 V unless specified otherwise.

83-002683E

Functional Description

The three status lines ($\overline{S0}$, $\overline{S1}$, $\overline{S2}$) from the μPD8086 CPU are decoded by command logic within the μPB8288 to determine which command is to be issued. Table 1 below illustrates the decoding and command generation of the status lines.

Table 1. Status Line Decoding

$\overline{S2}$	$\overline{S1}$	$\overline{S0}$	μPD8086 State	μPB8288 Command
0	0	0	Interrupt acknowledge	$\overline{INTA}$
0	0	1	Read I/O port	$\overline{IORC}$
0	1	0	Write I/O port	$\overline{IOWC}$, $\overline{AIOWC}$
0	1	1	Halt	None
1	0	0	Code access	$\overline{MRDC}$
1	0	1	Read memory	$\overline{MRDC}$
1	1	0	Write memory	$\overline{MWTC}$, $\overline{AMWC}$
1	1	1	Passive	None

There are two ways the command is issued depending on the mode of the μPB8288.

The I/O bus mode is enabled if the IOB pin is pulled high. In this mode, all I/O command lines are always enabled and not dependent upon AEN. When the processor sends out an I/O command, the μPB8288 activates the command lines using $\overline{PDEN}$ and DT/$\overline{R}$ to control any bus transceivers.

This mode is advantageous if I/O or peripherals dedicated to one microprocessor are in a multiprocessor system, allowing the μPB8288 to control two external buses. No waiting is required when the CPU needs to access the I/O bus, as an $\overline{AEN}$ low signal is needed to gain normal memory access.

If the IOB pin is tied to ground, the μPB8288 is in the system bus mode. In this mode, command signals are dependent upon the $\overline{AEN}$ line. Thus the command lines are activated 105 ns after the $\overline{AEN}$ line goes low. In this mode, there must be some bus arbitration logic to toggle the $\overline{AEN}$ line when the bus is free for use. Here, both memory and I/O are shared by more than one processor, over one bus, with both memory and I/O commands waiting for bus arbitration.

Among the command outputs are some advanced write commands which are initiated early in the machine cycle and can be used to prevent the CPU from entering unnecessary wait states.

The $\overline{INTA}$ signal acts as an I/O read during an interrupt cycle. This is to signal the interrupting device that its interrupt is being acknowledged, and to place the interrupt vector on the data bus.

The control outputs of the μPB8288 are used to control the bus transceivers in a system. DT/$\overline{R}$ determines the direction of the data transfer, and DEN is used to enable the outputs of the transceiver. In the IOB mode the MCE/$\overline{PDEN}$ pin acts as a dedicated data enable signal for the I/O bus.

The MCE signal is used in conjunction with an interrupt acknowledge cycle to control the cascade address when more than one interrupt controller (such as a μPD8259A) is used. If there is only one interrupt controller in a system, MCE is not used because the $\overline{INTA}$ signal gates the interrupt vector onto the processor bus. In multiple interrupt controller systems, MCE is used to gate the μPD8259A's cascade address onto the processor's local bus, where ALE strobes it into the address latches. This occurs during the first $\overline{INTA}$ cycle. During the second $\overline{INTA}$ cycle the addressed slave μPD8259A gates its interrupt vector onto the processor bus.

The ALE signal occurs during each machine cycle and is used to strobe data into the address latches and to strobe the status ($\overline{S0}$, $\overline{S1}$, $\overline{S2}$) into the μPB8288. ALE also occurs during a halt state to accomplish this.

The CEN (Command Enable) is used to control the command lines. If pulled high, the μPB8288 functions normally, and if grounded, all command lines are inactive.

Description

The μPB8289 bus arbiter is used with the μPB8288 bus controller to interface 8086 and 8088 microprocessors to a multimaster system bus. The μPB8289 controls the μPB8288 bus controller and the bus transceivers and address latches, preventing them from accessing the system bus if the processor does not have use of the bus.

An external command sequence will cause the associated microprocessor to enter a wait state until the bus is ready. The processor remains in the wait state until the bus arbiter acquires use of the multimaster system bus. Then, the arbiter allows the bus controller, data transceivers, and address latches to access the system.

Once use of the bus has been acquired and data has been transferred, transfer acknowledge (XACK) is returned to the processor to indicate that the accessed slave device is ready. The processor may then complete its transfer cycle.

Features

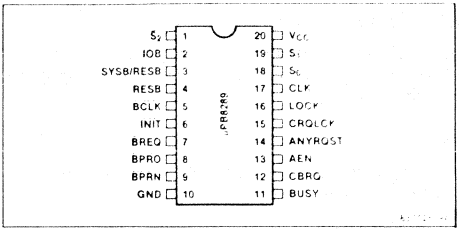
- ☐ Multimaster system bus protocol
- ☐ 8086 and 8088 processor synchronization with multimaster bus
- ☐ Simple interface with the 8288 bus controller and 8283/8282 address latches to a system bus
- ☐ Four operating modes for flexible system configuration
- ☐ Simplified interface to Multibus® systems
- ☐ Parallel, serial, and rotating priority resolution
- ☐ Bipolar buffering and drive capability

Ordering Information

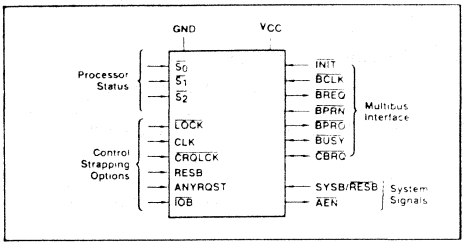
Part Number	Package Type	Max Frequency of Operation
μPB8289D	20-Pin Cerdip	8 MHz

Multibus is a registered trademark of Intel Corporation.

Pin Configuration



Functional Configuration



Pin Identification

No.	Symbol	Function
1, 18, 19	$\overline{S_0}$-$\overline{S_2}$	Status inputs
2	IOB	I/O bus input
3	SYSB/$\overline{RESB}$	System bus/resident bus inputs
4	$\overline{RESB}$	Resident bus input
5	$\overline{BCLK}$	System bus clock input
6	$\overline{INIT}$	Initialize input
7	$\overline{BREQ}$	Bus request output
8	$\overline{BPRO}$	Bus priority output
9	$\overline{BPRN}$	Bus priority input
10	GND	Ground
11	$\overline{BUSY}$	Bus interface signal I/O
12	$\overline{CBRQ}$	Common bus request I/O
13	$\overline{AEN}$	Address enable output
14	ANYRQST	Any request input
15	$\overline{CRQLCK}$	Common request lock input
16	$\overline{LOCK}$	Lock input
17	CLK	Clock input
20	V_{CC}	+5 V power supply

Pin Functions

$\overline{S_0}$-$\overline{S_2}$ (Status Inputs)

The μPB8289 decodes these status inputs from the 8086 or 8088 processor to begin bus requests and surrenders.

$\overline{IOB}$ (I/O Bus)

This input signal tells the μPB8289 that there is an I/O peripheral bus and a multimaster system bus.

SYSB/$\overline{RESB}$ (System Bus/Resident Bus)

This input determines when bus requests and surrenders are permitted in SR mode.

$\overline{RESB}$ (Resident Bus Input)

$\overline{RESB}$ tells the μPB8289 that there is a multimaster and resident bus. When the signal is high, the SYSB/$\overline{RESB}$ pin handles bus arbitration.

$\overline{BLCK}$ (System Bus Clock)

This clock input synchronize all system bus interface signals.

$\overline{INIT}$ (Initialize)

This active low-input resets all bus arbiters on the multimaster bus. No arbiters have use of the bus following INIT.

$\overline{BREQ}$ (Bus Request)

An arbiter uses this output to request use of the multimaster system bus.

$\overline{BPRO}$ (Bus Priority Output)

In serial priority resolving schemes, this output daisy-chains to $\overline{BPRN}$ of the next lower priority arbiter.

$\overline{BPRN}$ (Bus Priority Input)

This input tells the arbiter it may acquire the bus on the next falling edge at $\overline{BCLK}$.

$\overline{BUSY}$ (Bus Interface Signal)

When the bus is available, this I/O signal notifies all arbiters on the bus. The highest requesting arbiter seizes the bus and pulls BUSY low to keep other arbiters off the bus.

$\overline{CBRQ}$ (Common Bus Request)

This signal is an input from a lower priority arbiter requesting the bus. It is an output from arbiters that surrender the multimaster bus upon request.

$\overline{AEN}$ (Address Enable)

This output tells the 8288 bus controller, 8284 clock driver, and the processor's address latches when to tri-state their output drivers.

ANYRQST (Any Request)

This signal allows the multimaster bus to be surrendered to a lower priority arbiter.

$\overline{CRQLCK}$ (Common Request Lock)

This input prevents the μPB8289 from surrendering the bus in response to a request on the $\overline{CBRQ}$ input.

$\overline{LOCK}$ (Lock)

This input prevents the arbiter from surrendering the multimaster system bus to any other bus arbiter, regardless of its priority.

CLK (Clock)

This is the clock signal from the 8284 clock generator.

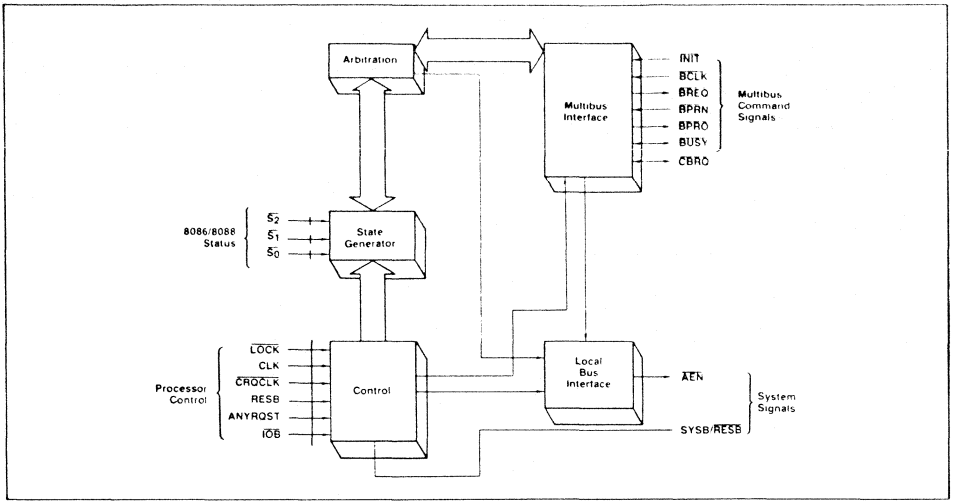
GND (Ground)

This is the ground.

V_{CC} (Power Supply)

This is the +5 V power supply.

Block Diagram



Functional Description

Bus Master Arbitration

Higher priority masters generally acquire use of the bus when a lower priority master completes its present transfer cycle. Lower priority masters acquire the bus when no higher priority master is accessing the system bus. The ANYRQST strapping option allows the arbiter to surrender the bus to a lower priority master as if it were a higher priority master. The arbiter maintains the bus as long as no other bus masters are requesting the bus and its processor has not entered the halt state. The arbiter does not voluntarily surrender the bus and must be forced off by a request from another bus master, unless the arbiter's processor has entered the halt state. Additional strapping options allow for other sets of conditions.

Priority Resolving Techniques

The μPB8289 provides several techniques for resolving priority between the many possible bus masters of a multimaster system bus. All of these techniques assume that one bus master will have priority over all others at any given time. You may use parallel, serial, or rotating priority resolving.

Parallel Priority Resolving

This technique (figures 1, 2) uses a bus request line ($\overline{BREQ}$) for each arbiter on the multimaster system bus. Each $\overline{BREQ}$ line goes to a priority encoder that generates the address of the highest priority active $\overline{BREQ}$ line. This binary address is decoded to select the bus priority in line ($\overline{BPRN}$) that is returned to the highest priority arbiter. The arbiter that receives priority ($\overline{BPRN}$ true) allows its bus master onto the multimaster system bus as soon as the bus becomes available. An arbiter that gets priority over another arbiter cannot immediately seize the bus, but must wait until the current bus transaction is complete. When the transaction is complete, the current occupant of the bus surrenders the bus by releasing $\overline{BUSY}$. $\overline{BUSY}$ is an active low OR tied line which goes to every arbiter on the system bus. When $\overline{BUSY}$ goes high (inactive), the priority arbiter seizes the bus and brings $\overline{BUSY}$ low to keep other arbiters off the bus. Note that all multimaster system bus transactions are synchronized to the bus clock ($\overline{BCLK}$).

Figure 1. Parallel Priority Resolving

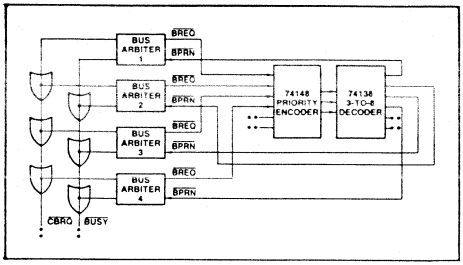
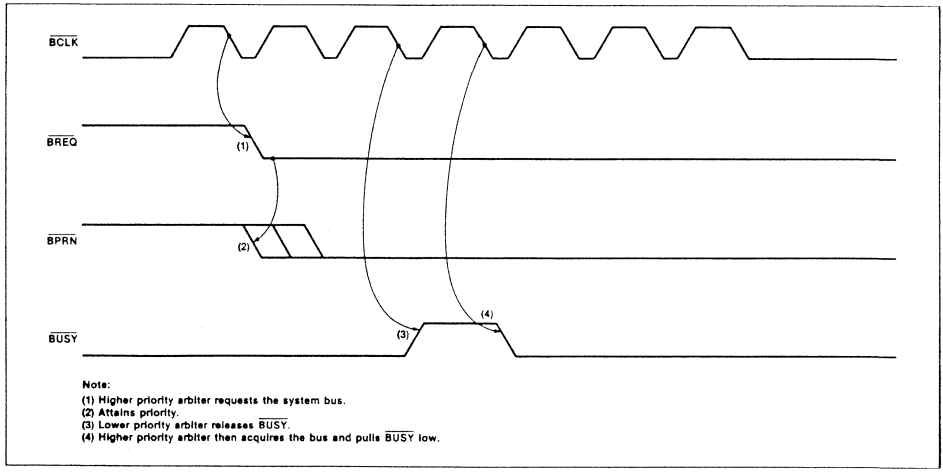


Figure 2. Higher Priority Arbiter Obtaining the Bus from a Lower Priority Arbiter

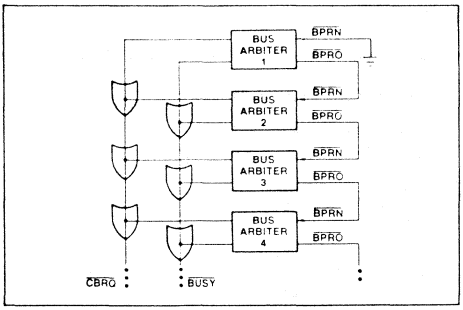


Note:
(1) Higher priority arbiter requests the system bus.
(2) Attains priority.
(3) Lower priority arbiter releases $\overline{BUSY}$.
(4) Higher priority arbiter then acquires the bus and pulls $\overline{BUSY}$ low.

Serial Priority Resolving

The serial priority resolving technique (figure 3) daisy-chains the bus arbiters together by connecting the higher priority arbiter's $\overline{BPRO}$ output to the $\overline{BPRN}$ of the next lowest priority arbiter. This eliminates the need for the priority encoder-decoder arrangement. The number of arbiters that may be daisy-chained together is a function of $\overline{BCLK}$ and the propagation delay from arbiter to arbiter. At 10 MHz, only 3 arbiters may be daisy-chained.

Figure 3. Serial Priority Resolving



Rotating Priority Resolving

This technique resembles the parallel priority resolving technique except that priority is dynamically reassigned. The priority encoder is replaced by a circuit that rotates priority between arbiters to allow each arbiter an equal chance to use the system bus.

Modes of Operation

The μPB8289 has two basic operating modes: I/O peripheral bus mode ($\overline{IOB}$ mode), and resident bus mode (RESB mode). The $\overline{IOB}$ strapping option configures the μPB8289 into $\overline{IOB}$ mode and the RESB strapping option configures it to RESB mode. If both options are strapped false, the arbiter interfaces the processor to a multimaster system bus only. If both options are strapped true, the arbiter interfaces the processor to a multimaster system bus, a resident bus, and an I/O bus. Figure 4 shows the μPB8289 in a typical CPU system.

$\overline{IOB}$ Mode

$\overline{IOB}$ mode allows the processor to access both an I/O peripheral bus and a multimaster system bus. On an I/O peripheral bus, all devices on the bus, including memory, are treated as I/O devices and addressed by I/O commands. All memory commands are directed to the multimaster system bus. In $\overline{IOB}$ mode, the processor communicates with and controls peripherals over the peripheral bus and communicates with system memory over the system memory bus. Figure 5 shows the μPB8289 in this mode.

RESB Mode

RESB mode allows the processor to communicate over both a resident bus and a multimaster system bus. A resident bus can issue memory and I/O commands, but it is separate from the multimaster system bus. The resident bus has one master and is dedicated to only that master. The 8086 and 8088 can communicate with a resident bus and a multimaster system bus. The processor can access the memory and peripherals of both buses. Memory mapping selects which bus is accessed. The SYSB/$\overline{RESB}$ input on the arbiter instructs the arbiter on which bus to access. The signal connected to SYSB/$\overline{RESB}$ also enables and disables commands from one of the bus controllers. Figure 6 shows the μPB8289 in this mode.

Mode Summary

	Status Lines From 8086 or 8088 or 8089			IOB Mode Only	RESB (Mode) Only IOB = High RESB = High		IOB Mode RESB Mode IOB = Low RESB = High		Single Bus Mode IOB = High RESB = Low
	$\overline{S2}$	$\overline{S1}$	$\overline{S0}$	IOB = Low	SYSB/RESB = High	SYSB/RESB = Low	SYSB/RESB = High	SYSB/RESB = Low	
	0	0	0	x	✓	x	x	x	✓
I/O commands	0	0	1	x	✓	x	x	x	✓
	0	1	0	x	✓	x	x	x	✓
Halt	0	1	1	x	x	x	x	x	x
Memory commands	1	0	0	✓	✓	x	✓	x	✓
	1	0	1	✓	✓	x	✓	x	✓
	1	1	0	✓	✓	x	✓	x	✓
Idle	1	1	1	x	x	x	x	x	x

Notes:

(1) x = Multimaster system bus is allowed to be surrendered.

(2) ✓ = Multimaster system bus is requested.

Multimaster System Bus

Mode	Pin Strapping	Requested (1)	Surrendered (2)
Single bus multimaster mode	$\overline{IOB}$ = high RESB = low	When the processor's status lines go active	HLT + TI • HPBRQ†
RESB mode only	$\overline{IOB}$ = high RESB = high	SYSB/$\overline{RESB}$ = High 2 active	(SYSB/$\overline{RESB}$ = low + TI) CBRQ + HLT + HPBRQ
IOB mode only	$\overline{IOB}$ = low RESB = low	Memory commands	(I/O status + TI) • CBRQ + HLT + HPBRQ
IOB mode • RESB mode	$\overline{IOB}$ = low RESB = high	(Memory command) • (SYSB/$\overline{RESB}$ = high)	(I/O status commands) + (TI) (SYSB/$\overline{RESB}$ = low) • CBRQ + HPBRQ† + HLT)

Note:

(1) Except for HALT and idle status.

(2) $\overline{LOCK}$ prevents surrender of bus to any other arbiter. $\overline{CRQLCK}$ prevents surrender of bus to a lower priority arbiter.

(3) HLT = processor halt; $\overline{S}_2 \cdot \overline{S}_0$ = 011.

(4) TI = processor idle; $\overline{S}_2 \cdot \overline{S}_0$ = 111.

(5) + means OR.

(6) • means AND.

† HPBRQ = higher priority bus request or $\overline{BPRN}$ = 1.

Absolute Maximum Ratings

T_A = 25°C

Operating temperature	0°C to 70°C
Storage temperature	−65°C to +150°C
Voltage on any pin	−0.5 V to +7 V
All input voltages	−1.0 V to +5.5 V
Power dissipation	1.5 W

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

T_A = 0°C to +70°C; V_{CC} = 5 V ± 10%

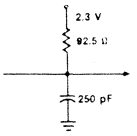
Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input low voltage	V_{IL}			0.8	V	
Input high voltage	V_{IH}	2.0			V	
Input clamp voltage	V_C			−1.0	V	V_{CC} = 4.50 V, I_C = −5 mA
Input forward current	I_F			−0.5	mA	V_{CC} = 5.50 V, V_F = 0.45 V
Reverse input leakage current	I_R			60	μA	V_{CC} = 5.50 V V_R = 5.50 V
Output low voltage	V_{OL}					
$\overline{BUSY}$, $\overline{CBRQ}$				0.45	V	I_{OL} = 20 mA
$\overline{AEN}$				0.45	V	I_{OL} = 16 mA
$\overline{BPRO}$, $\overline{BREQ}$				0.45	V	I_{OL} = 10 mA
Output high voltage $\overline{BUSY}$, $\overline{CBRQ}$	V_{OH}	Open collector				
		2.4			V	I_{OH} = 400 μA
All other outputs						
Power supply current	I_{CC}			165	mA	

Capacitance

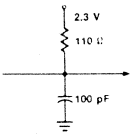
Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input capacitance	C_{IN} status			25	pF	
Input capacitance	C_{IN} (others)			12	pF	

Note:

1) BUSY, $\overline{CBRQ}$



2) $\overline{AEN}$



3) BPRO, BREQ

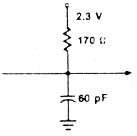


Figure 4. Typical CPU System Using the μPD8289 Bus Arbiter

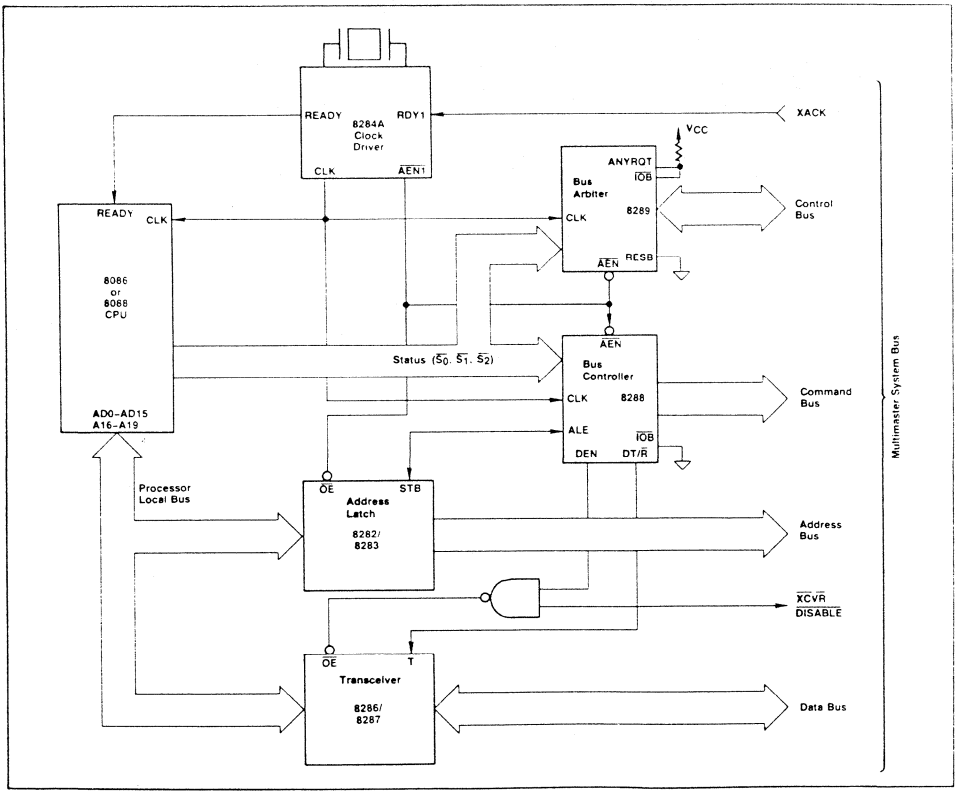


Figure 5. Typical Medium-Complexity IOB System

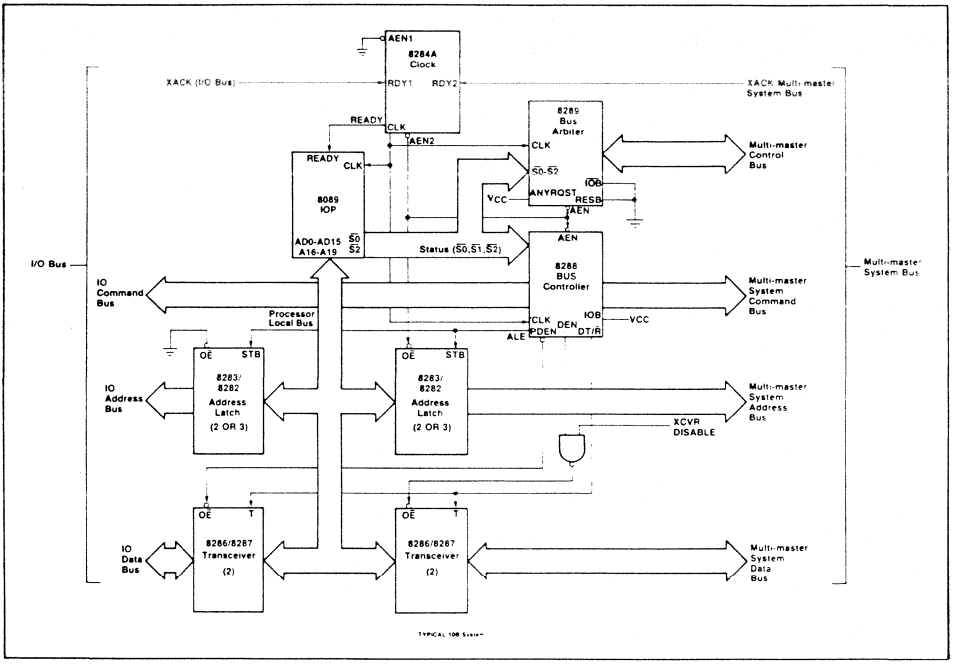
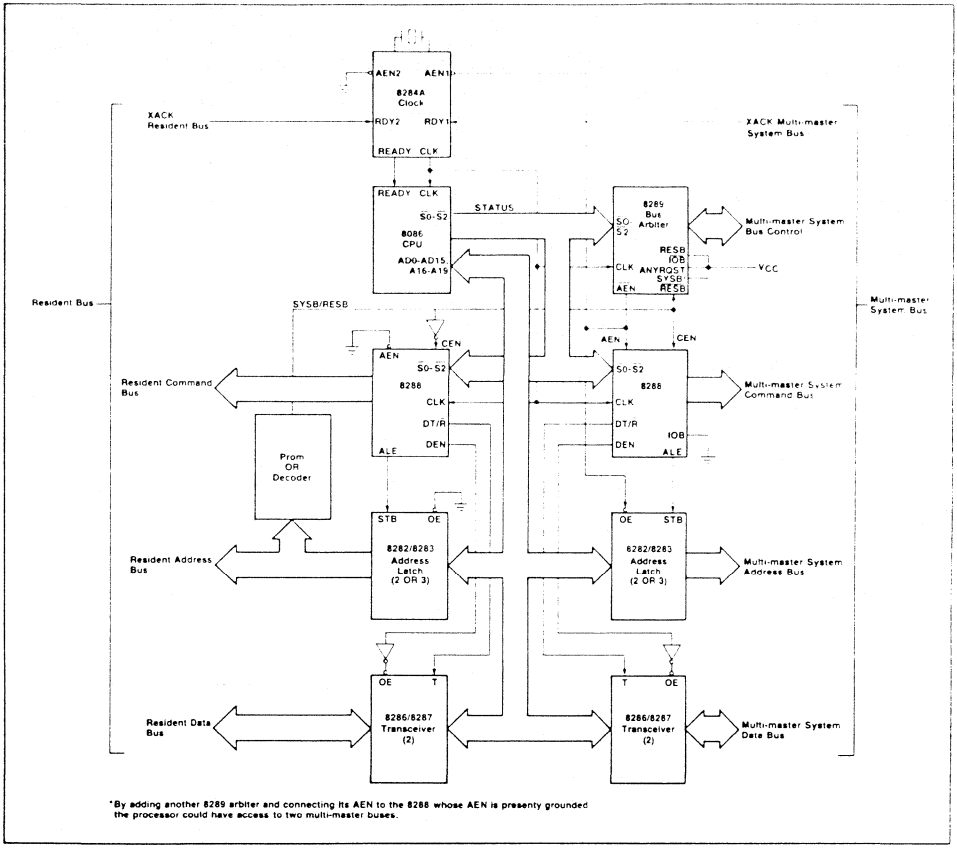


Figure 6. Typical System, Resident Bus Configuration



*By adding another 8289 arbiter and connecting its AEN to the 8288 whose AEN is presently grounded the processor could have access to two multi-master buses.

AC Characteristics

T_A = 0°C to +70°C; V_{CC} = 5V ±10%

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
CLK cycle period	t_{CLCL}	125			ns	
CLK low time	t_{CLCH}	65			ns	
CLK high time	t_{CHCL}	35			ns	
Status active setup	t_{SVCH}	65		$t_{CLCL}-10$	ns	
Status inactive setup	t_{SHCL}	50		$t_{CLCL}-10$	ns	
Status active hold	t_{HVCH}	10			ns	
Status inactive hold	t_{HVCL}	10			ns	
$\overline{BUSY}$↑↓ setup to $\overline{BCLK}$↓	t_{BYSBL}	20			ns	
$\overline{CBRQ}$↑↓ setup to $\overline{BCLK}$↓	t_{CBSBL}	20			ns	
$\overline{BCLK}$ cycle time	t_{BLBL}	100			ns	
$\overline{BCLK}$ high time	t_{BHCL}	30		0.65 (t_{BLBL})	ns	
LOCK inactive hold	t_{CLLL1}	10			ns	
LOCK active setup	t_{CLLL2}	40			ns	
$\overline{BPRN}$↑↓ to $\overline{BCLK}$ setup time	t_{PNBL}	15			ns	
SYSB/$\overline{RESB}$ setup	t_{CLSR1}	0			ns	
SYSB/$\overline{RESB}$ hold	t_{CLSR2}	20			ns	
Initialization pulse width	t_{IVIH}	3 t_{BLBL} + 3 t_{CLCL}			ns	
Input rise time	t_{ILIH}			20	ns	From 0.8 V to 2.0 V
Input fall time	t_{IHIL}			12	ns	From 2.0 V to 0.8 V

Timing Response

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
BCLK to BREQ delay (1)	t_{BLBRL}			35	ns	
BCLK to BPRO (1)(2)	t_{BLPOH}			40	ns	
$\overline{BPRN}$↑↓ to BPRO↑↓ delay (1)(2)	t_{PNPO}			25	ns	
BCLK to BUSY low	t_{BLBYL}			60	ns	
BCLK to BUSY float (3)	t_{BLBYH}			35	ns	
CLK to AEN high	t_{CLAEH}			65	ns	
BCLK to AEN low	t_{BLAEL}			40	ns	
BCLK to CBRQ low	t_{BLCBL}			60	ns	
BCLK to CBRQ float (3)	t_{RLCRH}			35	ns	
Output rise time	t_{OLOH}			20	ns	From 0.8 V to 2.0 V
Output fall time	t_{OHOL}			12	ns	From 2.0 V to 0.8 V

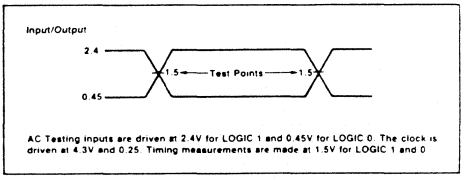
Note:

(1) Denotes that the spec applies to both transitions of the signal.

(2) BCLK generates the first BPRO. Subsequent changes of BPRO are generated through BPRON.

(3) Measured at 0.5 V above GND.

AC Test Condition



AC Testing inputs are driven at 2.4V for LOGIC 1 and 0.45V for LOGIC 0. The clock is driven at 4.3V and 0.25. Timing measurements are made at 1.5V for LOGIC 1 and 0

Timing Waveforms

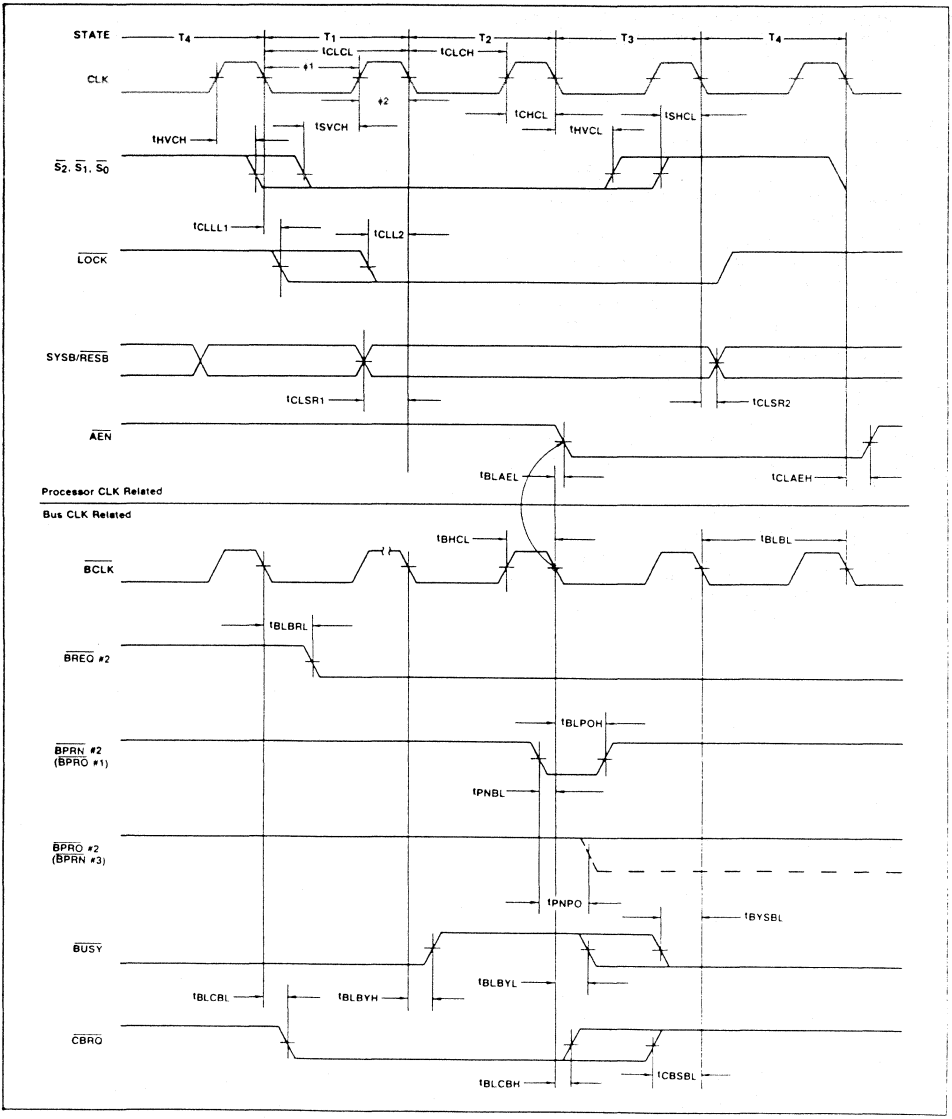
The signals related to CLK are typical processor signals and do not relate to the depicted sequence of events of the signals referenced to $\overline{BCLK}$. The signals shown related to the $\overline{BCLK}$ represent a hypothetical sequence of events for illustration. Assume three bus arbiters of priorities 1, 2, and 3 configured in the serial priority resolving scheme.

Assume arbiter 1 has the bus and is holding $\overline{BUSY}$ low. Arbiter 2 detects its processor wants the bus and pulls $\overline{BREQ}$ #2 low. If $\overline{BPRN}$ #2 is high (as shown), arbiter 2 pulls $\overline{CBRQ}$ low. $\overline{CBRQ}$ signals to higher-priority arbiter 1 that a lower-priority arbiter wants the bus. A higher-priority arbiter would be given $\overline{BPRN}$ when it makes the bus request rather than having to wait for another arbiter to release the bus through $\overline{CBRQ}$.

Arbiter 1 relinquishes the multimaster system bus when it enters a state of not requiring it, by lowering its $\overline{BPRO}$ #1 (tied to $\overline{BPRN}$ #2) and releasing $\overline{BUSY}$. Arbiter 2 now sees that it has priority from $\overline{BPRN}$ #2 being low and releases $\overline{CBRQ}$. As soon as $\overline{BUSY}$ signifies the bus is available (high), arbiter 2 pulls $\overline{BUSY}$ low on the next falling edge of $\overline{BCLK}$.

Note that if arbiter 2 didn't want the bus at the time it received priority, it would pass priority to the next lower priority by lowering its $\overline{BPRO}$ #2 (TPNPO). Note also that even a higher-priority arbiter which is aquiring the bus through $\overline{BPRN}$ will momentarily drop $\overline{CBRQ}$ until it has acquired the bus.

Timing Waveforms



PACKAGING INFORMATION 8

Section 8 – Packaging Information

Package/Device Cross Reference

Package	Device
16-Pin Plastic DIP (300 mil)	μPB8216C μPB8226C
18-Pin Plastic DIP (300 mil)	μPD7755C μPD7756C μPD71011C μPD71084C
18-Pin Cerdip (300 mil)	μPB8284AD
20-Pin Plastic DIP (300 mil)	μPB8282C μPB8283C μPB8286C μPB8287C μPD71082C μPD71083C μPD71086C μPD71087C μPD71088C μPD71611C μPD71613C
20-Pin Cerdip (300 mil)	μPB8288D μPB8289D
20-Pin Plastic SO (Small Outline) (300 mil)	μPD71011G μPD71082G μPD71083G μPD71084G μPD71086G μPD71087G μPD71088G
24-Pin Plastic DIP (600 mil)	μPD71054C μPD8243C μPD8243HC μPD82C43C μPD8253C-2 μPD8253C-5
24-Pin Plastic SO (400 mil)	μPD82C43G
28-Pin Plastic DIP (600 mil)	μPD8251AC μPD8251AFC μPD8259AC-2 μPD9306AC μPD71051C μPD71059C
28-Pin Ceramic DIP (600 mil)	μPD7220AD
28-Pin Plastic SO (Small Outline) (375 mil)	μPD71065G
28-Pin Plastic Leaded Chip Carrier (PLCC)	μPD71051L μPD71054L μPD71059L
30-Pin Plastic Shrink DIP (400 mil)	μPD71066CT
40-Pin Plastic DIP (600 mil)	μPD765AC μPD765AC-2 μPD780C μPD780C-1 μPD780C-2 μPD7201AC μPD7210C μPD7265C μPD7265AC-2 μPD7759C μPD8085AC-2 μPD8085AHC μPD8085AHC-2 μPD8155C μPD8155C-2 μPD8155HC μPD8155HC-2 μPD8156C μPD8156C-2 μPD8156HC μPD8156HC-2 μPD8237AC-5 μPD8255AC-2 μPD8257C-2 μPD8279C-2 μPB9201C μPD70008C μPD70008AC-4 μPD70008AC-6 μPD70108C-5 μPD70108C-8 μPD70116C-5 μPD70116C-8 μPD71055C μPD72001C μPD72065C μPD72066C

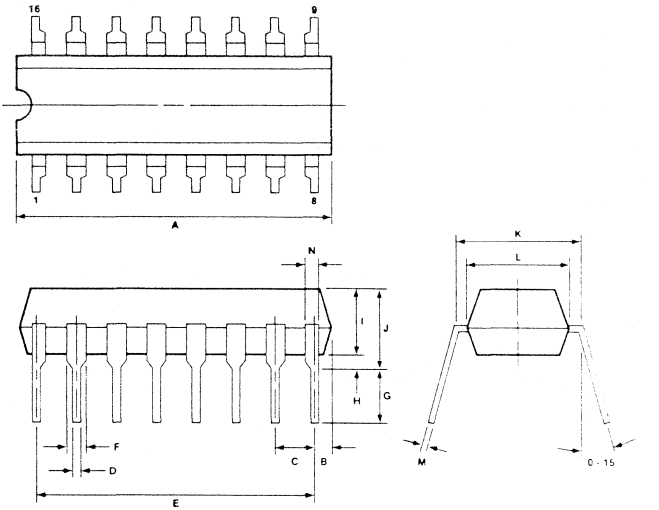
Package/Device Cross Reference

Package	Device
40-Pin Ceramic DIP (600 mil)	μPD7201AD μPD7220AD μPD7220AD-1 μPD7220AD-2 μPD7260D μPD7261AD μPD7261BD-18 μPD7262D μPD7281D μPD70108D-5 μPD70108D-8 μPD70108D-10 μPD70116D-5 μPD70116D-8 μPD70116D-10 μPD72191D
40-Pin Cerdip (600 mil)	μPD8086D μPD8086D-2 μPD8088D μPD8088D-2
44-Pin Plastic flat	μPD70008AG-4 μPD70008AG-6 μPD71051G μPD71054G μPD71055G μPD71059G
44-Pin Plastic Leaded Chip Carrier (PLCC)	μPD70008AL-6 μPD70108L-5
44-Pin Plastic Leaded Chip Carrier (PLCC) (cont)	μPD70108L-8 μPD70116L-5 μPD70116L-8 μPD71055L μPD72001L μPD72065L μPD72066L
48-Pin Plastic DIP (600 mil)	μPD71071C μPD72105C
48-Pin Ceramic DIP (600 mil)	μPD71071D
52-Pin Plastic Miniflat	μPD70108G-5 μPD70108G-8 μPD70116G-5 μPD70116G-8 μPD71071G μPD72065G μPD72066G μPD7225G
52-Pin Plastic Leaded Chip Carrier (PLCC)	μPD71071L μPD72105L
68-Pin Plastic Leaded Chip Carrier (PLCC)	μPD70208L μPD70216L
68-Pin Ceramic PGA	μPD70208R μPD70216R μPD70616R
80-Pin Plastic Miniflat	μPD70208G μPD70216G μPD7228G/AG
132-Pin Ceramic PGA	μPD9305R
64-Pin Plastic Flat	μPD7227G

16-Pin Plastic DIP (300 mil)

Item	Millimeters	Inches
A	20.32 max	0.8 max
B	1.27 max	.05 max
C	2.54 [TP]	.10 [TP]
D	.5 ± .10	.02 $^{+.004}_{-.005}$
E	17.78	.70
F	1.2 min	.047 min
G	3.5 ± .3	.138 ± .012
H	.51 min	.02 min
I	4.31 max	.17 max
J	5.08 max	.2 max
K	7.62 [TP]	.3 [TP]
L	6.4	.252
M	.25 $^{+.10}_{-.05}$	.01 $^{+.004}_{-.003}$
N	1.0 min	.039 min

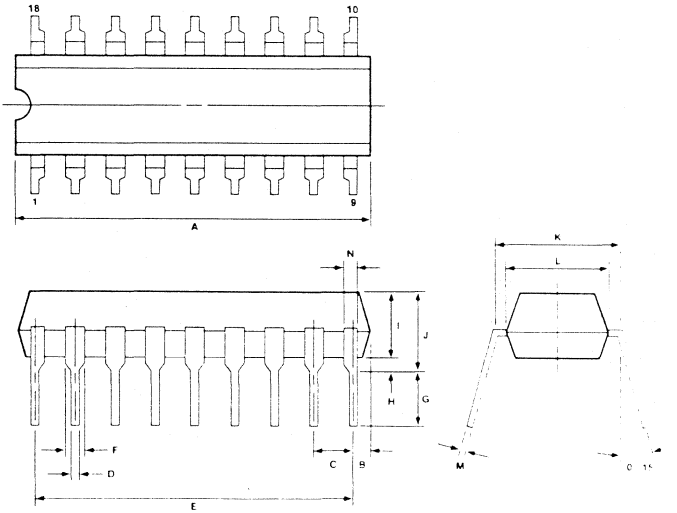
Notes:
1. Each lead centerline is located within .25 mm [.01 inch] of its true position [TP] at maximum material condition.
2. Item "K" to center of leads when formed parallel.



18-Pin Plastic DIP (300 mil)

Item	Millimeters	Inches
A	22.86 max	.9 max
B	1.27 max	.05 max
C	2.54 [TP]	.10 [TP]
D	.5 ± .10	.02 $^{+.004}_{-.005}$
E	20.32	.8
F	1.2 min	.047 min
G	3.5 ± .3	.138 ± .012
H	.51 min	.02 min
I	4.31 max	.17 max
J	5.08 max	.2 max
K	7.62 [TP]	.3 [TP]
L	6.4	.252
M	.25 $^{+.10}_{-.05}$	.01 $^{+.004}_{-.003}$
N	1.0 min	.039 min

Notes:
1. Each lead centerline is located within .25 mm [.01 inch] of its true position [TP] at maximum material condition.
2. Item "K" to center of leads when formed parallel.



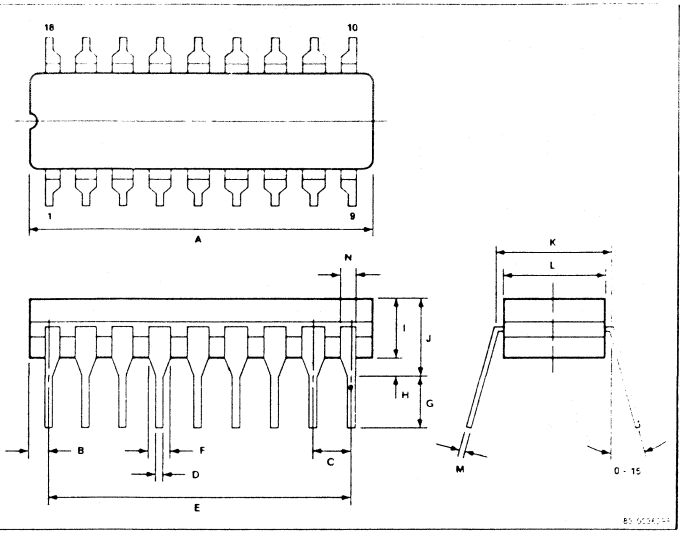
18-Pin Cerdip (300 mil)

Item	Millimeters	Inches
A	22.86 max	.900 max
B	1.27 max	.050 max
C	2.54 [TP]	.100 [TP]
D	.46 ± .05	.018 ± .002
E	20.32	.800
F	1.42 min	.055 min
G	3.5 ± .3	.138 ± .012
H	.51 min	.020 min
I	3.95	.156
J	5.08 max	.200 max
K	7.62 [TP]	.300 [TP]
L	6.60	.260
M	.25 ± .05	.010 $^{+.002}_{-.003}$
N	.89 min	.035 min

Notes:

[1] Each lead centerline is located within .25 mm [.010 inch] of its true position [TP] at maximum material condition.

[2] Item "K" to center of leads when formed parallel.



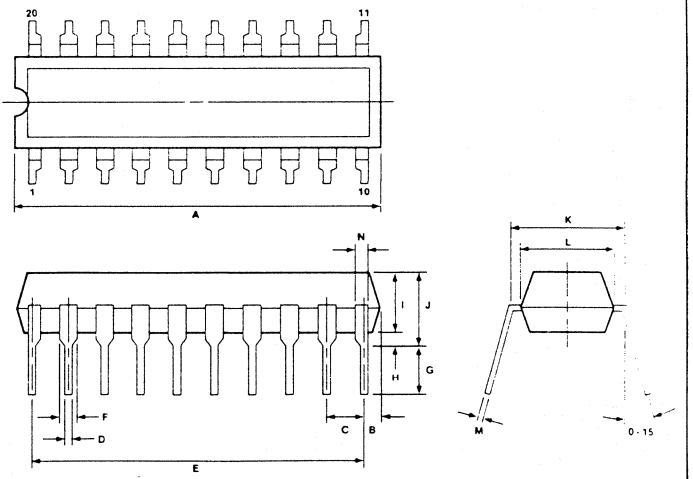
20-Pin Plastic DIP (300 mil)

Item	Millimeters	Inches
A	25.40 max	1.000 max
B	1.27 max	.050 max
C	2.54 [TP]	.100 [TP]
D	.50 ± .10	.020 $^{+.004}_{-.005}$
E	22.86	.900
F	1.1 min	.043 min
G	3.5 ± .30	.138 ± .012
H	.51 min	.020 min
I	4.31 max	.170 max
J	5.08 max	.200 max
K	7.62 [TP]	.300 [TP]
L	6.4	.252
M	.25 $^{+.10}_{-.05}$	.010 $^{+.004}_{-.003}$
N	.9 min	.035 min

Note:

[1] Each lead centerline is located within .25 mm [.010 inch] of its true position [TP] at maximum material condition.

[2] Item "K" to center of leads when formed parallel.



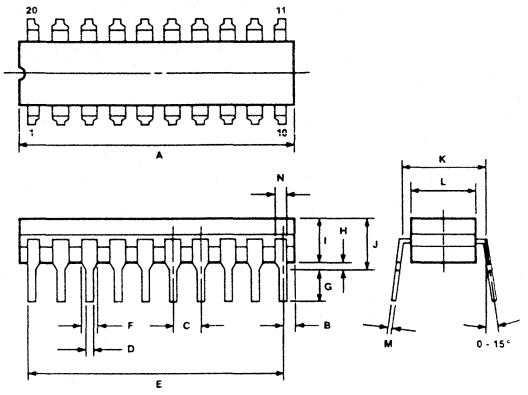
20-Pin Cerdip (300 mil)

Item	Millimeters	Inches
A	25.40 max	1.000 max
B	1.27 max	.050 max
C	2.54 [TP]	.100 [TP]
D	.46 ±.06	.018 ±.002
E	22.86	.900
F	1.42 min	.055 min
G	3.5 ±.3	.138 ±.012
H	.51 min	.020 min
I	3.95	.156
J	5.08 max	.200 max
K	7.62 [TP]	.300 [TP]
L	7.32	.288
M	.25 ±.05	.010 $^{+.002}_{-.003}$
N	.89 min	.035 min

Note:

[1] Each lead centerline is located within .25 mm [.01 inch] of its true position [TP] at maximum material condition.

[2] Item "K" to center of leads when formed parallel.

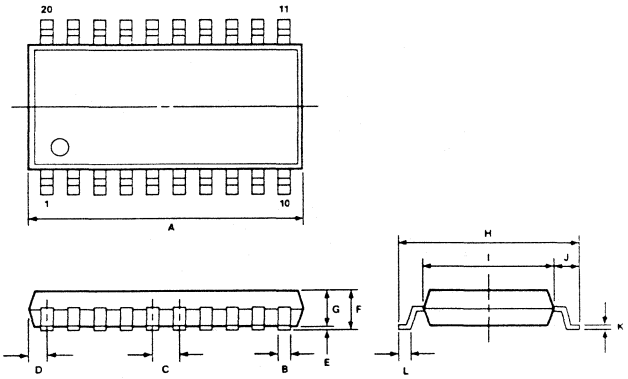


20-Pin Plastic SO (Small Outline) (300 mil)

Item	Millimeters	Inches
A	13.00 max	.512 max
B	.78 max	.031 max
C	1.27 [TP]	.050 [TP]
D	.40 $^{+.10}_{-.05}$	.016 $^{+.004}_{-.003}$
E	.1 ±.1	.004 ±.004
F	1.8 max	.071 max
G	1.50	.059
H	8.2 ±.3	.323 ±.012
I	6.0	.236
J	1.1	.043
K	.15 $^{+.10}_{-.05}$	.006 $^{+.004}_{-.002}$
L	.6 ±.2	.024 $^{+.008}_{-.009}$
M	.12	.005

Note:

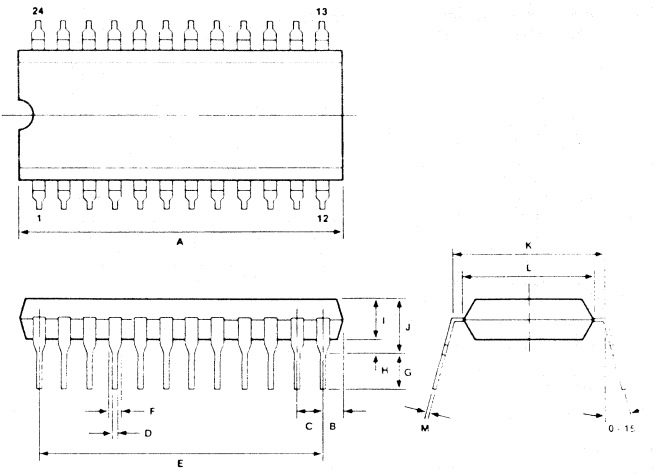
[1] Each lead centerline is located within .12 mm [.005 inch] of its true position [TP] at maximum material condition.



24-Pin Plastic DIP (600 mil)

Item	Millimeters	Inches
A	33.02 max	1.3 max
B	2.54 max	.10 max
C	2.54 [TP]	.10 [TP]
D	.5 ± .10	.02 $^{+.004}_{-.005}$
E	27.94	1.1
F	1.2 min	.047 min
G	3.6 ± .3	.138 ± .012
H	.51 min	.02 min
I	4.31 max	.17 max
J	5.72 max	.226 max
K	15.24 [TP]	.60 [TP]
L	13.2	.52
M	.25 $^{+.10}_{-.05}$	.01 $^{+.004}_{-.003}$

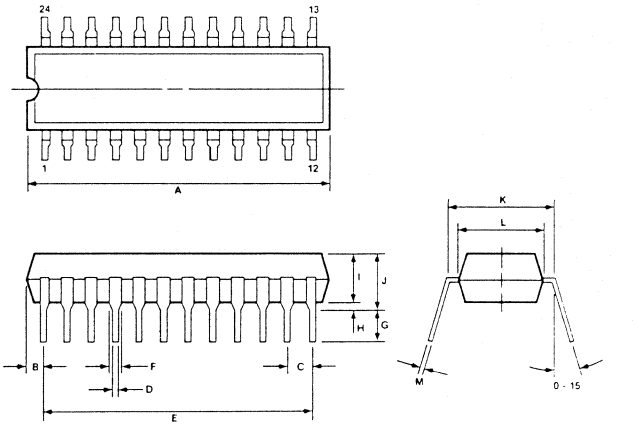
Notes
1. Each lead centerline is located within .25 mm [.01 inch] of its true position [TP] at maximum material condition.
2. Item "K" to center of leads when formed parallel.



24-Pin Plastic Skinny DIP (400 mil)

Item	Millimeters	Inches
A	35.56 max	1.400 max
B	3.81 max	.150 max
C	2.54 [TP]	.100 [TP]
D	.50 $^{+.1}_{-.05}$	.020 $^{+.004}_{-.005}$
E	27.94	1.100
F	1.1 min	.043 min
G	3.6 ±.3	.142 ±.012
H	.51 min	.020 min
I	4.31 max	.170 max
J	5.72 max	.226 max
K	10.16 [TP]	.400 [TP]
L	8.6	.339
M	.25 $^{+.10}_{-.05}$	.010 $^{+.004}_{-.003}$

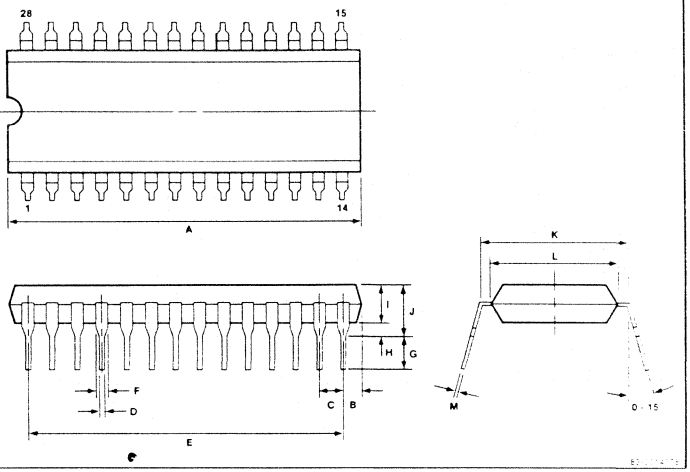
Note:
[1] Each lead centerline is located within .12 mm [.005 inch] of its true position [TP] at maximum material condition.
[2] Item "K" to center of leads when formed parallel.



28-Pin Plastic DIP (600 mil)

Item	Millimeters	Inches
A	38.1 max	1.5 max
B	2.54 max	.10 max
C	2.54 [TP]	.10 [TP]
D	.5 ± .10	.02 $^{+.004}_{-.005}$
E	33.02	1.3
F	1.2 min	.047 min
G	3.6 ± .3	.142 ± .012
H	.51 min	.02 min
I	4.31 max	.17 max
J	5.72 max	.226 max
K	15.24 [TP]	.60 [TP]
L	13.2	.52
M	.25 $^{+.10}_{-.05}$	.01 $^{+.004}_{-.003}$

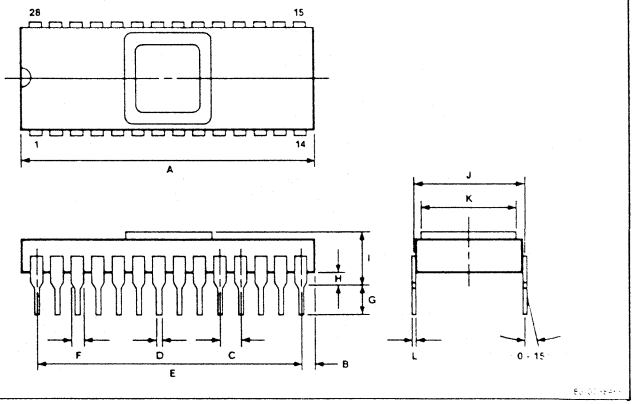
Notes:
1. Each lead centerline is located within .25 mm [.01 inch] of its true position [TP] at maximum material condition.
2. Item "K" to center of leads when formed parallel.



28-Pin Ceramic DIP (600 mil)

Item	Millimeters	Inches
A	38.10 max	1.500 max
B	2.54 max	.100 max
C	2.54 [TP]	.100 [TP]
D	.46 ± .05	.018 ± .002
E	33.02	1.3
F	.92 min	.036 min
G	3.5 ± .3	.138 ± .012
H	1.0 min	.039 min
I	4.57 max	.180 max
J	15.24 [TP]	.600 [TP]
K	14.93	.588
L	.25 ± .05	.010 $^{+.002}_{-.003}$

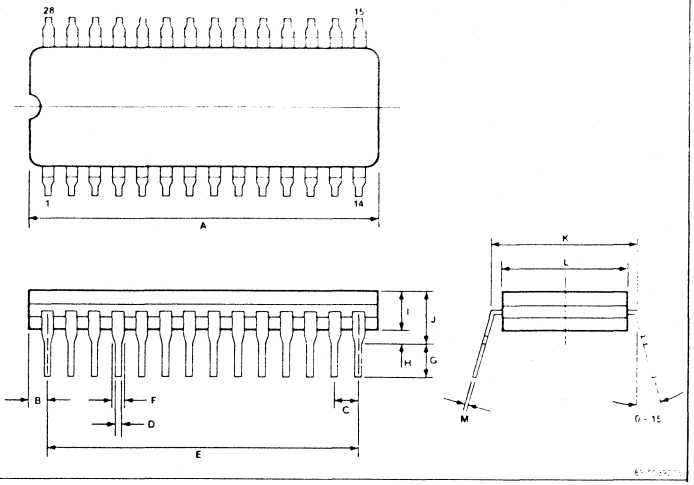
Note:
[1] Each lead centerline is located within .25 mm [.01 inch] of its true position [TP] at maximum material condition.
[2] Item "K" to center of leads when formed parallel.



28-Pin Cerdip (600 mil)

Item	Millimeters	Inches
A	38.10 max	1.500 max
B	2.54 max	.100 max
C	2.54 [TP]	.100 [TP]
D	.50 ± .10	$.020^{+.004}_{-.005}$
E	33.02	1.300
F	1.2 min	.047 min
G	3.5 ± .3	.138 ±.012
H	.51 min	.020 min
I	3.80	.150
J	5.08 max	.200 max
K	15.24 [TP]	.600 [TP]
L	13.21	.520
M	.25 ± .05	$.010^{+.002}_{-.003}$

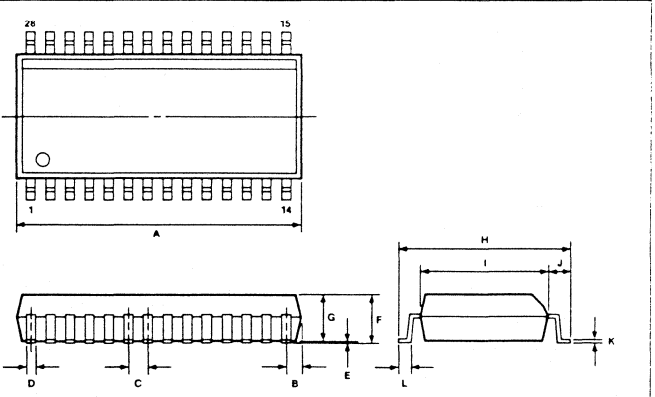
Note:
[1] Each lead centerline is located within .25 mm [.01 inch] of its true position [TP] at maximum material condition.
[2] Item "K" to center of leads when formed parallel.



28-Pin Plastic SO (Small Outline) (375 mil)

Item	Millimeters	Inches
A	18.07 max	.712 max
B	.78 max	.031 max
C	1.27 [TP]	.050 [TP]
D	$.40^{+.10}_{-.05}$	$.016^{+.004}_{-.003}$
E	.1 ±.1	.004 ±.004
F	2.9 max	.115 max
G	2.50	.098
H	10.3 ±.3	$.406^{+.012}_{-.013}$
I	7.2	.283
J	1.6	.063
K	$.15^{+.10}_{-.05}$	$.006^{+.004}_{-.002}$
L	.8 ±.2	$.031^{+.009}_{-.008}$

Note:
[1] Each lead centerline is located within .12 mm [.005 inch] of its true position [TP] at maximum material condition.



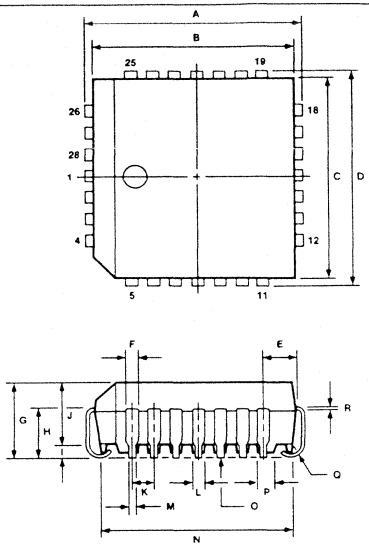
28-Pin Plastic Leaded Chip Carrier (PLCC)

Item	Millimeters	Inches
A	12.45 ±.2	.490 ±.008
B	11.50	.453
C	11.50	.453
D	12.45 ±.2	.490 ±.008
E	1.94 ± .15	.076 $^{+.007}_{-.006}$
F	.6	.024
G	4.4 ±.2	.173 $^{+.009}_{-.008}$
H	2.8 ±.2	.110 $^{+.009}_{-.008}$
I	0.7 min	.028 min
J	3.6	.142
K	1.27 [TP] Note 1	.050 [TP]
L	.7	.028
M	.40 ±.10	.016 $^{+.004}_{-.005}$
N	10.42 ±.20	.410 $^{+.009}_{-.008}$
O	.15 Note 2	.006
P	1.0	.040
Q	R .8	R .031
R	.20 $^{+.10}_{-.05}$	.008 $^{+.004}_{-.002}$

Note:

[1] Each lead centerline is located within .12 mm [.005 inch] of its true position [TP] at maximum material condition.

[2] Flat within .15 mm [.006 inch] total



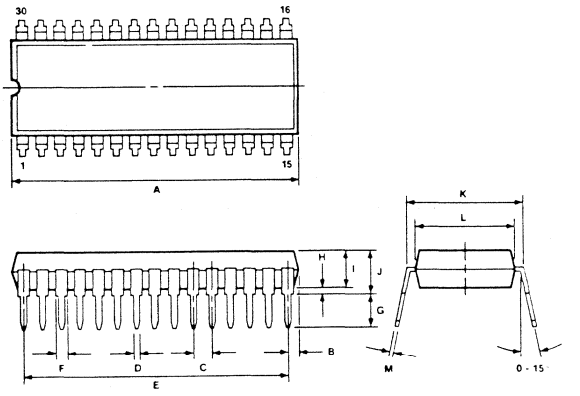
30-Pin Plastic Shrink DIP (400 mil)

Item	Millimeters	Inches
A	28.46 max	1.121 max
B	1.78 max	.070 max
C	1.778 [TP]	.070 [TP]
D	.50 ±.10	.020 $^{+.004}_{-.005}$
E	24.89	.980
F	.85 min	.033 min
G	3.2 ±.3	.126 ±.012
H	.51 min	.020 min
I	4.31 max	.170 max
J	5.08 max	.200 max
K	10.16 [TP]	.400 [TP]
L	8.6	.339
M	.25 $^{+.10}_{-.05}$	.010 $^{+.004}_{-.003}$

Note

[1] Each lead centerline is located within .17 mm [.007 inch] of its true position [TP] at maximum material condition.

[2] Item "K" to center of leads when formed parallel



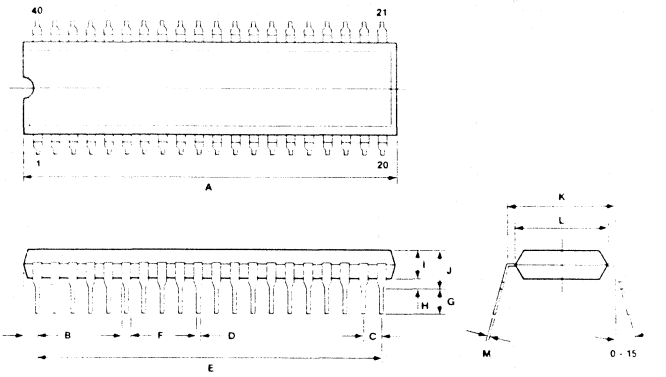
40-Pin Plastic DIP (600 mil)

Item	Millimeters	Inches
A	53.34 max	2.100 max
B	2.54 max	.100 max
C	2.54 [TP]	.100 [TP]
	.50 ± .10	.020 $^{+.004}_{-.005}$
E	48.26	1.900
F	1.2 min	.047 min
G	3.6 ± .3	.142 ± .012
H	.51 min	.020 min
I	4.31 max	.170 max
J	5.72 max	.226 max
K	15.24 [TP]	.600 [TP]
L	13.2	.520
M	.25 $^{+.10}_{-.05}$	.010 $^{+.004}_{-.003}$

Notes:

[1] Each lead centerline is located within .25 mm [.010 inch] of its true position [TP] at maximum material condition.

[2] Item "K" to center of leads when formed parallel.



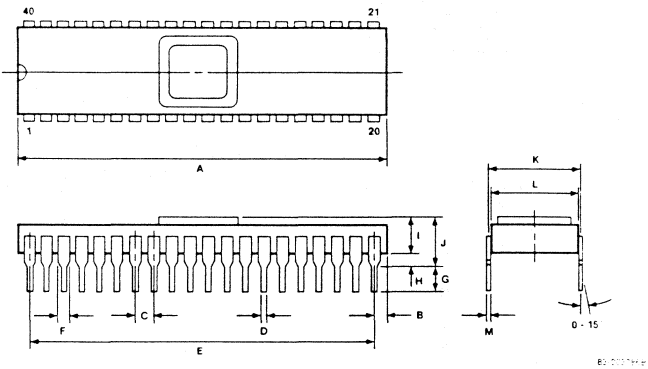
40-Pin Ceramic DIP (600 mil)

Item	Millimeters	Inches
A	53.34 max	2.100 max
B	2.54 max	.100 max
C	2.54 [TP]	.100 [TP]
D	.46 ± .05	.018 ± .002
E	48.26	1.900
F	.92 min	.036 min
G	3.5 ± .03	.0138 ± .012
H	1.0 min	.039 min
I	2.64	.104
J	4.57 max	.180 max
K	15.24 [TP]	.600 [TP]
L	14.93	.588
M	.25 ± .05	.010 $^{+.002}_{-.003}$

Note:

[1] Each lead centerline is located within .25 mm [.001 inch] of its true position [TP] at maximum material condition.

[2] Item "K" to center of leads when formed parallel.



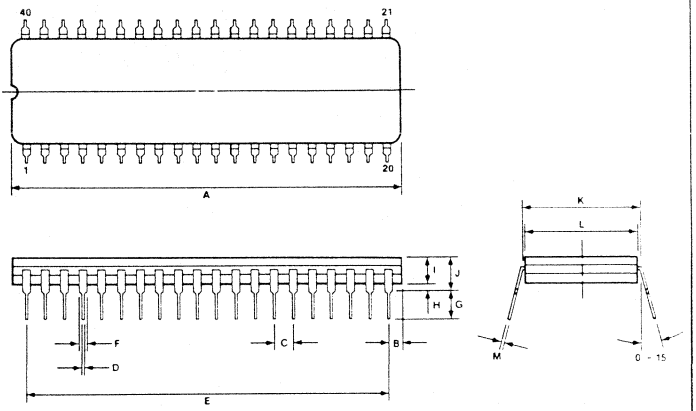
40-Pin Cerdip (600 mil)

Item	Millimeters	Inches
A	53.34 max	2.100 max
B	2.54 max	.100 max
C	2.54 [TP]	.100 [TP]
D	.50 ±.10	$.020^{+.004}_{-.005}$
E	48.26	1.900
F	1.2 min	.047 min
G	3.5 ±.3	0.138 ±.012
H	.51 min	.020 min
I	3.80	.150
J	5.08 max	.200 max
K	15.24 [TP]	.600 [TP]
L	13.21	.520
M	.25 ± .05	$.010^{-.002}_{-.003}$

Note:

[1] Each lead centerline is located within .25 mm [.01 inch] of its true position [TP] at maximum material condition.

[2] Item "K" to center of leads when formed parallel.



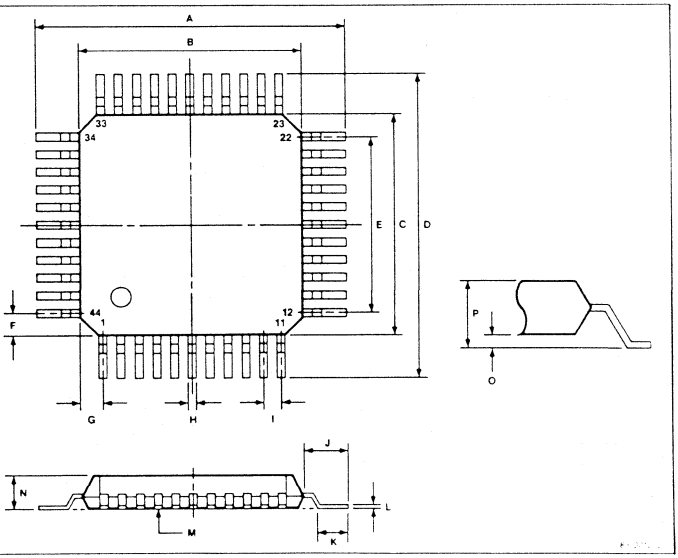
44-Pin Plastic Miniflat

Item	Millimeters	Inches
A	13.6 ±.4	$.535^{+.017}_{-.016}$
B	10 ±.2	$.394^{+.008}_{-.009}$
C	10 ±.2	$.394^{+.008}_{-.009}$
D	13.6 ± .4	$.535^{+.017}_{-.018}$
E	8.0	.315
F	1.0	.039
G	1.0	.039
H	$.35^{+.20}_{-.10}$	$.014^{+.006}_{-.005}$
I	.8 [TP] Note 1	.031 [TP]
J	1.8 ±.2	$.071^{+.008}_{-.009}$
K	1.0 ±.2	$.039^{+.009}_{-.008}$
L	$.15^{+.10}_{-.05}$	$.006^{+.004}_{-.003}$
M	.15 Note 2	.006
N	1.45 ±.1	$.057^{+.005}_{-.004}$
O	0.0 ±.1	0.000 ±.004
P	1.65 max	.065 max

Note:

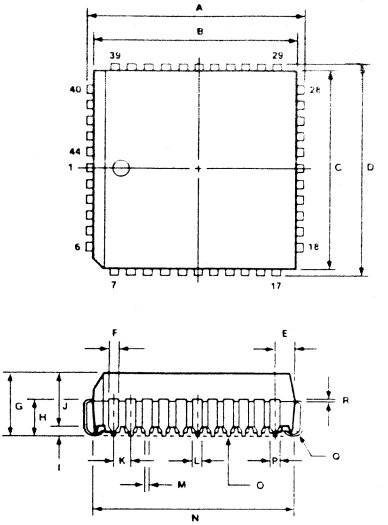
[1] Each lead centerline is located within .15 mm [.006 inch] of its true position [TP] at maximum material condition.

[2] Flat within .15 mm [.006 inch] total.



44-Pin Plastic Leaded Chip Carrier (PLCC)

Item	Millimeters	Inches
A	17.5 ± .2	.689 ± .008
B	16.58	.653
C	16.58	.653
D	17.5 ± .2	.689 ± .008
E	1.94 ± .15	.076 $^{+.007}_{-.006}$
F	.6	.024
G	4.4 ± .2	.173 $^{+.009}_{-.008}$
H	2.8 ± .2	.110 $^{+.009}_{-.008}$
I	.7 min	.028 min
J	3.6	.142
K	1.27 [TP] Note 1	.050 [TP]
L	.7	.028
M	.40 ± .10	.016 $^{+.004}_{-.005}$
N	15.50 ± .20	.610 $^{+.009}_{-.008}$
O	.15 Note 2	.006
P	1.0	.040
Q	R .8	R .031
R	.20 $^{+.10}_{-.05}$	.008 $^{+.004}_{-.002}$



Note

[1] Each lead centerline is located within .12 mm [.005 inch] of its true position [TP] at maximum material condition.

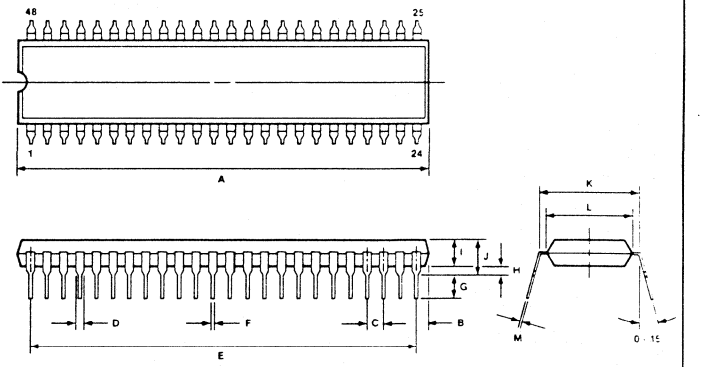
[2] Flat within .15 mm [.006 inch] total

48-Pin Plastic DIP (600 mil)

Item	Millimeters	Inches
A	63.50 max	2.5 max
B	2.54 max	.10 max
C	2.54 [TP]	.10 [TP]
D	.5 ± .10	.02 $^{+.004}_{-.005}$
E	58.42	2.3
F	1.1 min	.043 min
G	3.6 ± .3	.142 ± .012
H	.51 min	.02 min
I	4.31 max	.17 max
J	5.72 max	.226 max
K	15.24 [TP]	.60 [TP]
L	13.8	.543
M	.25 $^{+.10}_{-.05}$	.01 $^{+.004}_{-.003}$

Notes:

1. Each lead centerline is located within .25 mm [.01 inch] of its true position [TP] at maximum material condition.
2. Item "K" to center of leads when formed parallel.



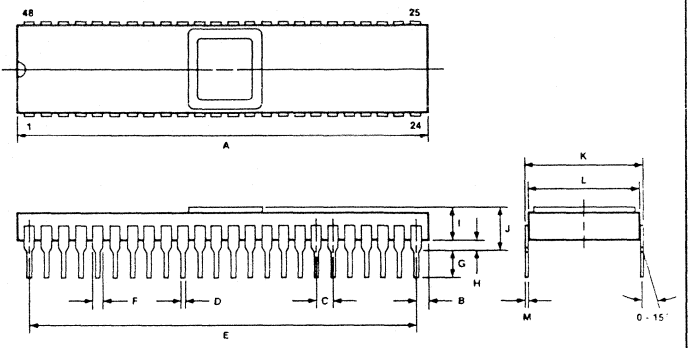
48-Pin Ceramic DIP (600 mil)

Item	Millimeters	Inches
A	63.50 max	2.500 max
B	2.54 max	.100 max
C	2.54 [TP]	.100 [TP]
D	.46 ±.05	.018 ±.002
E	58.42	2.300
F	.92 min	.036 min
G	3.5 ±.3	.138 ±.012
H	1.0 min	.039 min
I	2.74 Note 1	.108
J	4.57 max	.180 max
K	15.24 [TP]	.600 [TP]
L	14.93	.588
M	.25 ±.05 Note 2	.010 $^{+.002}_{-.003}$

Note:

[1] Each lead centerline is located within .25 mm [.01 inch] of its true position [TP] at maximum material condition.

[2] Item "K" to center of leads when formed parallel.



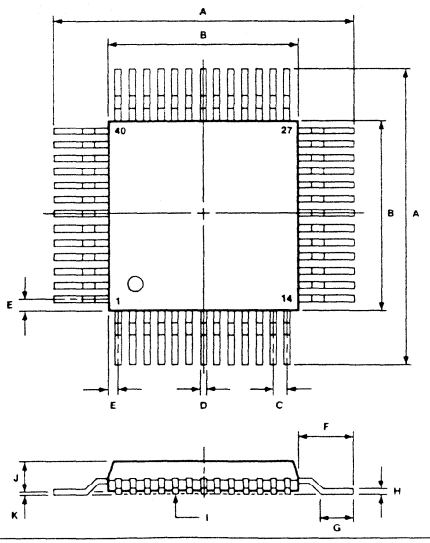
52-Pin Plastic Flat pack

Item	Millimeters	Inches
A	21.0 ±.4	.827 ±.016
B	14 ±.2	.551 $^{+.009}_{-.008}$
C	1.0 [TP] Note 1	.039 [TP]
D	.40 ±.10	.016 $^{+.004}_{-.005}$
E	1.0	.039
F	3.5 ±.2	.138 $^{+.008}_{-.009}$
G	2.2 ±.2	.087 $^{+.008}_{-.009}$
H	.15 $^{+.10}_{-.05}$	.006 $^{+.004}_{-.003}$
I	.15 Note 2	.006
J	2.6 $^{+.02}_{-.01}$	.102 $^{+.009}_{-.004}$
K	.1 ±.1	.004 ±.004

Note:

[1] Each lead centerline is located within .20 mm [.008 inch] of its true position [TP] at maximum material condition.

[2] Flat within .15 mm [.006 inch] total.



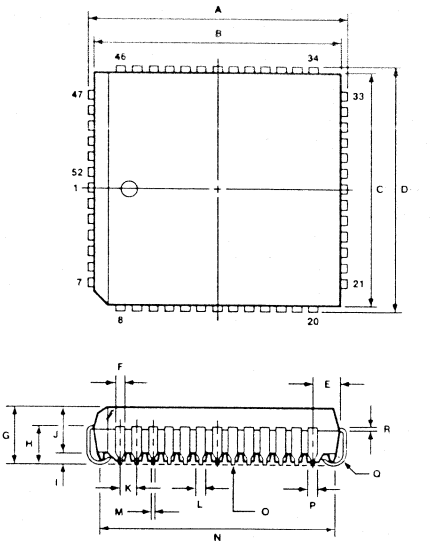
52-Pin Plastic Leaded Chip Carrier (PLCC)

Item	Millimeters	Inches
A	20.1 ± .2	.791 $^{+.009}_{-.008}$
B	19.12	.753
C	19.12	.753
D	20.1 ± .2	.791 $^{+.009}_{-.008}$
E	1.94 ± .15	.076 $^{+.007}_{-.006}$
F	.6	.024
G	4.4 ± .2	.173 $^{+.009}_{-.008}$
H	2.8 ± .2	.110 $^{+.009}_{-.008}$
I	.7 min	.028 min
J	3.6	.142
K	1.27 [TP] Note 1	.050 [TP]
L	.7	.028
M	.40 ± .10	.016 $^{+.004}_{-.005}$
N	18.04 ± .20	.710 $^{+.009}_{-.008}$
O	.15 Note 2	.006
P	1.0	.040
Q	R .8	R .031
R	.20 $^{+.10}_{-.05}$	.008 $^{+.004}_{-.002}$

Note:

[1] Each lead centerline is located within .12 mm [.005 inch] of its true position [TP] at maximum material condition.

[2] Flat within .15 mm [.006 inch] total.



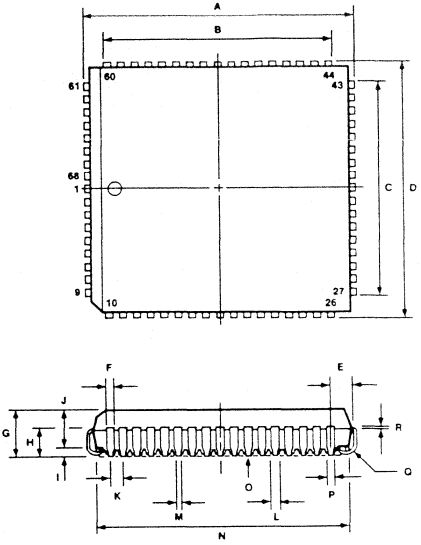
68-Pin Plastic Leaded Chip Carrier (PLCC)

Item	Millimeters	Inches
A	25.2 ±.2	.992 ±.008
B	24.20	.953
C	24.20	.953
D	25.2 ±.2	.992 ±.008
E	1.94 ±.15	.076 $^{+.007}_{-.006}$
F	.6	.024
G	4.4 ±.2	.173 $^{+.009}_{-.008}$
H	2.8 ±.2	.110 $^{+.009}_{-.008}$
I	.7 min	.028 min
J	3.6	.142
K	1.27 [TP] Note 1	.050 [TP]
L	.7	.028
M	.40 ±.10	.016 $^{+.004}_{-.005}$
N	23.12 ±.20	.910 $^{+.009}_{-.008}$
O	.15 Note 2	.006
P	1.0	.040
Q	R .8	R .031
R	.20 $^{+.10}_{-.06}$	.008 $^{+.004}_{-.002}$

Note:

[1] Each lead centerline is located within .12 mm [.005 inch] of its true position [TP] at maximum material condition.

[2] Flat within .15 mm [.006 inch] total.

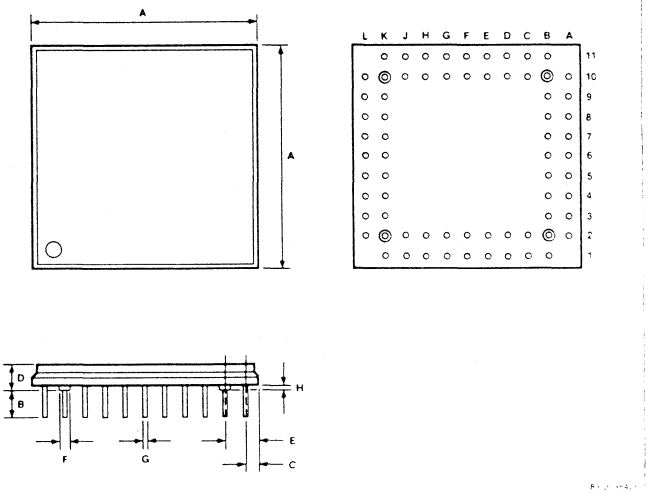


68-Pin Ceramic PGA

Item	Millimeters	Inches
A	27.9 $^{+.8}_{-.4}$	1.10 $^{+.031}_{-.015}$
B	2.8 ±.3	.110 ±.012
C	1.25	.049
D	5.08 max	.200 max
E	2.54 [TP]	.100 [TP]
F	φ 1.2 ±.2	.047 ±.008
G	φ .46 ±.05	.018 ±.002
H	.5 min	.020 min

Note:

[1] Each lead centerline is located within .25 mm [.010 inch] of its true position [TP] at maximum material condition.



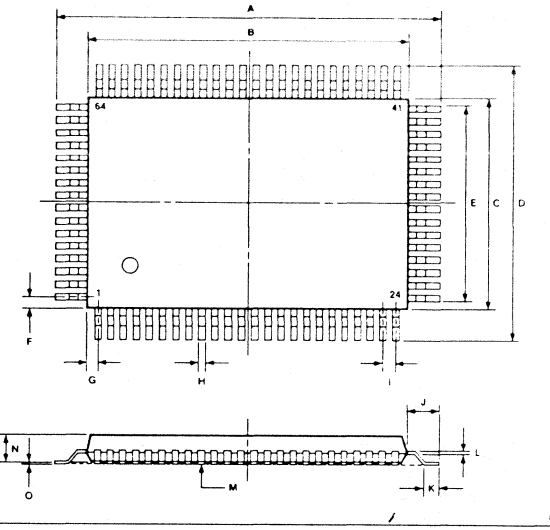
80-Pin Plastic Miniflat

Item	Millimeters	Inches
A	24.7 ± .4	.972 $^{+.017}_{-.016}$
B	20 ± .3	.795 $^{+.009}_{-.008}$
C	14 ± .2	.551 $^{+.009}_{-.008}$
D	18.7 ± .4	.736 ± .016
E	12	.472
F	1.0	.039
G	.8	.031
H	.35 ± .1	.014 $^{+.004}_{-.003}$
I	.8 [TP] Note 1	.031 [TP]
J	2.35 ± .3	.093 $^{+.006}_{-.009}$
K	1.2 ± .2	.047 $^{+.009}_{-.006}$
L	.15 $^{+.10}_{-.009}$	.006 $^{+.004}_{-.003}$
M	.15 Note 2	.006
N	2.05 $^{+.2}_{-.1}$	.081 $^{+.006}_{-.005}$
O	.1 ± .1	.004 ± .004

Note:

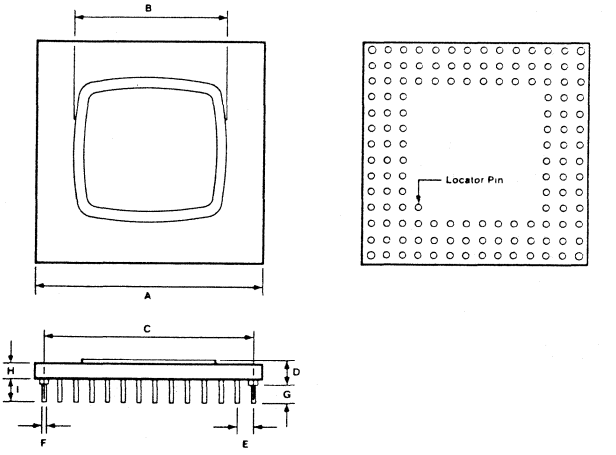
[1] Each lead centerline is located within .15 mm [.006 inch] of its true position [TP] at maximum material condition.

[2] Flat within .15 mm [.006 inch] total.



132-Pin Ceramic PGA

Item	Millimeters	Inches
A	35.56	1.400
B	22.70	.894
C	33.02	1.300
D	4.5 max	.177 max
E	2.54	.100
F	φ .40	.016
G	2.8	.110
H	2.28	.090
I	3.8	.150



Notes: