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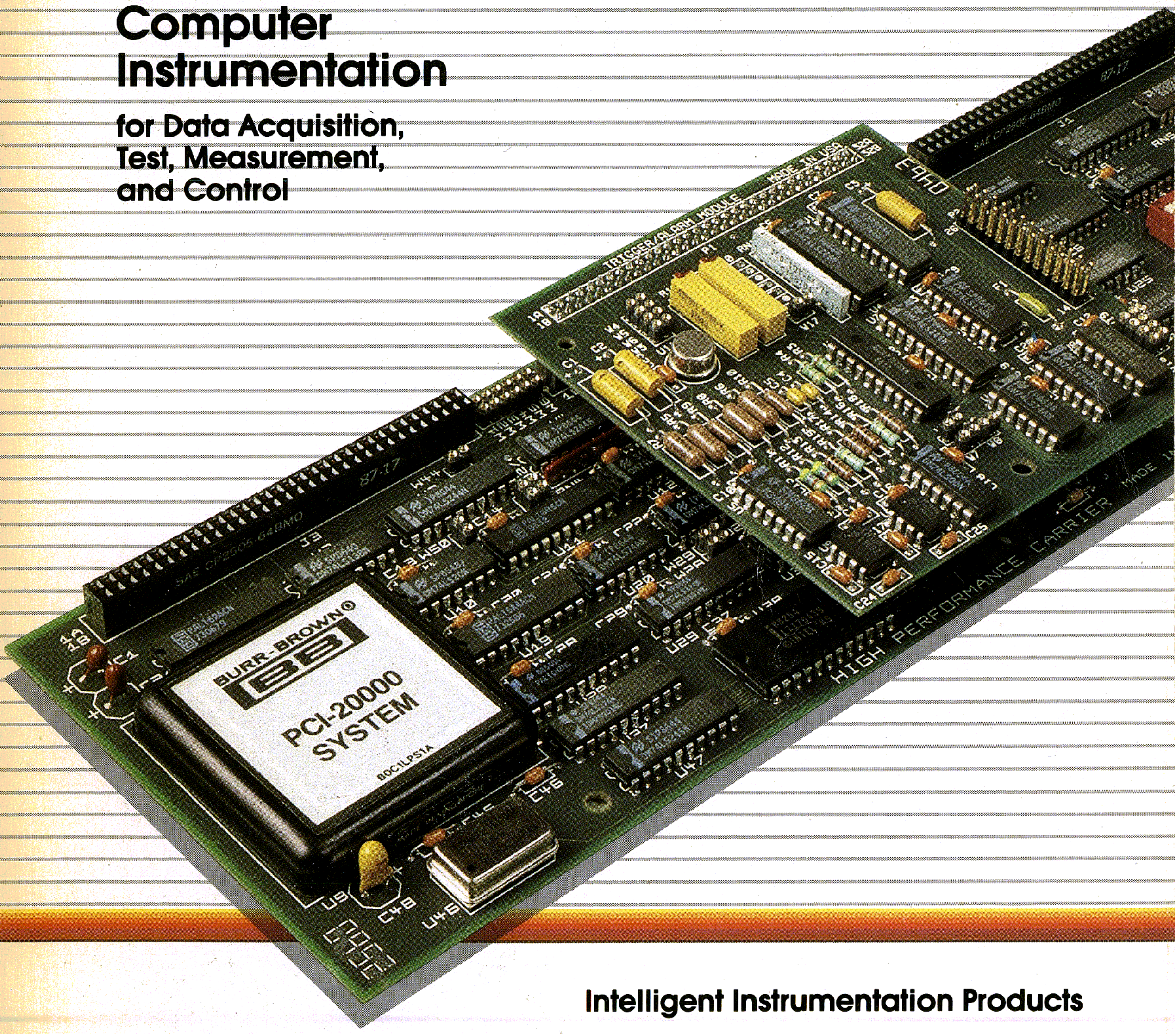
4th Edition

The Handbook of Personal Computer Instrumentation

for Data Acquisition, Test, Measurement, and Control



Intelligent Instrumentation Products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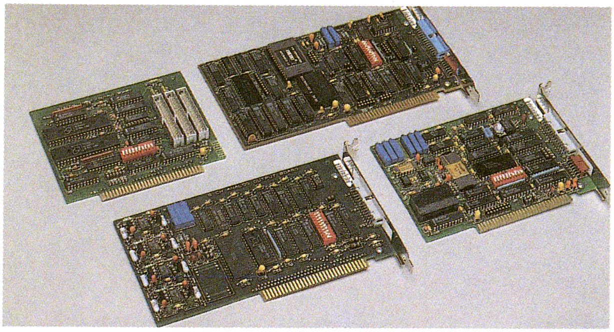

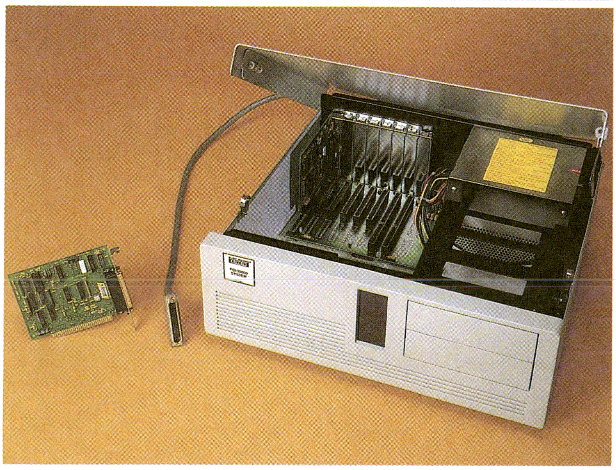

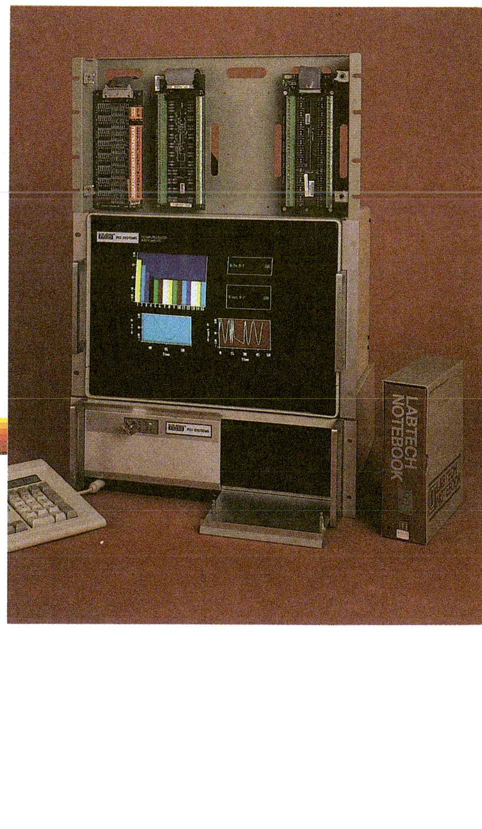
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PREFACE TO THE FOURTH EDITION

THE UBIQUITOUS COMPUTER

Today the personal computer is everywhere, a powerful tool for industry and scientific research.

Teamed with a precision analog/digital interface system, a personal computer can effectively perform all the functions of larger, dedicated instrumentation and control systems-- and at a fraction of their former cost. And with many software and hardware options currently available, the personal computer interface can be easily configured and expanded to satisfy a wide variety of instrumentation and control applications.

THE RIGHT TOOL SET

Personal computers and their software provide a standard set of tools for data management tasks. New systems and software are evolving for more specialized applications in industry-- special tools tailored for use in the areas of:

- data acquisition
- test instrumentation
- measurement
- control

These new tools make the power, versatility and low cost of the personal computer available for a wide range of new and demanding applications.

Now an engineer can combine the tools to acquire data, test products and systems, and perform controls. Using these same tools he can organize , display, provide graphics, and print data/reports. Powerful systems are thus flexible, programmable and inexpensive.

NEED FOR A HANDBOOK

The rapid developement, evolution, and acceptance of the personal computer along with personal-computer instrumentation (PCI) systems, such as the PCI-20000, have created a need for a handbook to better acquaint engineers with just what these newest tools really are. The handbook explains what an engineer should consider as he begins to configure PCI systems and to use them to increase his productivity.

So here it is, a **real** handbook (and not just a set of product data sheets). This handbook begins with tutorial information to help a new user to get started in the world of data acquisition. The tutorial section is followed by a large applications section, including many specific applications examples and sample programs. At the end, there are specifications, technical information, and how-to-configure charts for the PCI products that are the leadership products for the personal computer instrumentation industry today.

FOURTH EDITION

An extremely large, worldwide demand for the first three editions of the PCI Handbook has brought about the availability of the fourth edition sooner than expected. This fourth edition contains information on many new products, such as single-board systems, self-contained carrier or mother boards, intelligent carriers (mother boards) with digital-signal-processor integrated circuits, PC-Bus expanders, and an exciting PCI Work Station. This handbook has already become the industry's standard-of-reference for Personal Computer Instrumentation used in data acquisition, test, measurement, and control.

Free Burr-Brown Demonstation Diskettes showing product capabilities, specifications, and applications for the PCI-20000 system are available through Burr-Brown sales offices. These diskettes run on the IBM PC and compatible computers containing a graphics card. Please contact your local sales office for your free diskette. See office listings at the back of this handbook.

MODEL NUMBER INDEX

(Complete Subject Index at back of handbook)

PCI-20000 System

PCI-500 System

Other PCI Products

MAJOR TOPICS

(Complete Subject Index at back of handbook)

BURR-BROWN CORPORATION
INTELLIGENT INSTRUMENTATION PRODUCTS

1141 West Grant Road #131 Tucson, AZ 85705

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TAB INDEX

Section 1
Data Acquisition and Control, An Overview

The term data acquisition and control (DA&C) can mean different things to each of us. Observing a voltmeter and manually recording its reading certainly constitutes data acquisition. Furthermore, when we turn the dimmer knob on a room lamp, we achieve control. These are, of course, very simple examples. Think about the number of DA&C actions taken by each of us at work, in industry, in driving a car, in everyday life.

Simply stated, data acquisition is the collecting of information that describes a given situation. The data typically reflects what was happening when a given condition was satisfied. Usually, this condition is defined by a uniform time-base, but it could be controlled by any event. "Real-time" systems are characterized by their ability to perform a given data acquisition and/or control task within an appropriate time window. How fast such a system must respond depends upon the speed and accuracy requirements of that given application.

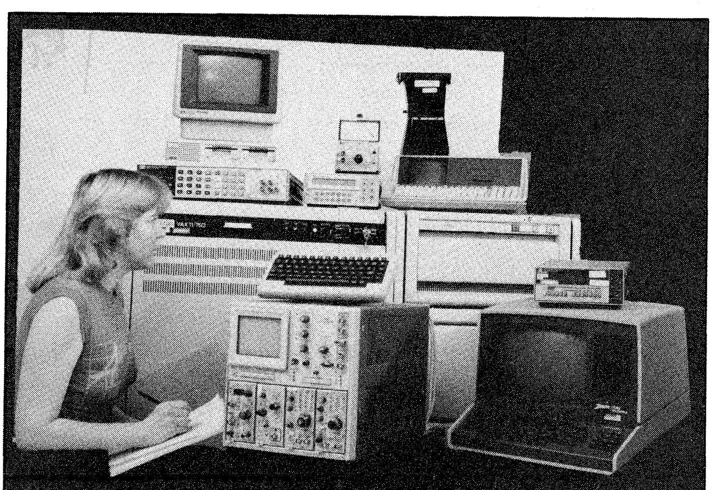
For every data acquisition or control system, no matter how slow it may be, there is an application sufficiently slow that, for that application, the system is real-time.

Control implies the generation of an output signal in response to input data. Control can be "open loop" or "closed loop". Turning off the heat at 4:00 p.m. is an example of open-loop control, while turning off the heat because it is too hot represents closed-loop control.

Data is collected by technicians, engineers, physicists, chemists or others involved in research, test, development, production, quality control, management, process control, etc.. Industries involved include: electrical, electronics, steel, mechanical, chemical, oil, food, energy, genetics, medical, and paper. Data can be collected by anyone, anywhere to deduce trends, establish alarms, make decisions, and control operations.

We have been data takers since the beginning of time. We have sensed our environment and learned to take beneficial action. We read thermometers, voltmeters, scales and oscilloscopes. We record the data, analyze it, use it, and communicate it. However, methods are changing. Now the emphasis is on getting machines to meet many of our data acquisition and control needs. The unselfish motive is productivity. Speed, accuracy, dependability, reliability and cost are related factors.

In the past, when process monitoring was the principal task, an automatic data logger was the accepted form of automation. Data loggers include strip chart recorders, printers, and tape recorders. When monitoring alone was not enough, programmable controllers were often matched to the requirements of the job. However, in an increasing number of applications, data loggers and programmable controllers could not do everything that was desired. This was due, in part, to the narrow range of functions supported by their hardware and software. In contrast, todays' state-of-the-art systems, offering a full range of capabilities, are based upon our most effective productivity machine, the modern digital computer.



Data Acquisition Systems Take Many Forms, Including Pencil and Paper.

Figure 1.1 suggests the components of a data acquisition and control system. The computer not only provides the analysis and decision-making capability, but also controls the active signal-conditioning and data-conversion functions. A given system might not include all of the elements shown in Figure 1.1. In this handbook, all further references to data acquisition or control apply to those applications in which a computer plays an important role.

Modern computers offer high speed, flexibility, adaptability, consistency, reliability and mass memory. These features provide extensive capabilities for mathematics, analysis, storage, display, report generation, control and communications. However, most real-world signals (temperature, pressure, flow, speed, intensity, position, etc.) cannot be read directly by digital computers. These parameters are represented by analog signals distinguished by their continuum of levels. However, computers can recognize only digital (off or on) levels. Therefore, a translation-type product is required.

The Link—Data acquisition and control products translate real-world signals into a format that digital computers can accept. DA&C systems can also regenerate analog and other signals from computer instructions. In this way DA&C systems bridge the gap between the pervasive digital computer and the real world.

The personal computer (PC), in contrast to other forms of computers, is the fastest growing "engine" for new DA&C system designs. Many of the reasons for this trend will be explored in the next section.

The PC has already made significant inroads into many important applications areas. These include:

- Laboratory data collection and automation
- Medical instrumentation and patient monitoring
- Automatic test equipment (ATE) for incoming inspection, life test, burn-in, production test, and final test
- Industrial monitoring and control
- Environment and utility management.

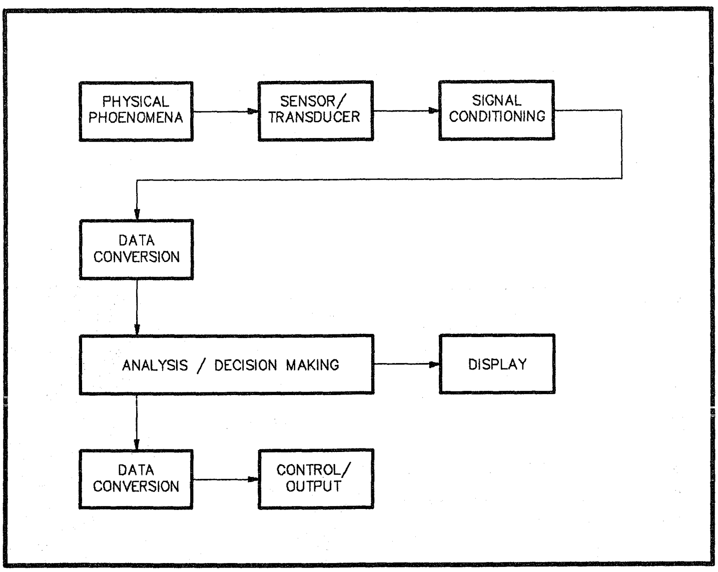


FIGURE 1.1 Data Acquisition and Control Flow Diagram.

Section 2
Different Types of Systems & How They Connect to the Personal Computer

An important part of any data acquisition system is its host computer. There are two possible ways for the DA&C hardware to interface with the computer: direct connection to the PC bus (internal bus products) or connection via a standard communication channel such as RS-232, RS-422 or IEEE-488 (external bus products). Each method has its advantages and disadvantages.

Throughout this section, the term "system" will be used in several ways. A system can include everything that is required to perform the complete data acquisition task, including the host computer. The term "system" can also be used to describe a group of circuit elements. Perhaps this should more accurately be called a subsystem.

External Bus Products—The advantages associated with external bus products (using RS-232, etc.) include:

- Virtually any size system can be configured
- The DA&C system can be placed remotely from the host computer (so that the DA&C system can be located close to the field signals)
- The DA&C system has the possibility of off-loading some of the data-collecting tasks from the host computer
- The DA&C system can be interfaced to virtually any type of computer

Figure 2.1 shows a simplified block diagram of an external bus system. Communications through RS-232, RS-422 or IEEE-488 requires the data acquisition system to have its own internal microprocessor. This local microcomputer also facilitates remote operation and helps reduced the load on the host PC. Systems of this type reside in their own enclosures. These enclosures or "boxes" provide space not only for the microcomputer, but also for the power supplies and the analog and digital input/output hardware. In most cases the I/O functions are grouped by type on individual plug-in boards. This allows both the selection of I/O types and a choice of the number of channels to be supported. To facilitate very large point-count systems, add-on expansion enclosures are also available.

The ability to have remote (distant from the host computer) DA&C boxes allows the construction of distributed systems. Thus, a large number of parameters can be monitored or controlled even though they physically originate far from each other and far from the host PC. For example, the data from many different production lines, each with separate DA&C subsystems, can be interconnected via RS-422. This allows monitoring by a single PC, which could be in a supervisor's office, in another building several thousand feet (or hundreds of meters) away. This type of capability can greatly improve productivity and reduce overall system cost.

Internal Bus Products—The main advantages of making direct connection to the PC bus include:

- High speed
- Low-cost
- Smaller size

Cost is reduced with this kind of DA&C system because it does not require its own separate enclosure or power supply. Power is obtained from the PC. When the data acquisition hardware resides inside the host computer, important advantages in both size and space utilization are obtained. High speed is achieved by eliminating the relatively slow, external, communications-channel protocol. As an example, the data acquisition rate using RS-232 at 9600 baud is limited to about 20 analog channels per second. In contrast, some direct PC bus products can take data faster than 1 million channels per second. Figure 2.2 shows a simplified block diagram of an internal bus system.

Three major types of internal bus (PC bus) products exist, distinguished by the way in which the Input/Output channels are configured. All are board-level systems that make direct connection to the computer expansion bus, yielding the speed and cost advantages mentioned above. Some boards have a "fixed"

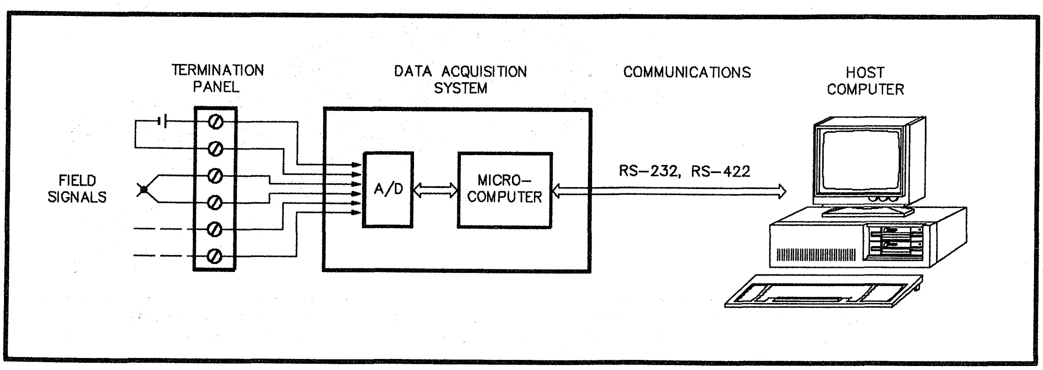


FIGURE 2.1. An External Bus DA&C System, Block Diagram.

arrangement of analog and digital input/outputs. This means that whatever configuration one buys, that's what he has regardless of future needs. Limitations of this type of system include lack of channel expansion capability, and the inability to add functions not originally purchased. However, cost is usually lowest. In contrast, "Modular" systems allow the user to select, even in the field, the quantity and configuration of the I/O functions desired. This feature is provided by a family of function modules. Thus, modular, board-level systems share some of the positive features of the box systems. These include expandability and user selection of I/O functions. Fixed products include single function and general purpose configurations. The focused, single function, boards are often effective in small applications or in well defined instances where the board is embedded in a larger end product (an OEM product).

Often, general purpose fixed I/O configurations require significant compromise. Either the number of channels desired cannot be obtained, or the user must purchase functions not required. With the great diversity of uses, it is inevitable that a mismatch between the available I/O and the actual requirements will exist. Some fixed-configuration products allow for selected types of channel expansion via external add-on boards or boxes. When cost, space, and ease of use are considered, this type of product is less attractive than systems that can meet all I/O requirements inside the host computer. Modular board-level systems are far more effective in this regard and are readily tailored for specific applications. The PCI-20000 system includes products that represent the state-of-the-art in both modular and focused plug-in board systems for the PC-bus. Detailed information and specifications on the PCI-20000 system are included in later sections of this handbook.

Figure 2.3 is a photograph showing a "fixed-configuration" I/O board alongside a "modular" type of I/O product.

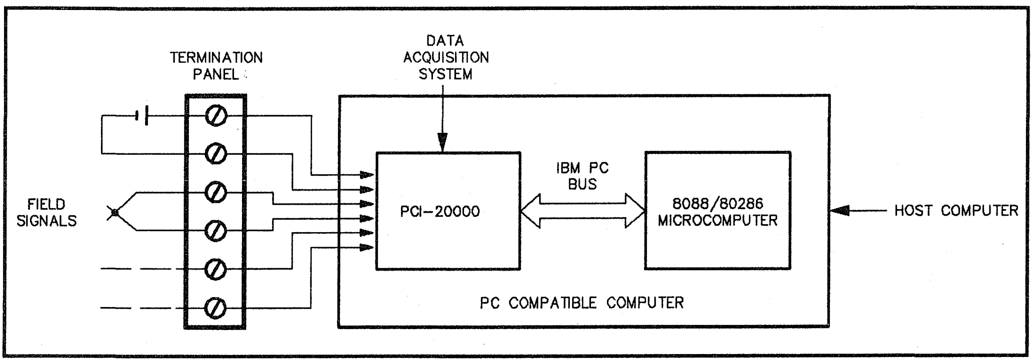


FIGURE 2.2 Internal PC Bus System.

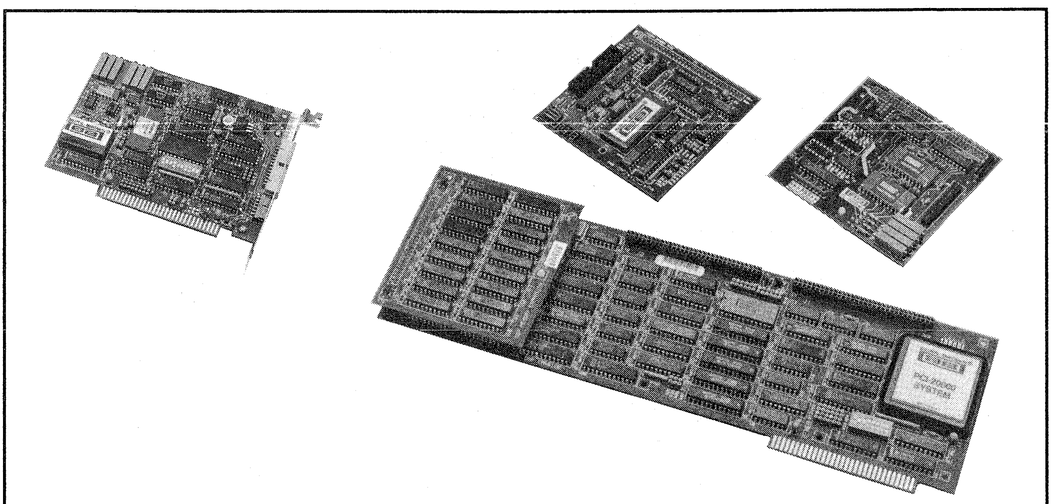


FIGURE 2.3. Comparison of a "Fixed-Configuration" I/O Board with the Modern, Modular PCI-20000 System (left board is a fixed configuration; the boards on the right are PCI-20000).

Section 3
Personal Computers in Data Acquisition & Control

Historically, industrial and scientific data acquisition and control (DA&C) tasks were implemented with large mainframe or minicomputer systems. Typically, these were powerful 16-bit machines that ran in time-sharing or multitasking modes. Their complexity and expense dictated that they be configured as centralized utilities shared by many users and applications. Small or remote jobs were often relegated to manual, or at best, simple electronic data-logging techniques. These tasks could not justify the capital expense or manpower overhead of computerization. Thus, these smaller tasks could not benefit from the flexibility and power of a computerized solution.

The advent of the modern personal computer (PC) makes it possible for virtually everyone to take advantage of the flexibility, power and efficiency of computerized data acquisition and control. PCs offer high performance and low cost along with an ease of use that is unprecedented. Thanks to a significant degree of standardization among PC and DA&C manufacturers, a large family of hardware/software tools and applications packages have evolved. The result is that an individual engineer or scientist can now implement a custom DA&C system within a fraction of the time and expense formerly required. It is now practical to tailor highly efficient solutions to unique applications. Furthermore, personal computers invite innovation. This type of innovation has revolutionized the office and is now revolutionizing factories, production lines, testing, and laboratories. Figure 3.1 shows the relationship between the DA&C system and its host computer.

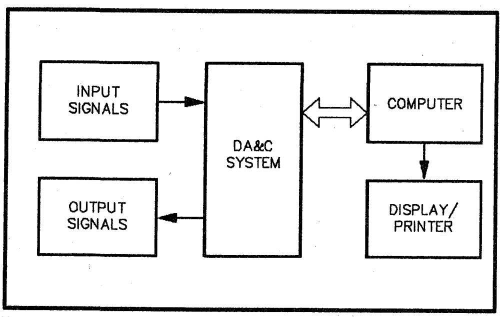


FIGURE 3.1. A Computerized Data Acquisition & Control System.

Because of the obvious advantages of personal computers, along with their increasingly widespread usage, we will assume the use of a PC in the remainder of this handbook. However, it is important to remember that some of the systems described can be used with virtually any type of computer.

There are several popular architectures associated with today's PCs. In general, most computer families are differentiated by the microcomputer chip used. For example: 8080, 8086, 8088, 80286 (from Intel), 68000 (from Motorola) and Z80, Z8000 (from Zilog). More about the differences in some of these microprocessors will be described later. Each type is enjoying (or has enjoyed) a strong market share in specific areas (i.e., home, office, etc.). Recent studies indicate that technical, scientific and industrial applications are dominated by computers conforming to the de facto standards set down by IBM.

(The original IBM PCs were built around the 8088, while recent offerings utilize the 80286 and 80386. The free-enterprise system has yielded to a vast array of IBM PC "work- alikes". Therefore, when we refer to the IBM PC (or just PC), we are referring to this generic family of compatible computers. Some of these competing models offer advantages in features, performance and/or cost. A partial listing of IBM-compatible computers is shown later in this section for reference purposes.

In the context of DA&C applications, "true" IBM PC compatibility includes both hardware and software requirements. Only those computers that can run, without modification, the same software written for the IBM PC are compatible. Likewise, a compatible machine must accept the same range of add-on (or add-in) boards that plug directly inside the IBM PC.

INSIDE THE IBM PC

The PC consists of a system unit (microcomputer, memory, power supply, etc.), a keyboard and one or more output devices such as monitors, printers and plotters. The system unit is usually housed in an enclosure, separate from other major components such as the monitor. An exception to this rule would be portable PCs, which integrate all devices into an easy-to-carry case (example: Compaq portables).

"Lap-top" and other miniature computers are usually not included in the true PC-compatible category, because they lack expansion slots. This definition could be debated because some small computers do offer external expansion capabilities.

An expansion slot is a physical and electrical space set aside for the connection of accessory hardware items to the PC. Electrical connection is made directly to the internal microcomputer bus. These accessory items usually take the form of a plug-in, printed-circuit board (i.e., a graphics interface, a memory expansion module or a data acquisition device).

Plug-in boards can be designed to be addressed by the microcomputer in two different ways, either as I/O ports or as memory locations. There are advantages to both systems. However, memory addressing offers a higher level of performance that includes improved speed, extended address space, and the full use of the processor's instruction set.

Some of the computer I/O and memory addresses are reserved by the computer manufacturers for standard functions (i.e. graphics cards, RS-232 ports, memory, disk controllers, etc.). Most other types of plug-in boards are equipped with a bank of switches that allows the user to select an appropriate address location. Included at the end of this handbook section is a "map" that identifies both the I/O and the memory-address allocations for the most common PCs. Thus, if you know your computer's hardware configuration, using the map will make the selection of additional available address locations easy.

PCs employ several distinct memory types: RAM, ROM, floppy disk and hard disk. Other memory technologies include magnetic tape and bubble. RAM and ROM are semiconductor devices offering a very high-speed operation. Random-access memory (RAM) has both read and write capabilities that can be accessed by the microcomputer. Read-only memory (ROM), on the other hand, contains a fixed set of information that can only be read by the microcomputer. The microcomputer itself is often referred to as the central processing unit (CPU).

The name RAM is somewhat of a misnomer, because both RAM and ROM along with many other memory types are random-access. ROM is pre-programmed at the factory to contain the most fundamental CPU operating instructions. This includes the code required to start or to "boot" the computer, and is known as the BIOS (basic input/output system). All other active program information is contained in RAM. The amount of RAM that can be used is determined by the particular microcomputer chip used and the available software. The 20-bit address bus of the 8088 limits memory locations to about 1Mbyte. The 80286 has a 24-bit bus which can address about 16Mbytes. RAM is normally termed "volatile", because in most systems its data will be destroyed if power is lost. Permanent storage of data and programs is usually provided by the disk drives.

Most people who use computers will not wish to "talk" directly with the CPU, BIOS or the disk drives because of the complexities involved. Extensive interface software has been developed to bring the power of the PC within easy reach of non- specialists. This software is known as the operating system (OS). The most widely used OS is PC or MS DOS (disk operating system). Other operating systems include CP/M and Unix.

Even among compatible PCs, the effectiveness of the expansion slots varies considerably. The main considerations include: the number of available slots, length of the slots and the power supply available. Because of their mechanical design, some computer types make it easier than others to insert boards into expansion slots.

The speed at which a PC can process instructions (i.e. run a program) is dependent upon many factors. Some ingredients are under the programmer's control. Choice of language and the efficiency of the resulting code are significant. Software efficiency refers, in part, to how many machine cycles are required to execute the desired instructions. A "tight" program requires the fewest number of machine cycles and is thus very efficient.

Other factors are related to the PC's electrical design. Selection of the microcomputer chip, additional logic, circuit configuration and clock frequency are all important.

The clock frequency sets the speed of the microcomputer, but not necessarily its execution efficiency. For a given clock frequency one microcomputer can do more work than another. The 8088 and 80286 are both 16-bit chips. However, the 8088's bus can transfer only 8 bits at a time, compared to 16 bits for the 80286. If all other factors are equal, this results in a 2:1 speed advantage. Normally, the 8088 is clocked at 4.77MHz. 80286 machines are available with speeds of 6 to 12MHz. Still other characteristics of the 80286 contribute to improved efficiency.

In contrast to the many benefits of the 80286 machines, there is at least one important drawback. In presently available 80286 computers, the configuration of the direct memory access (DMA) circuitry is not optimized for DA&C. This can result in DMA transfers which are slower than expected (by as much as 2:1).

Computers are now starting to emerge that use the new 80386 processor. This chip promises to further increase speed and the amount of addressable RAM. Estimates are that 1 to 2 years will be required for vendors to produce the required software to exploit the 80386's full potential.

FIGURE 3.2 "Compatible" Computers. ⟶

This computer listing shows the personal computers known to us at handbook press time, whose manufacturers stated that their machines were "IBM compatible" (in most cases we have not verified compatibility by actual test). Also shown are the numbers of expansion slots claimed by the manufacturers, plus our estimate of expansion slots usable for data acquisition boards, after a "normal" personal computer system (with graphics capability, color monitor, serial port, etc.) is configured.

CAUTION —Please recognize that each PCI-20000 carrier system can require between 1 and 2 computer expansion slots depending upon the configuration of the I/O. "Boards" require just one slot. In addition, it had been reported that some PC "clone" manufacturers have not implemented their DMA circuitry in the same way as IBM. The result is that the speed of DMA execution can be significantly reduced from normal specifications in these machines.

Manufacturer	Model Number	Processor	Speed	Usable Expan. Slots
Acer Technologies Corp.	Acer 900	80286	12	7
	Acer 910	80286	10	5
	Acer 915	80286	12	4
	Acer 1100	80386	16	6
Advanced Logic Research Inc.	Access 386	80386		7
	Dart-10	80286	8/10	7
	Dart-12	80286	12.5	7
	Flexnode 286	80286	20	3
	Flex Cache 20386	80386	20	6
Alphanumeric	ANI 8D	80286	8/10	7
Amax Engineering	PC 286-12	80286	12	7
	PC/386	80386	20	7
Amdex Corp.	Amdek System 286A	80286	12.5	6
American Computer & Perip.	286-ST	80286	12	8
	88	8088		7
American Computer Products	Maxim 286	80286	16	8
American Mitac Corporation	Paragon S	80286	6/10	5
	Paragon V	80286	8/12	6
	Paragon VE	80286	8/16	6
	Paragon 386	80386	20	5
AST Research Corporation	Premium/286	80286	6/8/10	6
	Premium/386	80386	20	6
AT&T	6300	8088		7
	6300 Plus	80286		7
	6286 WGS	80286	12	7
	6386 WGS	80386	20	6
Bentley Computer Products	Bentley Turbo	8088	8	4
	Bentley 286	80286	12	7
Bi-Tech Enterprises Inc.	Bi-Tech AT/20	80286	20	7
CAD Council	Protean 286	80286	12	8
Canon Inc.	A-200 HD	8088		5
	A2006X II	80286		4
Club American Technologies	Model 208	80286	8	7
	Model 211	80286	10	7
	Model 212	80286	12	7
Compaq	Deskpro 286	80286	12	7
	Deskpro 386/20	80386	20	6
	Portable II	80286		2
	Portable III	80286		2
CompuAdd Inc.	286/10	80286	10	7
	286/12	80286	12	7
Computer Components Corp.	Heritage 286/10	80286	8/10	7
	Heritage 286/12	80286	8/12	7
Convergent Technologies	Network PC	80286	8	3
Core International Inc.	ATomizer 286	80286	12	7
	ATomizer 386/20	80386	20	4
Data General	Dasher/One 2	8088		1
	Dasher/286	80286	10	6
Dell Computer Corporation	System 200	80286	12.5	5
	System 220	80286	20	3
	System 300	80386	16	6
	System 310	80386	20	6
Delta Computer	Prestige SF	80286	8/12	3
Dyna Computer	286 ZX	80286	16	7
Eltech Research	286-12Bplus	80286	12	7
Epson America, Inc.	Equity II	8088		4
	Equity II+	80286	8/12	5
	Equity III+	80286	6/8/12	8
Everex Systems	Step 286/16	80286	16	7
	Step 386/20	80386	20	7
Five Star Computers	FS 286	80286	6/10	10
Focus Technology	Loop 286	80286	12.5	4
Fortron Corp.	80286-16	80286	16	7
47th Street Computer Inc.	Maxim Turbo 286	80286	6/8/10	8
Hewlett-Packard	Vectra ES PC	80286	8	6
	Vectra ES/12 PC	80286	12	6
	Vectra RS/20	80386	20	3
Hyundai Electronics America	Super-286 C	80286	8/10	6
IBM	5531	8088		6
	7531	8086		6
	7532	8086		6
	AT	8086	8	6
	PC	8088	4.77	4
	XT	8088	4.77	5
	PS/2 Model 30	80286	8	3
Intelligent Data Systems	IDS 286	80286	12	8
Intelligent Micro Systems	IMS 286/10	80286	10	7
	IMS 286/12	80286	12	7
JC Information Systems	JC Lips 286	80286	12-20	7
Kaypro	286-12	80286	6-12	8
	286-16	80286	8/10/12	8
	PC 10	8088		6
Laser Digital	Pacer-286	80286	12-16	8
Leading Edge	PC Mod D with Hard Disk Drive	8088		3
	D2	80287	6/8/10	6
Logic	AT	80286		7
Maxum	286	80286		7
	286 Turbo	80286		

Memorex Telex	7020	80286	8	2
Mitac Corp.	Paragon S	80286	6/10	5
	Paragon V	80286	8/12	6
	Paragon VE	80286	8/16	6
	Paragon 386	80386	20	4
Mitsubishi Electronics	MB 286-310	80286	6/8/12	5
NCR Corp.	PC 710	80286	6/10	8
	PC 810	80286	6/10	7
NEC Information Systems	PowerMate 1	80286	8/10	6
	PowerMate 1 Plus	80286	12	6
	PowerMate 2	80286	8/10	6
Olivetti	M 290	80286	12	4
Packard Bell	PB286	80286	8/10/12	7
PC Designs Inc.	GV-286/M 120	80286	12	7
Panasonic Industrial Co.	Business Partner	8086		6
	FX-600	8086		6
PC Designs	ET-286i	80286		3
PC Source	Turbo 88	8088		4
	286/10	80286	10	7
	286/12	80286	12	7
PC Technologies	PCT-AT	8086		8
	PCT-AT Turbo	8086		8
	PCT-Turbo-XT	8088		8
PC's Limited	286	80286		7
	AT	8086		7
	Turbo PC	8088		7
Samsung	S500	80286	10	8
Sanyo Business Systems	MBC 17 Plus	80286	6/10	5
Sanyo	MBC 885	8088		8
Siemens	PC 16-05	8088		7
Sperry	PC	8088		7
	PC/HT	8088		5
Standard	Standard-286	80286	12	5
	Standard-88	8088		6
	Standard-386	80386	16	3
	Turbo-88	8088		6
Tandon Computer Corp.	PCA-20 Plus	80286	6/8	4
	PAC 286	80286	8/10	4
	PAC 286 Plus	80286	8/10	4
Tandy	1000 SX	8088		4
	3000 NL	80286	10	6
	1000 TL	80286	4/8	5
	4000	80386	16	7
Televideo Systems Inc.	Teldas II	80286	12	7
Texas Indus. Microsystems	IPC-2000	8088		8

Unisys Corp.	PW Series 300	80286	8/10	8
	PW Series 500	80286	6/8/12	5
Vector Computer Corp.	Excalibur 286	80286	10/20	8
Victor	V286	80286	12	7
Wang Laboratories Inc.	PC 240	80286	6/8/10	3
	PC 280	80286	6/8/10	8
Wells American	CompuStar	80286	6-20	6
Wyse	WYSEpc 286	80286	8-12.5	6
	WYSEpc WY-1100	8088		2
Zenith/Heath	Z-148	8088		1
	Z-150	8088		8
	Z-158	8088		6
	Z-200			10
	Z-248/12	80286	12	4
	Z-286	80286	8	4
	Z-286LP	80286	8	2
	SW-3000 Industrial	80286	8	6

The "memory map" presented here has been compiled from many sources, including extensive practical experience. It is significant that the region of the PC's memory map that is of most interest to DA&C users is that area with the least available information. "User areas" are open for many potential applications. As such, there is always the possibility of an address conflict. That is, more than one expansion board could be set up to use the same memory locations. The good news is that a very large field of addresses exists, and sufficient space for any practical system can always be found. Reference to this memory map should make address selection easy.

The addresses shown in **boldface** in Figures 3.3D, 3.3E, and 3.3F are suggested memory locations for the installation of PCI-20000 products. However, because each PC configuration can be different, specific addresses can not be predetermined. Given a knowledge of your PC's configuration, this memory map information will allow a large number of suitable locations to be isolated.

Alternative PCI-20000 System Address Locations:

(1) PC/XT only
(2) Without LIM Board
(3) PC or AT (not XT)
(4) Usually open
(5) Without EGA
(6) Without EGA
(7) AT, without 128K expansion board

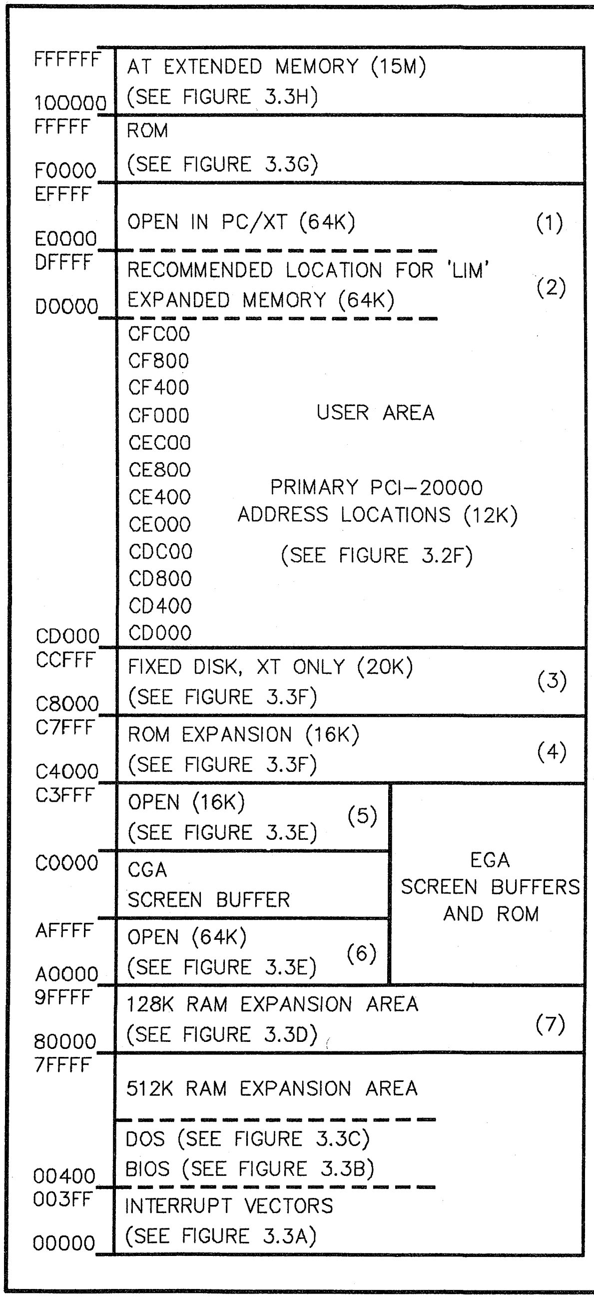


FIGURE 3.3. Memory Map for PC/XT/AT.

00000-00003	= Interrupt 0, divide-by-zero error.
00004-00007	= Interrupt 1, single-step operation.
00008-0000B	= Interrupt 2, non-maskable interrupt.
0000C-0000F	= Interrupt 3, break-point.
00010-00013	= Interrupt 4, arithmetic overflow.
00014-00017	= Interrupt 5, BIOS print-screen routine.
00018-0001B	= Interrupt 6, reserved.
0001C-0001F	= Interrupt 7, reserved.
00020-00023	= Interrupt 8, hardware timer 18/2/sec.
00024-00027	= Interrupt 9, keyboard.
00028-0002B	= Interrupt A, reserved.
0002C-0002F	= Interrupt B, communications.
00030-00033	= Interrupt C, communications.
00034-00037	= Interrupt D, alternate printer.
00038-0003B	= Interrupt E, floppy disk atten signal.
0003C-0003F	= Interrupt F, printer control.
00040-00043	= Interrupt 10, invokes BIOS video I/O service routines.
00044-00047	= Interrupt 11, invokes BIOS equipment configuration check.
00048-0004B	= Interrupt 12, invokes BIOS memory-size check.
0004C-0004F	= Interrupt 13, invokes BIOS disk I/O service routines
00050-00053	= Interrupt 14, invokes BIOS RS-232 I/O routines.
00054-00057	= Interrupt 15, invokes BIOS cassette I/O, extended AT service routines.
00058-0005B	= Interrupt 16, invokes BIOS keyboard I/O routine.
0005C-0005F	= Interrupt 17, invokes BIOS printer I/O.
00060-00063	= Interrupt 18, ROM BASIC.
00064-00067	= Interrupt 19, invokes BIOS boot-strap start-up routine.
00068-0006B	=-Interrupt 1A, invokes BIOS time-of-day routines.
0006C-0006F	= Interrupt 1B, BIOS ctrl-break control
00070-00073	= Interrupt 1C, gen at timer clock tick.
00074-00077	= Interrupt 1D, video initialization control param pointer.
00078-0007B	= Interrupt 1E, disk parameter table pointer.
0007C-0007F	= Interrupt 1F, graphics character table pointer.
00080-00083	= Interrupt 20, invokes DOS program termination.
00084-00087	= Interrupt 21, invokes all DOS function calls.
00088-0008B	= Interrupt 22, user-created, DOS-controlled interrupt routine invoked at program end.
0008C-0008F	= Interrupt 23, user-created, DOS-controlled interrupt routine invoked on keyboard break.
00090-00093	= Interrupt 24, user-created, DOS-controlled interrupt routine invoked at critical error.
00094-00097	= Interrupt 25, invokes DOS absolute disk read service.
00098-0009B	= Interrupt 26, invokes DOS absolute disk write service.
0009C-0009F	= Interrupt 27, ends program and keeps program in memory under DOS.
000A0-000FF	= Interrupts 28 through 3F, reserved.
00100-00103	= Interrupt 40, disk I/O (XT).
00104-00107	= Interrupt 41, fixed disk parameters (XT).
00108-00123	= Interrupt 42 through 48, reserved.
00124-00127	= Interrupt 49, keyboard supplement translation table pointer.
00128-0017F	= Interrupts 49 through 5F, reserved.
00180-0019F	= Interrupts 60 through 67, user-defined interrupts.

PCI-20046S can be programmed to use any one of the interrupts in the range of 60 thru 67. Interrupt 60 is used by ASYST, version 1.53. Interrupt 67 is used by the Expanded Memory Manager.

001A0-001FF	= Interrupts 68 through 7F, not used.
00200-00217	= interrupts 80 through 85, reserved for BASIC.
00218-003C3	= Interurpts 86 through F0, BASIC interpreter.
003C4-003FF	= Interrupts F1 through FF, not used.

FIGURE 3.3A. Interrupt Vectors.

00400-00401	= Address of RS-232 adapter 1.
00402-00403	= Address of RS-232 adapter 2.
00404-00405	= Address of RS-232 adapter 3.
00406-00407	= Address of RS-232 adapter 4.
00408-00409	= Address of printer adapter 1.
0040A-0040B	= Address of printer adapter 2.
0040C-0040D	= Address of printer adapter 3.
0040E-0040F	= Address of printer adapter 4.
00410-00411	= Equipment flag.
00412	= Manufacturing test indicator.
00413-00414	= Useable memory size in K.
00415-00416	= Memory in I/O channel for 64K--planar PC.
00417-00418	= Keyboard status bits.
00419	= Alternate keyboard numeric input (future use).
0041A-0041B	= Keyboard buffer head pointer.
0041C-0041D	= Keyboard buffer tail pointer.
0041E-0043D	= Keyboard buffer.
0043E	= Floppy disk seek status.
0043F	= Floppy disk motor status.
00440	= Floppy disk motor timeout.
00441	= Floppy disk status.
00442-00448	= Floppy disk controller status bytes.
00449	= CRT mode code.
0044A-0044B	= CRT column screen width.
0044C-0044D	= CRT regeneration buffer length.
0044E-0044F	= Starting address in regeneration buffer.
00450-00451	= Cursor position for CRT page 1.
00452-00453	= Cursor position for CRT page 2.
00454-00455	= Cursor position for CRT page 3.
00456-00457	= Cursor position for CRT page 4.
00458-00459	= Cursor position for CRT page 5.
0045A-0045B	= Cursor position for CRT page 6.
0045C-0045D	= Cursor position for CRT page 7.
0045E-0045F	= Cursor position for CRT page 8.
00460-00461	= Cursor mode.
00462	= Active page number.
00463-00464	= Address of current display adapter.
00465	= CRT mode.
00466	= Palette setting.
00467-00468	= Time count.
00469-0046A	= CRC register.
0046B	= Last input value.
0046C-0046D	- Low word of timer count.
0046E-0046F	= High word of timer count.
00470	= Timer rolloever.
00490-004Cf	= Used by MODE.COM.
00471	= Break indicator.
00472-00473	= Reboot (Alt-Ctrl-Del) indicator.
00474-00477	=Fixed disk data area (XT).
00478	= Printer 1 timeout (XT).
00479	= Printer 2 timeout (XT).
0047A	- Printer 3 timeout (XT).
0047B	= Printer 4 timeout (XT).
0047C	= RS-232 card 1 timeout (XT).
0047D	= RS-232 card 2 timeout (XT).
0047E	= RS-232 card 3 timeout (XT).
0047F	= RS-232 card 4 timeout (XT).
00480-00483	= Additional keyboard buffer pointers (XT).
00484-004A8	= EGA BIOS buffer.
00484	= Number of character rows.
00485	= Bytes per character.
00487	= Status byte.
00488	= Feature bits, DIP switches.
004A8	= Pointer save.
004D0-004EF	= Reserved.
004F0-004FF	= intra-application communication area.

FIGURE 3.3B. BIOS Data Area.

00500	= Print screen status
00504	= Single-drive status (drive A or B).
00510-00511	= BASIC's default data segment pointer
00512-00513	- IP for BASIC's timer interrupt vector
00514-00515	- CS for BASIC's timer interrupt vector.
00516-00517	= IP for BASIC's ctrl-break interrupt.
00518-88519	= CS for BASIC's ctrl-break interrupt.
0051A-0051B	= IP for BASIC's fatal-error interrupt.
0051C-0051D	= CS for BASIC's fatal-error interrupt.
00600-XXXXX	= DOS and "other things".

FIGURE 3.3C. DOS And BASIC Data Area.

7FFFF	= Top of 512K.
80000-9FFFF	**= AT, 128K RAM expansion area.***
9FFFF	= Top of 640K, end of memory expansion area.

***Suggested memory location for installation of PCI-20000 products.**

FIGURE 3.3D. RAM Expansion Area.

A0000-AFFFF	**= Enhanced Graphics Adapter (EGA) screen buffers.***
B0000-B7FFF	= Monochrome adapter or EGA.
B0000-B0FFF	= Monochrome screen buffer.
B1000-B7FFF	= Reserved for screen buffers.
B8000-BFFFF	= Color/graphics adapter (CGA) or EGA.
B8000-BBFFF	= CGA buffer.
BC000-BFFFF	= CGA/EGA screen buffers.
C0000-C3FFF	**= EGA BIOS.***

***Suggested memory location for installation of PCI-20000 products.**

FIGURE 3.3E. CRT Screen Buffers.

C4000-C7FFF	**= ROM expansion area.***
C8000-CCFFF	**= Fixed disk control (XT).***
CD000-CFFFF	**= User PROM, memory-mapped I/O.***
D0000-DFFFF	**= User PROM, recommended "LIM" location.***
E0000-EFFFF	**= ROM expansion area, optional I/O for PC/XT.***

***Suggested memory location for installation of PCI-20000 products.**

FIGURE 3.3F. User Area.

F0000-FDFFF	= ROM BASIC.
FE000-FFFD9	= BIOS.
FFFF0-FFFF4	= First code executed after power-on.
FFFF5-FFFFC	= BIOS release date.
FFFFE-FFFFF	= Machine ID.

FIGURE 3.3G. ROM.

100000-FFFFFF	= I/O channel memory (PC/AT extended memory, 15Mb maximum)

FIGURE 3.3H. AT Extended Memory.

000-00F	=	DMA controller (8237A).
020-021	=	Interrupt controller (8259A).
040-043	=	Timer (8253).
060-063	=	PPI (8255A).
080-083	=	DMA page register (74LS612).
0A0	=	NMI mask register.
200-20F	=	Joystick (game controller).
210-217	=	Expansion unit.
2F8-2FF	=	Serial port (secondary).
300-31F	=	Prototype card.
320-32F	=	Fixed disk.
378-37F	=	Parallel printer (primary).
380-38F	=	SDLC.
3B0-3BF	=	Monochrome adapter/printer.
3D0-3D7	=	Color/graphics adapter.
3F0-3F7	=	Diskette controller.
3F8-3FF	=	Serial port (primary).

FIGURE 3.4. IBM XT I/O Map.

000-01F	=	DMA controller (8237A-5).
020-03F	=	Interrupt controller (8259A).
040-05F	=	Timer (8254).
060-06F	=	Keyboard (8042).
070-07F	=	NMI mask register, real-time clock.
080-09F	=	DMA page register (74LS612).
0A0-0BF	=	Interrupt controller 2 (8259A).
0C0-0DF	=	DMA controller 2 (8237A).
0F0-0FF	=	Math coprocessor.
1F0-1F8	=	Fixed disk.
200-207	=	Joystick (game controller).
258-25F	=	Intel "Above Board".
278-27F	=	Parallel printer (secondary).
300-31F	=	Prototype card.
060-36F	=	Reserved.
378-37F	=	Parallel printer (primary).
080-38F	=	SDLC or bisynchronous communications (secondary).
3A0-3AF	=	Bisynchronous communications (primary).
3B0-3BF	=	Monochrome adapter/printer.
3C0-3CF	=	EGA, reserved.
3D0-3DF	=	Color/graphics adapter.
3F0-3F7	=	Diskette controller.
3F8-3FF	=	Serial port (primary).

Figure 3.5 IBM AT I/O Map.

3

INTERRUPT DRIVEN DATA ACQUISITION WITH THE PCI-20000 SYSTEM

INTRODUCTION

Many computer-based data acquisition applications can benefit from the use of interrupts. Interrupts provide immediate communication from the data acquisition hardware to the computer. They can be used to synchronize data acquisition with external events, to provide prompt response to alarm conditions, and to improve system performance. The PCI-20000 system is designed to make it easy to connect appropriate interrupt signals.

This Application Note is designed to provide an understanding of:

- How microprocessor interrupts work
- How interrupts are implemented on the IBM PC and compatibles
- How to determine which data acquisition applications are good interrupt applications
- How to design software to support interrupts.

Descriptions of sample data acquisition systems using interrupts are included, along with listings of sample interrupt handler routines. Examples show how to program the PC's interrupt controller and how to make use of the IBM PC system clock for data acquisition.

In order to use interrupts effectively, you must follow these steps:

- Analyze your system to determine whether interrupts are, in fact, necessary, and which signals should be used to generate interrupts.
- Connect the selected signals to the computer's interrupt system
- Write software which will enable the computer to respond to interrupts and to handle the interrupts when they occur.

WHAT ARE INTERRUPTS?

A microprocessor runs programs by executing **machine instructions** which it reads from memory. Ordinarily, the processor executes instructions sequentially, in the order in which they appear in memory. A special processor register, the **instruction pointer**, keeps track of the next instruction to be executed. Certain instructions, namely **jump** instructions, and certain input signals, namely **interrupts**, cause the processor to start taking instructions from a different area of memory.

A **call** instruction is a special type of jump used to execute subprograms. Before jumping to the new program location, the processor saves the instruction pointer in a block of memory called the **stack**. Another processor register, the **stack pointer**, keeps track of the "top" of the stack. The processor stack is like a stack of plates. Items are added to and removed from the top of the stack. The last item put on the stack will be the first one removed. The call instruction **pushes** the instruction pointer onto the stack. This stores the instruction pointer on top of the stack and updates the stack pointer to show the next location as the top of the stack. The last instruction in a subprogram is a **return** instruction, which **pops** the instruction pointer off the stack. The stack is restored to its condition prior to the call, and the processor continues executing the instructions following the original call instruction.

An interrupt is a special input signal to a microprocessor. When a transition (usually high-to-low) occurs on the interrupt line, the processor latches the interrupt state and finishes the instruction it is currently executing. If interrupts are **enabled**, the processor then saves the instruction pointer and a word describing its current state on the stack, provides an **interrupt acknowledge** signal, and starts executing a special **interrupt handler** routine. The last instruction of an interrupt handler is an **interrupt return** instruction, which is similar to a return instruction. The original instruction pointer and state of the processor are restored, and the processor resumes executing instructions following the one that was interrupted.

Interrupts can be inhibited during part of a program by executing a **disable interrupt** instruction. If the processor receives an interrupt when interrupts are disabled, it will not respond until it encounters an **enable interrupt** instruction. If an interrupt is pending when an enable interrupt instruction is executed, the processor will then acknowledge the interrupt and execute the interrupt handler routine.

COMMUNICATING WITH EXTERNAL DEVICES

In order for the computer to be useful, the processor must be able to communicate with the outside world. It does this through the keyboard, CRT, disk drives, printer, data acquisition system, and other **peripheral devices**. The processor communicates with the peripherals by reading data from them or writing data to them. Many microprocessors have separate address spaces for **input** and **output (I/O)** and **memory**. A peripheral device can be designed to occupy either I/O addresses or memory addresses. I/O addresses are accessed through **input** and **output** instructions; memory addresses are accessed through **memory load** and **memory store** instructions.

The processor's communication with peripherals is complicated by the fact that the programmer usually can't predict exactly what a peripheral will be doing when the processor reaches a particular place in a program. If the processor attempts to read data from a device when the device hasn't yet supplied the data, the result will be meaningless. If the processor doesn't read the data soon enough, the device may have already supplied new data, or the data may no longer be valid. For example, if two keys were depressed since the last time the keyboard was checked, information about the first key would be replaced by information about the second. Similarly, if the processor attempts to write data to a device that is not ready, the device won't respond as expected.

In order to synchronize communication between the processor and its peripherals, there are two techniques that can be used:

The processor can **poll** a device, periodically reading a status register to determine whether the device requires attention.

The device can be set up to **interrupt** the processor when it needs service.

Both of these methods have advantages and disadvantages which must be weighed for each application.

Polling

The processor polls the device periodically by reading one or more **status registers**, memory or I/O locations whose values allow the processor to determine whether the device needs attention. If the device does need attention, an appropriate subroutine is called. Otherwise, the processor may continue to pull peripheral devices or it may perform other tasks. A program using polling is usually designed with a single loop containing instructions that poll peripherals and perform all other tasks. A program that handles peripheral devices by polling can be written in any programming language, using ordinary programming skills. Such programs are usually relatively easy to write, understand, and debug.

Although polling is very simple, this method has disadvantages. The processor must always be able to execute the entire loop fast enough to be able to keep up with the demands of the peripherals. A loop which is fast enough most of the time may occasionally fail if too many tasks must be performed on any one pass through the loop. For example, if the processor polls several peripherals, they may occasionally all require service. As more complexity is added to a developing program, a polling loop that originally worked well can become too long. Furthermore, if accurately timed operations must be performed, as is common in data acquisition, a long polling loop may not allow the timing source to be checked often enough to insure adequate accuracy.

Interrupts

With this technique, peripherals signal the processor when they require attention by generating interrupts. Prompt attention to all peripherals is insured as long as demands on the system are reasonable, and the programmer does not need to intersperse polling operations with other program tasks. This method is particularly well suited to an application which requires accurate timing of data acquisition while the processor is performing other operations. Interrupts are also useful if several peripherals requiring service at different rates are used.

In order to make use of interrupts a programmer must write interrupt handler procedures. The addresses of these procedures must be placed in a special location in memory, the **interrupt vector table**, so that they can be executed when an interrupt occurs. This usually requires some knowledge of assembly language. (Some high-level languages provide interrupt handling capability with procedures to perform absolute memory reads and writes, input and output operations, and interrupt routine entry and exit sequences.) The program flow depends on the occurrence of interrupts and is no longer obvious to the reader of a program listing. Mistakes in handling a computer's interrupt system can result in catastrophic program failures, which makes programs utilizing interrupts especially difficult to debug.

3

Buffered I/O

A very robust programming technique uses **buffered I/O**, which combines the advantages of polling and interrupts. This technique is particularly useful for applications such as control loops or real-time displays, in which the program must process data as it is being acquired.

An application program using buffered input is written as a polling loop in which the processor waits for data, processes the data, and returns to wait for more data. An interrupt handler routine responds to interrupts to read the data and store it in a **circular buffer**, which is a short array for temporary data storage. The interrupt handler maintains an **insertion counter** to indicate the next position in the buffer which it updates each time data is stored in the buffer. When the counter reaches the end of the array, it is set back to the beginning of the array, completing the circle. A second **removal counter** is maintained by a polling procedure which is called by the application program to read the data buffer. The polling procedure compares the two counters. if they are different, new data exists at the position of the removal counter. The polling procedure updates the counter and returns the new data to the application program. If no new data exists, the polling procedure can be designed to wait for data or to return to the application program with an indication of no data.

If a suitable data acquisition rate is used, the buffer should never contain more than a few entries. However, the interrupt handler must compare the removal counter with the updated insertion counter to detect a possible buffer overflow. If this has happened, the polling procedure should return an error value to the application program.

Buffered output can be handled similarly. The application program passes data to the polling procedure. The data is stored in a circular buffer if there is room for it and rejected otherwise. In this case the polling procedure updates the insertion counter and the interrupt handler updates the removal counter. If data must be updated at regular intervals, as in the case of waveform generation, the buffer must not be allowed to become empty. If the data is being sent to a printer or similar device, the interrupt handler may simply disable the interrupt if the buffer becomes empty.

Choosing the Optimum Strategy

It must be emphasized that using interrupts is not always preferable to polling, and that polling can provide significantly better performance than interrupts for some applications.

The best strategy for high performance (high data acquisition rates) is to use polling and provide a **tight loop** (written in assembly language or machine language) which continuously monitors a status register until the desired condition is satisfied. The peripheral is then serviced, and the processor returns to the tight loop. Unlike the general polling loop described above, this loop performs no other operations (except possibly to exit the routine after enough cycles have elapsed!).

If precise timing of data acquisition or data output is of primary consideration, and if the timing uncertainty due to a tight polling loop is unacceptable, then timing should be controlled by an external timing source. For example, analog data acquisitions might be triggered by the falling edge of a square-wave pulse train produced by a programmable counter or a frequency generator. The end-of-convert signal from the converter would then be used to signal the processor to read the converted data. Either interrupts or polling could be used, depending on other requirements of the system.

Interrupts are a good way to control data acquisition when the acquisition rate is low enough that there is a significant amount of time available between interrupts. Interrupts can provide a significant advantage over polling if the program must handle more than one device, or if the program must perform other tasks while acquiring data. Most interrupt applications are best handled using buffered I/O.

Examples

It is worthwhile thinking through most applications before deciding to use interrupts, to see if polling could do the job. In many cases there is little or no improvement gained by using interrupts, and polling should be used because of its simplicity and ease of implementation.

An example of good polling application is a program which must take data very rapidly. A higher sampling rate can be achieved by polling a timing source rather than having the timer interrupt the processor. This is because of the **interrupt overhead**. When an interrupt is detected, the processor must save its status and instruction pointer on the stack and restore them on exit. These operations take much longer than a tight look which reads and tests a status register until a condition is satisfied. The processor can respond to a timing signal with greater accuracy when a polling loop is used rather than interrupts. This is because the processor must complete the current instruction before acknowledging an interrupt, and the time required for an instruction varies widely. .

On the other hand, a program taking data several times per second can make good use of interrupts from the timing source. For such low sampling rates, small variations in the processor's response time to the timing signal are unimportant. Another good application for interrupts is data acquisition with a slow analog-to-digital converter, using a signal from the converter to interrupt the processor when the conversion is complete. (An integrating converter might require 300mSec for a conversion. The use of interrupts allows the processor to perform other tasks, such as logging data to disk, performing control functions, or updating a display, while it waits for the peripheral.

Most applications fall somewhere between these extremes. Suppose, for example, that data is to be taken at 20kHz, or that you are using a converter with an expected conversion time of 50us. Before deciding whether to use polling or interrupts, you must estimate the interrupt overhead, which depends on the processor and clock speed your computer uses. It may seem wasteful to have the processor spinning its wheels in a polling loop for 50us, but depending on the interrupt overhead, you may find that it is not possible to improve performance. An example interrupt overhead estimate appears later in this Application Note. The practical limit for sampling rates using interrupts on the IBM PC may range from a few samples per second to a few thousand samples per second, depending on the data acquisition process, other tasks the system must perform, and the programming language used.

8088/8086 FAMILY PROCESSORS AND THE IBM PC

The discussion above is applicable to most modern microprocessors, with minor variations in terminology. We can apply this discussion to the IBM PC and compatible computers with a few qualifications.[1]

The 8086 family microprocessors have 16-bit registers (including instruction pointer and stack pointer registers), but they can address 1 Mbyte of memory, which requires 20 address bits. A complete address is specified by combining the contents of a **segment register** with an **offset register**:

Address = 16 * **Segment + Offset**

The processor has four segment registers, the **Code Segment** (CS), **Stack Segment** (SS), **Data Segment** (DS), and **Extra Segment** (ES).

The "instruction pointer" described above is actually formed by combining the SP (stack pointer offset) register with the SS register.

The IBM PC and compatible computers make use of an **interrupt controller** chip (Intel 8259A[2]) to provide eight different **vectored, prioritized** interrupts.[3,4] The interrupt controller automatically identifies the source of the interrupt and causes the processor to execute the appropriate interrupt and causes the processor to execute the appropriate interrupt handler routine from an interrupt vector table stored in the computer's memory. Because the interrupts are prioritized, high-priority events can interrupt the servicing of low-priority interrupts. Any of the eight interrupts can be inhibited, independent of the processor's interrupt enable and disable capability.

When a high-to-low transition occurs on one of the eight interrupt lines, and that interrupt channel is not inhibited, the controller produces a high-to-low transition on its output line. When the processor responds with the interrupt acknowledge signal, the controller causes the processor to execute a special **software interrupt** instruction. Whenever the controller generates an interrupt, interrupts with lower priority (higher number) are automatically inhibited until the controller is cleared by the processor. The new interrupt condition is latched by the controller, but is not passed to the processor until servicing of the higher priority interrupt is complete. Higher priority interrupts can interrupt a lower priority interrupt handler if the program issues an enable interrupt instruction. The low priority interrupt routine is put on "hold" until the high priority interrupt has been serviced.

The eight hardware interrupt inputs are "mapped" by the controller to software interrupts 8 through 15. A software interrupt instruction appears in assembly language as

INT n

where **n** is a number from 0 to 255. When an **INT n** instruction is executed, the processor saves the program location (IP and CS) and status, and jumps to an interrupt handler whose **address** (offset and segment) is stored at memory location 4*n. For example, **INT 8** would cause the 2-byte word beginning at location 32 (20H) to be loaded into the IP register and the next word (location 34, or 22H) to be loaded into the CS register. The next instruction to be executed will be at this address.

A hardware interrupt can be simulated by putting an appropriate **INT n** instruction in a program. Other software interrupts, which don't correspond to hardware interrupts, are used by the operating system or other programs which are loaded independently but which must be able to communicate with each other. The operating system and its extensions required different amounts of memory depending on the system configuration, so there is no way to predict the exact memory location at which a program will be loaded. It is important to have **absolute** memory locations that can be used for communication between programs. Some of these locations may be used to store information other than the addresses of interrupt handlers. For example, an **interrupt vector** might contain the address of a data table, or it might be used as a "mailbox" to store other information to be passed between programs.

CONNECTING THE PCI-20000 INTERRUPT SIGNAL

The IBM PC interrupt controller has eight interrupt inputs, IRQ0 through IRQ7, which are mapped by the controller to software interrupts **INT 8** through **INT 15**. IRQ0 and IRQ1 are used for system timer and keyboard interrupts. These signals are always generated by circuitry on the computer system board. The other six interrupts are connected to pins in the **I/O** channel, the slot where expansion boards are plugged in. The IBM PC design reserves most of these interrupts for particular peripherals, but if those devices aren't present, the interrupts can be used for other purposes. PCI-20000 series Carriers permit any of these six interrupts to be selected by placing an appropriate jumper.[1] Of course, no more than one of these jumpers should be in place, and any conflict with other devices should be avoided.

IBM's interrupt signals are assigned as follows:[3,4]

IBM PC I/O Channel Interrupt Signals

Interrupt	IBM Assignment
IRQ2	Reserved
IRQ3	COM2 (second serial I/O port)
IRQ4	COM1 (first serial I/O port)
IRQ5	Fixed disk
IRQ6	Diskette
IRQ7	Printer

3

The IBM PC-AT has an additional interrupt controller whose interrupts are mapped to INT 71H through INT 77H.[6] The output signal from the second controller goes to IRQ2, which is replaced in the first I/O Channel connector by IRQ9. The operating system calls the code set up for IRQ2 when an interrupt occurs on IRQ9, so that hardware and software designed for the PC will also work on the AT. However, the AT's reset and power-on sequence checks for activity on IRQ9 in order to detect special peripherals. If you use the IRQ2 jumper to select IRQ9 on the AT you must insure that your hardware will never generate interrupts during a reset or power-on, or your computer will be unable to start up. In fact, it's a bad idea to allow any peripherals to generate interrupts during the computer startup.

In addition to selecting the PC interrupt number your system will use, you must install jumpers to connect signals from the I/O Modules to the interrupt line. Before installing these jumpers, be sure that the corresponding module provides appropriate interrupt signals and that your program requires a signal from that module. You may find it helpful to study the examples in the section on Sample Systems. Don't install more module interrupt jumpers than you need, since you will just make it more difficult and time-consuming for your interrupt routine to determine the source of the interrupt.

HANDLING INTERRUPTS IN SOFTWARE

Although your application programs will be mainly written in a high-level language, you will probably have to write at least part of your interrupt handler routines in assembly language or machine language. If you have never programmed in assembly language for the IBM PC, start by writing some practice routines which perform simple tasks, such as adding two numbers and returning the sum to a calling program. This will allow you to become familiar with the 8088/8086 instruction set, the assembler, and the assembly language interface used by your high- level language.

Some programming languages, such as Turbo Pascal[7], make use of **in-line machine language** or **in-line assembly language**. These features allow you to intersperse machine instructions with high- level programming statements. If you will be using in-line code to handle interrupts with a high-level language, you should write some similar practice programs before you begin to program interrupt handler routines.

In order to make use of interrupts, you must provide an interrupt handler to perform whatever tasks you require when an interrupt occurs. DOS provides routines to store and retrieve interrupt handler addresses through the DOS Function Call, INT 21H. For details, you should consult the DOS Technical Reference Manual[8] or the Microsoft MS-DOS Programmer's Reference Manual.[9] If you prefer, you can read and write the interrupt vectors, accessing Segment 0 directly, but you should do this with the processor interrupts disabled.

The interrupt handler must save any registers it uses and set up segment registers that it will require. The interrupt handler may read and write any memory or I/O location. The interrupt handler should not try to perform any I/O that requires calls to DOS. This normally includes screen output or printer output, keyboard input, and file I/O. All registers must be restored and the interrupt controller cleared before the interrupt return is performed.

After the address of the interrupt handler has been stored, the interrupt controller must be commanded to permit interrupts on the selected channel. At the end of the program, that channel's interrupts must again be inhibited. It's a good idea to make sure the interrupt controller will be re-programmed to its initial state even if the user exits the program by typing CTRL- Break. You can do this by replacing the DOS CTRL-Break function, which is called by INT 23H, by your own "clean up" routine.

The PC operating system does not provide any routines for programming the interrupt controller. The interrupt controller is programmed using the 8088's **IN** and **OUT** instructions. On IBM PCs and most compatibles, the interrupt controller occupies I/O addresses 20H and 21H. The interrupt enable mask is read from or written to I/O location 21H. Bit values of 0 in the mask correspond to interrupt channels that are enabled. The following sequence would enable interrupts on IRQ2 without changing the state of any other interrupts:

```
IN    AL,21H          ;read original mask
MOV   OLD_MASK,AL     ;save mask so it can be
                      ; restored
AND   AL,OFBH         ;set bit 2 to 0
OUT   21H,AL          ;write new mask
```

To restore the original controller mask:

```
MOV   AL,OLD_MASK     ;get original mask
OUT   21H,AL          ;write to controller
```

The interrupt controller must be cleared at the end of the interrupt handler routine. Unless this is done, no further interrupts of equal or lower priority will occur. The following sequence clears the controller:

```
MOV   AL,20H          ;this byte is the end-of-
                      ; interrupt command
OUT   20H,AL          ;clear the controller
```

USING THE SYSTEM CLOCK FOR DATA ACQUISITION

Many data acquisition applications have relatively low speed requirements and can be adequately timed by the IBM PC's internal system clock. This clock is based on interrupts at approximately 18.2 Hz from an Intel 8253 timer. If you can make use of interrupts at this speed for your application, there are two simple ways to use the internal system clock. With either of these methods, the PC system clock continues to function, so you don't have to worry about maintaining the time-of-day clock, clearing the interrupt controller, or other "housekeeping" tasks performed by the system clock interrupt handler.

Using **INT 1CH**

This is the procedure recommended by IBM for installing a timer interrupt handler. The DOS timer interrupt handler always calls the user timer interrupt handler, **INT 1CH**, before performing an interrupt return. To install your timer interrupt handler routine, retrieve the current interrupt vector for **INT 1CH** and save it. Replace it with the address of your interrupt handler. Your interrupt handler must save all registers used, restore them at the end, and exit with an interrupt return instruction.

Using **INT 8**

This method can provide a more accurate time base than using **INT 1CH**, since your interrupt handler will execute before the DOS routine, which can take varying lengths of time. To replace the DOS **INT 8** interrupt handler with your routine, retrieve the current interrupt vector for **INT 8** and save it. Replace it with the address of your interrupt handler. Your interrupt handler must save all registers used and restore them at the end. Instead of exiting with an interrupt return, however, you will exit with a **FAR JUMP** to the original **INT 8** vector.

Regardless of which of these methods you use, you must be sure to restore the interrupt vector to its original value at the end of the program.

REPROGRAMMING THE SYSTEM CLOCK

If your application requires interrupts faster or slower than 18.2 Hz, you can still use the system timer. However, you must re-program the counter and restore it when your program finishes. The system timer is Counter 0 of an Intel 8253[2] which occupies I/O addresses 40H through 43H on IBM PCs and compatibles. The

```
MOV   AL,36H          ;set Mode 3, 16 bits,
                      ; binary
OUT   43H,AL          ;write control register
MOV   AX,TMR_CNT      ;load new count value
OUT   40H,AL          ;write low-order byte
MOV   AL,AH
OUT   40H,AL          ;write high-order btye
```

following sequence will program the counter to interrupt at a new rate:

```
MOV  AL,36H       ;set Mode 3, 16 bits,
                  ; binary
OUT  43H,AL       ;write control register
XOR  AL,AL        ;count value 0 (same as
                  ; 65536)
OUT  40H,AL       ;write low-order byte
OUT  40H,AL       ;write high-order byte
```

The following sequence will restore the counter to its original interrupt rate:

You can determine the value to load the count register with, **TMR_CNT**, as follows:

TMR_CNT = TI * F0

F0 is the frequency in Hz of the input signal to the 8253, which is 1.19318MHz on the IBM PC and most compatibles. TI is the time interval you want between interrupts. For example, to generate interrupts every 10mSec,

$$\text{TMR\_CNT} = (10 * 10^{-3}) * (1.19318 * 10^{6})$$
$$= 11932 \text{ (approximately)}$$

The count you program must be less than or equal to 65536 (0 corresponds to 65536). If you require a larger value, divide that value by a number large enough that the result is less han 65536. Call this number NDIV. Your interrupt handler must then maintain a counter in a memory location which is initially loaded with NDIV and is decremented by 1 on each interrupt. When this counter reaches 0, the interrupt handler should reload it with NDIV and call the data acquisition routine.

For example, to perform data acquisitions every second,

$$\text{TMR\_CNT} = 1 * (1.19318 * 10^{6})$$
$$= 20 * 59659$$

You would set NDIV to 20 and replace TMR_CNT with 59659.

If you want to maintain the time-of-day clock and the computer's other housekeeping tasks, you must arrange to call the original **INT 8** routine at the right frequency. You can do this by maintaining a counter in a memory location. On each interrupt, the interrupt handler adds the value TMR_CNT to this location. When the result overflows (the addition produces a carry), the system timer interrupt handler should be called. (This procedure results in an average clock frequency the same as that of the original clock, but the rate is not exactly constant.)

3

The following sequence might form the skeleton of a timer interrupt handler.

```
;These variables must be stored in the code segment:

PC+INT8  LABEL  DWORD        ;storage for original interrupt
PC_OFF8  DW     ?            ; offset
PC_SEG8  DW     ?            ; and segment
DSEG     DW     ?            ;storage for data segment value

;------------------------------------------------------------------------

MY_INT8: PUSH   DS           ;save data segment
         PUSH   AX           ;save accumulator
         ...                 ;save other registers as needed
         MOV    AX,CS:DSEG   ;load DS with correct value
         MOV    DS,AX        ; (saved in code segment)

;This section of code is required for counts greater than 65536:

         DEC    NDIV_CT      ;decrement NDIV counter
         JNZ    NOT_ZRO
         MOV    AX,NDIV      ;reload NDIV counter
         MOV    NDIV_CT,AX
;------------------------------------------------------------------------

;This section of code is always required:

         CALL ACQUIRE        ;call data acquisition routine
;------------------------------------------------------------------------

;This section of code is required whenever the timer has been reprogrammed:

NOT_ZRO: MOV    AX,TMR_CNT   ;update dummy system timer
         ADD    SYST_CT,AX   ;ADD sets carry flag on overflow
                             ;restore all saved registers
         POP    AX           ;POP doesn't affect flags (in
         POP    DS           ; particular, the carry flag)
         JNC    NOT_CYF      ;skip if timer didn't overflow
         JMP    CS:PC_INT8   ;jump to original routine
                             ; address (saved in code segment)
NOT_CYF: IRET                ;return from interrupt
;------------------------------------------------------------------------
```

```
;The above would be replaced by this section of code if the timer is not
;  reprogrammed:
                ...                     ;restore all saved registers
                POP     AX
                POP     DS
                JMP     CS:PC+INT8      ;jump to original routine
;---------------------------------------------------------------------------
```

The symbols **NDIV_CT** and **SYST_CT** refer to memory locations which are allocated in the data segment (not shown). The symbols **NDIV** and **TMR_CT** may refer to memory locations in the data segment, or they may be constants.

SAMPLE PCI-20000 SYSTEMS USING INTERRUPTS

Following are examples of PCI-20000 systems which might be used for interrupt-controlled data acquisition. Each example includes a brief description of the hardware configuration and the function of the software.

Example 1. Use a PCI-20020M Trigger/Alarm Module to generate an alarm interrupt.

Connect the PCI-20020M *IRQ0 to the interrupt line. When an interrupt occurs, your software will respond to the alarm. The alarm response might include recording the alarm activity, activation of other equipment, or updating a display. The example interrupt handler routine which appears in Listing 1 at the end of this Application Note could be used as a model for the interrupt handler.

This is a good example of an application in which interrupts give better performance than polling. Alarms by definition occur at unpredictable times. Interrupts allow the processor to perform other tasks and still be able to respond quickly to an alarm.

Example 2. Use the rate generator on a PCI-20007M Counter/Timer/Rate Generator Module to time data acquisition using any combination of I/O Modules.

Connect the PCI-20007M *IRQ0 signal to the interrupt line. Program the Rate Generator to produce an output signal of the desired frequency.[5] When an interrupt occurs, your software will perform the desired data acquisition sequence.

The Turbo Pascal sample program shown in Listing 2 at the end of this Application Note is designed for this system. The program uses a 3000Hz interrupt signal generated by a PCI-20007M module to time the acquisition of analog data using a PCI-20002M module. While the data acquisition progress is occurring the program also graphs the data being acquired. The use of the interrupt handler to acquire the analog data not only allows the program to do two processes at once, but ensures that the acquisition progresses at a well defined rate. Using this method, data acquisition and graphing occur simultaneously without interfering with each other.

Example 3. Use the rate generator on a PCI-20007M Counter/Timer/Rate Generator Module to control data acquisition from a PCI-20019M High Speed Analog Input Module.

Connect the PCI-20007M SYNC OUT signal to SYNC IN of the PCI- 20019M. Connect the PCI-20019M *IRQ0 signal to the interrupt line. You can optionally configure the input module for automatic channel advance. When an interrupt occurs, your software will read the converted data from the PCI-20019M. This is a good example of an application in which either polling or interrupts could be used, depending on speed requirements and other program tasks.

TIMING COMPARISONS OF INTERRUPTS AND POLLING

The time required to execute a data acquisition sequence may affect the rate at which data are acquired, and it may determine whether interrupts or polling are to be used to control data acquisition. Following are sample code sequences to support the data acquisition system of Example 3 using interrupts and polling. We will use this example to estimate the time required for a minimum data acquisition process, and to compare the processor overhead required to service an interrupt. The number of 8086 processor cycles required for each instruction is shown in the comment field.[1]

The total number of cycles of interrupt overhead is 220, corresponding to about 46uSec for a 4.77MHz processor clock. The instruction cycle counts shown are for an 8086 processor. These do not give a precise estimate of the ac-

```
;Interrupt entry sequence:

                                        ;51 cycles to respond to INT n
MY_INT8   PUSH     DS                   ;10   save registers
          PUSH     ES                   ;10
          PUSH     DI                   ;10
          PUSH     AX                   ;10
          MOV      AX,DSEG              ;4    load segment registers
          MOV      ES,AX                ;2
          MOV      AX,OCOOOH            ;4    DS addresses the PCI-20000
          MOV      DS,AX                ;2    carrier segment
          MOV      DI,BUFR_PTR          ;14   load buffer pointer
                                        ;127  total cycles for entry
```

;**Data acquisition sequence:**

```
         MOV       AX,CNVT_DAT ;16  read converter
         STOSW                 ;14  store data in memory and
                               ;     increment pointer
         CMP       DI,END_BUFR ;15   check for end of buffer
         JZ        END_PRC     ;4    quit if end of buffer
                               ;49  cycles data acquistion
```

;**Interrupt return sequence:**

```
         MOV       BUFR_PTR,DI ;15   store buffer pointer
         MOV       AL,20H      ;4    clear interrupt
         OUT       20H,AL      ;10
         POP       AX          ;8    restore registers
         POP       DI          ;8
         POP       ES          ;8
         POP       DS          ;8
         IRET                  ;32   return
                               ;93   total cycles for exit
END_PRC:....                   ;      quit at end of buffer
```


tual time required. The 8088 processor used in the IBM PC and compatibles requires more cycles because of its 8-bit bus. Some time is gained by the processor's "pre-fetch queue" which allows it to read the next program instructions during idle bus cycles, and the memory refresh circuitry competes with the processor for bus access. The actual overhead of this example is close to 55uSec for an IBM PC. (This corrected estimate is based on timing tests of similar code on an IBM PC.)

Compare the interrupt routine above with this polling routine which performs the same function:

The total loop overhead is 21 cycles minimum, and the data acquisition time is approximately

Typical instructions that access memory require 10-30 cycles, but a multiply or divide instruction might require over 100 cycles. Of course, for maximum timing accuracy, either application would be run with other interrupts masked or disabled. This polling loop is not very versatile; the computer is completely tied up while data is taken. For relatively slow sampling rates, the interrupt overhead becomes negligible, and the interrupt technique allows the processor to perform other tasks.

These sample code sequences contain a few symbols that are not defined above. Instruction timing depends on whether symbols used in **MOV** instructions refer to constants or to memory locations. The symbol **DSEG** is the

;**Setup sequence (performed once):**

```
MY_POLL: MOV       DI,beg_bufr    ;load buffer pointer
         MOV       CX,BUFR_CNT    ;load buffer length
         MOV       DL,MASK        ;get mask for status register
         PUSH      DS             ;load segment registers
         POP       ES
         MOV       AX,OCOOOH      ;DS addresses the PCI-20000
         MOV       DS,AX          ; carrier segment
```

;**Data acquisition sequence:**

```
POL_LP:  TEST      STATUS,DL      ;17  test data ready
         JNZ       POL_LP         ;4-16
                                  ;21 cycles loop overhead (min)
                                  ;33 cycles for additonal pass
         MOV       AX,CNVT_DAT    ;16 read converter
         STOSW                    ;11 store data in memory
                                  ; and increment pointer
         LOOP      POL_LP         ;17  continue
                                  ;44 cycles data acquisition
END_PRC:...                       ;quit at end of buffer
```

the same as in the interrupt same. Clearly, data could be taken more rapidly using polling than using interrupts. Furthermore, the accuracy with which the processor can respond to signal is limited only by the polling loop time of 33 cycles. An interrupt response is limited by the cycle time of the interrupted instruction.

default data segment value, a constant. The symbol CNVT_DAT refers to the memory location of an A/D converter data register. The symbols **BUFR_PTR, BEG_BUFR, END_BUFR,** AND **BUFR_CNT**, refer to memory storage locations in the default data segment.

The examples show two different ways of keeping track of the data count and the location in which the data is to be stored. Assembly language code to set up all the buffer variables might appear as follows, where **BUFR_LEN** is a constant.

```
BUFR_PTR DW    OFFSET BUFFER
BEG_BUFR DW    OFFSET BUFFER
END_BUFR DW    OFFSET BUFFER +
                 BUFR_LEN*2
BUFR_CNT DW    BUFR_LEN
BUFFER DW      BUFR_LEN
```

SAMPLE LISTINGS

Listings of two interrupt handling systems are given in this section. These listings, along with the examples and discussions above, can be used as a reference for designing an interrupt handling system to suit your application. The first listing contains several assembly language subroutines which can be adapted for use with any compiled language that produces object files (*.OBJ) that are combined by the linker, LINK.EXE. The second listing is a complete program in Turbo Pascal, in which in-line machine code is used to provide the interrupt-handling functions that are not available in Turbo Pascal.

Listing 1 contains sample interrupt handler routines written in assembly language, which can be assembled by the Macro Assembler and linked with your other program modules by LINK.EXE. The routines must be adapted to interface properly to your compiler. (They were tested with a program compiled by Microsoft C, Version 2.04.) Note that other compilers or version numbers may require changes to this code. Please refer to your compiler manual for guidance.

The documentation for your compiler will explain how to interface assembly language modules with compiled programs. You must make sure that the routines treat the registers and stack properly, and that the names of the routines are compatible with your language's naming conventions. The SEGMENT and GROUP declarations[10] must be changed to match the segment and group names used by your compiler. The PROC declarations may need to be changed from NEAR to FAR.

If you use interpreted BASIC, you can not directly use a file generated by an assembler. You must decide how you will load machine-language routines so that BASIC can access them. You might read in the machine instructions from a file or store them in DATA statements in your program. The instructions must be POKEd into memory before the routines can be called. Using machine language subroutines is described in Appendix C of the IBM BASIC manual.[11]

Listing 1 contains the following routines:

SET_INT saves the original values of the interrupt vectors for INT 8 (timer), INT 0AH (IRQ2), and INT 23H (control-break exit function) and sets up a new control-break exit routine.

CLR_INT restores all interrupt routines and re-programs the 8259A interrupt controller and the 8253 timer chips, which may have been altered by the program.

MY_CTBK is the control-break exit routine set up by **SET_INT**.

This routine insures that the interrupt routines and peripheral chips will be restored even if the user types control-break to exit the program. It calls **CLR_INT**, then jumps to the original control-break exit routine.

SET_IRQ2 sets up and interrupt handler for IRQ2 and programs the interrupt controller to enable IRQ2.

MY_IRQ2 is the interrupt handler set up by **SET_IRQ2**. It clears the interrupt controller and calls a user-supplied routine to acquire data or perform other functions.

SET_TIM sets up an interrupt handler for the system timer interrupt, and re-programs the system timer to interrupt at a new rate.

MY_TIM is the interrupt handler set up by **SET_TIM**. It calls a user-supplied routine to acquire data or perform other functions. It maintains the system time-of-day clock by calling the system timer interrupt handler at the proper rate.

Listing 2 shows a complete program, **INTERDMO.PAS**, which includes an interrupt handler routine. This program is written in Turbo Pascal[7], which has provisions for writing in-line machine code.

LISTING #1

```
            TITLE  Sample Interrupt Handlers
            .RADIX 16
;*************************************************************************
; IR2_DAT and TIM_DAT
;
; These are external procedures to acquire data or perform other desired
; functions.  They are called from the interrupt handlers for IRQ2 and the
; timer interrupt (IRQ0), respectively.  Because MS-DOS and PC-DOS are not
; re-entrant, there are limitations on what there routines can do.
;
; IR2_DAT and TIM_DAT should NOT perform I/O using standard DOS console I/O,
; printer I/O, or disk I/O routines.  This includes most I/O library func-
; tions provided with compiled languages such as C and Pascal.
;
; Many compilars generate code to perform "stack checking" at the beginning
; of each subroutine (Microsoft compilers do this).  You should DISABLE
; this feature when you compile the routines IR2-DAT and TIM_DAT, espec-
; ially if your program will perform console, printer, or disk I/O while
; data acquisition is taking place.  Your compiler manual should explain how
; to disable stack checking.
;
; You should initialize data buffers and other variables used by the IR2_DAT
; and TIM_DAT before calling SET_IR2 or SET_TIM.
```

```
;*****************************************************************************
; Language Interface
;
; In order to combine this module with object modules produced by a com-
; piler, the following SEGMENT and GROUP declarations must correspond to the
; requirements of the compiler.  The segment or group name (depending on the
; compiler requirements) must also appear in the OFFSET expressions that ap-
; pear in the program.  Some compilers alter the names of global (public and
; external) symbols.  The names declared PUBLIC and EXTRN in this file must
; match the names the compiler puts in the OBJ files.  If your linker is
; case-sensitive, the names must also be in the correct case.  You must
; refer to your compiler documentation for the correct SEGMENT and GROUP dec-
; larations and for the correct form of global names.
;
; The variable ERR_FL, which must be accessible by the calling program, is
; declared external.  The calling program must contain a global 2-byte in-
; teger variable ERR_FL which is located in the default data segment.
;
; The external routines IR2_DAT and TIM_DAT are expected to preserve DS, SS,
; and BP.  The interrupt handlers preserve all registers.  All other
; routines preserve DS, ES, SS, and BP.  Some languages may require other
; registers to be preserved.
;
;*****************************************************************************
; IBM PC AT
;
; If you are using an IBM PC AT or equivalent computer, you should make the
; following modifications to this module:  Immediately following EACH "in"
; or "out" assembly instruction, add the following
;
;         jmp   $+2
;
; This insures that the I/O chip has adequate time between successive acces-
; ses.

pgroup    GROUP     prog
prog      SEGMENT   PUBLIC        'PROG'
          ASSUME    cs:prog

INT_0A    DD        ?             ;storage for original interrupt vectors
INT_08    DD        ?
INT_23    DD        ?
D_SEG     DW        ?             ;storage for default data segment
TIMER     DW        0             ;count register
INIT_FL   DB        0             ;setup flag
OLD_MSK   DB        ?             ;original interrupt controller mask
BUSY_2    DB        0             ;IRQ2 re-entry flag
*****************************************************************************
; SET_INT
; This routine is intended to be called near the beginning of a program.  It
; preserves the original contents of the interrupt vectors for IRQ0 (timer,
; INT 8) and IRQ2 (data acquisition, INT 0AH, which will be changed, as well
; as the original contents of the 8259 interrupt enable mask.  A flag,
; INIT_FL, is checked to prevent the setup procedure from being executed
; twice.
;
; The routines SET_TIM and SET_IRQ2 which set up new interrupt handler
; routines check INIT_FL and call SET_INT if necessary.

          PUBLIC    SET_INT
SET_INT   PROC      NEAR

          push      bp                           ;save BP
          mov       bp,sp
          sub       sp,2                         ;allocate space for one
                                                 ; temporary word
          cmp       cs:INIT_FL,0
          jz        setup
          jmp       set_ex

setup:    mov       [bp-2],ds                    ;save DS in temporary
          inc       cs:INIT_FL
          mov       cs:D_SEG,ds     ;save DS value in code
                                                 ;area
          xor       ax,ax                        ;zero AX
          mov       ds,ax                        ;address Segment 0 with DS
; ******  The following is required if the timer interrupt is used.

          mov       ax,ds:(8*4)
          mov       dx,ds:(8*4+2)
          mov       WORD PTR cs:INT_08,ax        ;save original interrupt
          mov       WORD PTR cs:INT_08+2,dx      ; vectors
```

```
; ******     The following is required if either the timer or IRQ2 is
;            used.
             mov        ax,ds:(0a*4)
             mov        dx,ds:(0a*4+2)
             mov        WORD PTR cs:INT_0A,ax
             mov        WORD PTR cs:INT_0A+2,dx
             in         al,21                        ;save original interrupt
             mov        cs:OLD_MSK,al   ; mask
; ******     The following is required if either the timer or IRQ2 is
;            used.
             mov        ax,ds:(23*4)
             mov        dx,ds:(23*4+2)
             mov        WORD PTR cs:INT_23,ax
             mov        WORD PTR cs:INT_23+2,dx
; ******     Interrupts must be disabled to change interrupt vectors.
             cli                                     ;replace CTRL-BRK with
                                                     ; local routine
             mov        WORD PTR ds:(23*4),OFFSET pgroup:MY_CTBK
             mov        ds:(23*4+2),cs               ;CS contains segment to
             sti                                     ; address MY_CTBK

             mov        ds,[bp-2]                    ;restore DS
set_ex:      mov        sp,bp
             pop        bp                           ;restore BP
             ret

SET_INT      ENDP
;*****************************************************************************
; CLR_INT
; This routine must be called prior to the end of the program.  It restores
; the original contents of the interrupt vectors preserved by SET_INT.  The
; flag INIT_FL is checked and the routine is bypassed if SET_INT was never
; called.  CLR_INT is called form MY_CTBK if the user types a CTRL-BREAK.

             PUBLIC     CLR_INT
CLR_INT      PROC       NEAR
             push       bp                           ;save BP
             mov        bp,sp
             sub        sp,2                         ;allocate space for one
                                                     ; temporary word

             cmp        cs:INIT_FL,O
             jz         clr_ex
             mov        [bp-2],ds                    ;save DS in temporary
             xor        ax,ax                        ;address Segment O with
             mov        ds,ax                        ; DS
             cli
; ******     Interrupts must be disabled to change interrupt vectors or to
;            reprogram the timer.
; ******     The following is required if the timer interrupt is used.
             mov        al,36                        ;output timer control
             out        43,al                        ; word
             xor        ax,ax                        ;initialize time count
             out        40,al                        ; to zero
             mov        al,ah
             out        40,al
             mov        ax,WORD PTR cs:INT_08        ;restore original inter-
             mov        dx,WORD PTR cs:INT_08+2      ; rupt vectors
             mov        ds:(8*4),ax
             mov        ds:(8*4+2),dx
; ******     The following is required if IRQ2 is used.
             mov        al,cs:OLD_MSK   ;restore interrupt mask
             out        21,al
             mov        ax,WORD PTR cs:INT_OA
             mov        dx,WORD PTR cs:INT_OA+2
             mov        ds:(0a*4),ax
             mov        ds:(0a*4+2),dx

; ******     The following is required if either the timer or IRQ2 is
;            used.
```

```
          mov       ax,WORD PTR cs:INT_23
          mov       dx,WORD PTR cs:INT_23+2
          mov       ds:(23*4),ax
          mov       ds:(23*4+2),dx
          sti
          mov       ds:,[bp-2]                   ;restore DS
          mov       cs:INIT_FL,O    ;clear flag
clr_ex:   mov       sp,bp
          pop       bp                           ;restore BP
          ret
CLR_INT   ENDP

;*************************************************************************
; MY_CTBK
; This routine replaces the usual INT 23 "interrupt handler", which is
; called if a CTRL-BREAK is pressed during execution of the program.  It en-
; sures that the interrupt routines will be restored properly and that the
; interrupt controller and timer chips will be correctly reprogrammed.

          PUBLIC    MY_CTBK
MY_CTBK   PROC      NEAR

          push      ax                           ;save all registers
          push      bx
          push      cx
          push      dx
          push      si
          push      di
          push      es
          push      ds
          mov       ds,cs:D_SEG                  ;load data segment
          call      CLR_INT                      ;restore interrupts
          pop       ds                           ;restore registers
          pop       es
          pop       di
          pop       si
          pop       dx
          pop       cx
          pop       bx
          pop       ax
          jmp       cs:INT_23                    ;call regular INT 23
MY_CTBK   ENDP                                   ; routine

;*************************************************************************
; SET_IRQ2
; This routine calls SET_INT to perserve the initial interrupt routine ad-
; dresses, if necessary.  It sets up a special interrupt routine for IRQ2
; and enables interrupts from IRQ2 by reprogramming the interrupt controller.

          PUBLIC    SET_IRQ2
SET_IRQ2  PROC      NEAR

          push      bp                           ;save BP
          mov       bp,sp
          sub       sp,2                         ;allocate space for one
                                                 ; temporary word
          cmp       cs:INIT_FL,0
          jnz       enable
          call      SET_INT                      ;make sure SET_INT is
                                                 ; called
enable:   mov       [bp-2],ds                    ;save DS in temporary
          xor       ax,ax                        ;address Segment 0 with
          mov       ds,az                        ; DS
; ******  Interrupts must be disabled to change interrupt vectors.
          cli                                    ;set up IRQ2 routine
          mov       WORD PTR ds:(0a*4),OFFSET pgroup:MY_IRQ2
          mov       ds:(0a*4+2),cs               ;CS contains segment to
                                                 ; address MY_IRQ2
          in        al,21                        ;set interrupt mask
          and       al,0fbh
          out       21,al
          sti
```

```
        mov     ds,[bp-2]                       ;restore DS
        mov     sp,bp
        pop     bp                              ;restore BP
        ret
SET_IRQ2 ENDP

;****************************************************************************
; MY_IRQ2
;
; This is the interrupt handler for IRQ2.  It is written as a skeleton which
; calls the actual data acquisition routine, IR2_DAT.  (The routine IR2_DAT
; is not provided in this example.)  Since all registers are saved, IR2_DAT
; may be written in a high- level language.
;
; In order to detect a too-rapid data acquisition situation, interrupts are
; re-enabled immediately and the interrupt controller is cleared.  A flag is
; set to prevent re-entry in case one interrupt is not finished before
; another occurs.  If the routine is re-entered, it increments an error
; counter, ERR_FL, and immediately returns.  The calling program should
; check the error counter as an indication of bad data.

        PUBLIC  MY_IRQ2
MY_IRQ2 PROC    FAR
        push    ax                              ;save AX and DS
        push    ds
        mov     ds,cs:D_SEG                     ;set up program data
                                                ; segment
        cmp     cs:BUSY_2,0                     ;test for multiple entry
        mov     al,20                           ;write EOI to 8259 to
        out     20,al                           ; allow interrupt at
        jz      ir2_ok                          ; this level
        inc     ds:ERR_FL                       ;set flag
        jmp     SHORT ir2_ex
ir2_ok: mov     cs:BUSY_2,1                     ;set busy flag
; ******  Interrupts enabled after testing and setting BUSY_2.
        sti
        push    bx                              ;save all other registers
        push    cx
        push    dx
        push    si
        push    di
        push    bp
        push    es
        mov     es,cs:D_SEG                     ;set up extra segment
        mov     bp,sp                           ;save SP in BP
        call    IR2_DAT                         ;call data acquisition
                                                ; routine
        mov     sp,bp                           ;restore SP
        pop     es                              ;restore all registers
        pop     bp
        pop     di
        pop     si
        pop     dx
        pop     cx
        pop     bx
; ******  Routine must end with interrupts disabled.  No interrupts
;         can be allowed after BUSY_2 is cleared.
        cli
        mov     cs:BUSY_2,0                     ;clear busy flag
ir2_ex: pop     ds                              ;restore AX and DS
        pop     ax
        iret
MY_IRQ2 ENDP

;****************************************************************************
; SET_TIM
; This routine calls SET_INT to preserve the initial interrupt routine ad-
; dresses, if necessary.  It reprograms the PC's timer interrupt to a faster
; rate (twice the normal rate, as determined by TIM_CNT) and sets up a spe-
; cial interrupt routine for the timer interrupt.
```

```
            PUBLIC     SET_TIM
SET_TIM     PROC       NEAR

            push       bp                          ;save BP
            mov        bp,sp
            sub        sp,2                        ;allocate space for
                                                   ; temporaries
            cmp        cs:INIT_FL,0
            jnz        start
            call       SET_INT                     ;make sure SET_INT is
                                                   ; called
start:      mov        [bp-2],ds                   ;save DS in temporary
            cli
            mov        al,36                       ;reprogram timer chip
            out        43,al
            mov        ax,TIM_CNT
            out        40,al                       ;output timer count
            mov        al,ah
            out        40, al
            mov        cs:TIMER,0                  ;clear timer register
            xor        ax,ax
            mov        ds,ax                       ;set up local interrupt
                                                   ; routine
            mov        WORD PTR ds:(8*4),OFFSET pgroup:MY_TIM
            mov        ds:(8*4+2),cs
            sti
            mov        ds,[bp-2]                   ;restore DS
            mov        sp,bp
            pop        bp                          ;restore BP
            ret
SET_TIM     ENDP

;***************************************************************************
; Timer interrupt
;
; This is the interrupt handler for IRQ0.  It is written as a skeleton which
; calls the actual data acquisition routine, TIM_DAT.  (The routine TIM_DAT
; is not provided in this exampe.)  Since all registers are saved, TIM_DAT
; may be written in a high- level language.
;
; In order to maintain an accurate system clock, the PC's timer interrupt
; handler (the original INT 8 routine) is called every other time the inter-
; rupt occurs.

            PUBLIC     MY_TIM
MY_TIM      PROC       FAR

            push       ax                          ;save registers
            push       ds
            push       bx
            push       cx
            push       dx
            push       si
            push       di
            push       bp
            push       es
            mov        ds,cs:D_SEG                 ;get program data segment
            mov        es,cs:D_SEG
            mov        bp,sp                       ;save SP in BP
            call       TIM_DAT                     ;call data acquisition
                                                   ; routine
            mov        sp,bp                       ;restore SP from BP
            pop        es                          ;restore registers
            pop        bp
            pop        di
            pop        si
            pop        dx
            pop        cx
            pop        bx
            pop        ds
            add        cs:TIMER,TIM_CNT
            jc         tim_ex
            mov        al,20                       ;write EOI to 8259
            out        20,al
```

3

```
         pop      ax                      ;restore AX
         iret                             ;return from interrupt
tim_ex:  pop      ax                      ;restore AX
         jmp      cs:INT_08               ;call regular timer
MY_TIM   ENDP                             ; routine
prog     ENDS
         END
```

LISTING 2

```
{ PCI-20000, TURBO-PASCAL, INTERRUPT HANDLING DEMONSTRATION PROGRAM
  HARDWARE:PCI-20001C-2 OR -1 (W31 In, W23 In for Interrupt Level 3)
           PCI-20002M-1 (Mod 3), and PCI-20007M-1 (Mod 2) }

{$C-,U-}        {Disable Ctrl-Break}
Program InterDmo ;
Const
  MaxOff       =    619 ; { Maximum Data Buffer Offset            }
  MinOff       =     20 ; { Minimum Data Buffer Offset            }
  Stat 8259    =    $20 ; { 8259 Status Register Port Address     }
  Mask 8259    =    $21 ; { 8259 Mask Register Port Address       }
  KeysOnMask   =    $FD ; { 8259 Mask for Keyboard ONLY On        }
  EOI          =    $20 ; { 8259 End of Interrupt Command         }
  ModNo2M      =      3 ; { Module position number of  PCI2M      }
  CarSeg       =  $C000 ; { segment address of carrier            }
  RGN1         =  $0378 ; { N1 for 3000 ticks in 1 second         }
  RGN2         =  $0003 ; { N2 for 3000 ticks in 1 second         }
  HdwIntNo     =      3 ; { Hardware Interrupt Number             }
  PgmDS : Integer = 0   ; { Store for Program's Data Segment      }
Type
  DataBuffer = Array [MinOff..MaxOff] of Integer ; { Buffer for Data }
Var
  Set2M       : Byte Absolute CarSeg:$0302 ; { Channel and Gain Setup      }
  Strobe2M    : Byte Absolute CarSeg:$0304 ; { Strobe address to start ADC }
  MSB2M       : Byte Absolute CarSeg:$0304 ; { Read MSB address for ADC    }
  LSB2M       : Byte Absolute CarSeg:$0305 ; { Read LSB address for ADC    }
  RGCtrl      : Byte Absolute CarSeg:$0207 ; { Rate Gen. Control address   }
  RGCnt1      : Byte Absolute CarSeg:$0204 ; { Rate Gen. Counter 1 addr.   }
  RGCnt2      : Byte Absolute CarSeg:$0205 ; { Rate Gen. Counter 2 addr.   }
  RGGate      : Byte Absolute CarSeg:$020C ; { Rate Gen. Enable Gate addr. }
  IntOff      : Integer Absolute $0000:$002C ; { NOTE : Must be consistent }
  IntSeg      : Integer Absolute $0000:$002E ; {        with HdwIntNo.     }
  IntMask     : Byte        ; { Storage for 8259 interrupt mask               }
  SaveIntOff  : Integer     ; { Storage for interrupt handler offset address  }
  SaveIntSeg  : Integer     ; { Storage for interrupt handler segment addr.   }
  BufferOff   : Integer     ; { Pointer into Data Buffer for int. handler     }
  DispOff     : Integer     ; { Pointer into Data Buffer for grapher          }
  Buffer      : DataBuffer  ; { The Data Buffer                               }
  Ch          : Char        ; { Storage for a character pressed on keys       }

{ IntHandler -- this is the interrupt handler. }

Procedure IntHandler ;

Begin  { IntHandler }

  { ***** Save the state of the 8088 CPU ***** }

InLine   ($50/            { PUSH AX                    }
          $53/            { PUSH BX                    }
          $51/            { PUSH CX                    }
          $52/            { PUSH DX                    }
          $56/            { PUSH SI                    }
          $57/            { PUSH DI                    }
          $1E/            { PUSH DS                    }
          $06/            { PUSH ES                    }
```

```
          $2E/$8E/$1E/>PgmDS{ CS: MOV DS,PgmDS ; Setup DS    }
         ) ;

 { ***** Process the interrupt ***** }

 If BufferOff <>  (MaxOff + 1) Then   { If Buffer is not full }
 Begin
   If BufferOff  <>  (MinOff - 1) Then  { No read on first pass )
   Begin
         { ***** Get the ADC value ***** }
         Buffer[BufferOff] := (MSB2M shl 4) or (LSB2M shr 4) ;
   End ;

   { ***** Update Buffer Pointer ***** }
   BufferOff := BufferOff + 1 ;
   { ***** Start the next conversion ***** }
   Strobe 2M :=0     ;
 End
 Else
 Begin
   RGGate := 0    ; {Disable Rate Generator }
 End ;

 { ***** Notify 8259 of EOI ***** }
 Port[Stat8259] :=EOI ;
   { ***** Restore the state of the 8088 CPU ***** }

   InLine ($07/               { POP  ES                  }
          $1F/                { POP  DS                  }
          $5F/                { POP  DI                  }
          $5E/                { POP  SI                  }
          $5A/                { POP  DX                  }
          $59/                { POP  CX                  }
          $5B/                { POP  BX                  }
          $58/                { POP  AX                  }
          $8B/$E5/            { MOV  SP,BP               }
          $5D/                { POP  SP                  }
          $CF                 { IRET                     }
         ) ;
End ; { IntHandler}

  { InstallInt -- this routine installs the interrupt handler. }
  Procedure InstallInt ;
  Begin { InstallInt }
     { ***** Disable All Interrupts ***** }
     InLine ($FA) ;              { CLI }
     { ***** Save the current interrupt vector *****  }
  SaveIntOff := IntOff ;
  SaveIntSeg := IntSeg ;
  { ***** Store the new interrupt vector ***** }
  IntOff :=Ofs(IntHandler) ;
  IntSeg :=CSeg
  { ***** Save 8259 mask register ***** }
  IntMask := Port[Mask8259] ;
  { ***** Store new 8259 mask ***** }
  Port[Mask8259] := KeysOnMask xor (1 shl HdwIntNo) ;
  { ***** Re-Enable Interrupts ***** }
  InLine ($FB) ;                { STI }
End ; { InstallInt }

 { RemoveInt -- this routine removes the interrupt handler. }
 Procedure RemoveInt ;
 Begin  { RemoveInt }
     { ***** Disable All Interrupts ***** }
     InLine ($FA) ;             { CLI }
     { ***** Restore the old interrupt vector ***** }
     IntOff := SaveIntOff ;
     IntSeg := SaveIntSeg ;
     { ***** Restore old 8259 mask ***** }
     Port[Mask8259] := IntMask ;
```

```
    { ***** Re-Enable Interrupts ***** }
    InLine ($FB) ;              { STI }
    End ; { RemoveInt }

  Begin  { InterDmo }
    { ***** Save the programs Data Segment Register ***** }
    PgmDS :=DSeg ;
    { ***** Delay long enough for diskette to go off ***** }
    Delay(2000) ;
    { ***** Setup the 2M module to read channel 0 at gain of 1 ***** }
    Set2M :=$40 ;
  { ***** Setup the Rate Generator ***** }
    RGCtrl  : =  $34        ; { Setup RG Counter 1              }
    RGCtrl  : =  $74        ; { Setup RG Counter 2              }
    RGCnt1 : =  Lo(RGN1) ; { Write Low  Count LSB          }
    RGCnt1 : =  Hi(RGN1) ; { Write Low  Count MSB          }
    RGCnt2 : =  Lo(RGN2) ; { Write High Count LSB          }
    RGCnt2 : =  Hi(RGN2) ; { Write High Count MSB          }
    RGGate : =  0        ; { Disable Rate Generator        }

    { ***** Begin the demonstration ***** }
    HiRes        ;              { Setting High Resolution Mode }
    InstallInt ;
Repeat
    GotoXY(19,25) ;
    Write(' Press E to Exit, or A to Acquire data ? ') ;

    Repeat
        Repeat                  { Get A Key }
          Read(KBD, Ch) ;
        Until Not KeyPressed ;
        Ch := UpCase(Ch) ;
  Until (Ch = 'A') or (Ch = 'E') ;
  HiRes          ;              {Setting High Resolution Mode }
  If Ch = 'A' Then

  Begin

    Draw(    10,    0,   629,    0,  1) ;          { Draw Border             }
    Draw(   629,    0,   629,  186,  1)  ;
    Draw(   629,  186,    10,  186,  1)  ;
    Draw(    10,  186,    10,    0  1) ;
    GotoXY(19,25) ;
    Write('  Acquiring and Graphing Data     ') ;
    BufferOff := MinOff - 1;
    DispOff  := MinOff   ;
    RGGate    :    =    3    ;  {              Enable Rate Generator }

    Repeat

        If DispOff > (BufferOff - 1) Then
        Begin
        Draw(DispOff ,    Trunc(186-(Buffer[DisOff      ]/4096.0*177)),
             DispOff+1, Trunc(186-(Buffer[DispOff+1]/4096,0*177)), 1) ;
         DispOff :=DisOff + 1 ;
        End ;
      Until DispOff = MaxOff ;
    End ;
  Until Ch = 'E' ;
  RemoveInt ;
  { ***** Clean Up the Screen ***** }
  TextMode ;
End.  { InterDmo }
```

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3

DIRECT MEMORY ACCESS (DMA) TECHNIQUES FOR DATA ACQUISITION

INTRODUCTION

Direct memory access and computerized data acquisition are two concepts that have traditionally gone hand-in-hand. There is no faster and more efficient way to get large quantities of data into a personal computer than DMA.

Data acquisition generally involves the monitoring of several sources of physical data at a regular rate defined by a clock or external timing signal. The sources of data are typically mixes of A/D converters, event counters, switches, and contact closures. A/D converters are normally multi-channel devices which convert analog signals from several sources into digital signals for consumption by the computer. Often, some pre-amplification is required to boost the analog signals to the level required by the converter. Event counters, switches and contact closures are already digital signals, and they typically require only buffering to bring their levels to the required value.

Once the mixture of analog and digital input signals has been conditioned into a form acceptable by a computer, they need to be sampled at a regular rate and stored in memory. The three techniques for doing this are polling, interrupts, and direct memory access, or DMA. If the goal is to acquire the maximum amount of data at the highest speed, using the minimum amount of the computer's resources, then DMA is the technique of choice.

The amount of time required to respond to a direct memory access request is infinitesimal compared to the amount of time required to service an interrupt or execute a polling loop. This makes the goals of true background operation and high speed possible. Through-puts of 360k bytes/sec are achievable on an IBM PC or compatible computer using DMA. Burst rates of several megabytes per second are not uncommon among minicomputers. Since DMA is a hardware technique, the only computer resource used is bus bandwidth.

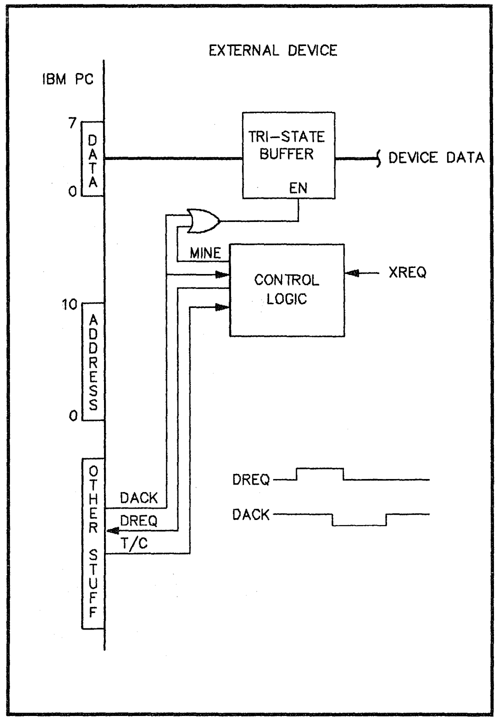

FIGURE 1a. Device-to-Memory DMA Block Diagram.

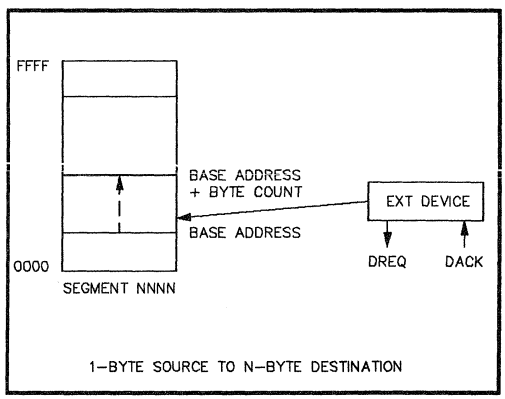

FIGURE 1b. Device-to-Memory DMA Memory Diagram.

DMA BASICS

The IBM PC's DMA controller contains four separate channels. One channel is used to refresh the machine's dynamic memory, another handles transfers to and from the floppy disk drive and a third is used to transfer data to and from the hard disk drive, if one exists. This leaves one channel for general use. As with interrupts, the DMA channels are prioritized. The transfers occur so quickly, however, that at rates of less than 100kHz or so, data acquisition would not be impacted.

The DMA controller needs to know where in memory the data from the requesting device is to go (called the "base address") and how many items are to be transferred (called the "byte count"). Then, each time it processes a DMA request, the controller effectively "steals" a bus cycle from the processor, issues the appropriate address to memory, and sends an acknowledge signal to the requesting device so that it can gate its data onto the computer's data bus. The controller then increments the base address and decrements the byte count for the next request. Since all of this occurs without any software interaction, true background operation is achieved. The computer is free to do any task required, while data acquisition proceeds accurately and invisibly behind the scenes.

LIMITATIONS OF SOME DMA TECHNIQUES

The main drawback to DMA data acquisition is that one can typically only transfer one type of data per DMA channel — usually a sequential group of analog inputs from an A/D converter, so its versatility is limited. Many real applications require a mixture of digital, analog and counter channels. Indeed, most data acquisition systems offer all these data types, but not under DMA control.

The reason for this limitation is that DMA controller chips available today are designed to transfer data efficiently from a single device, or "pipe" to a large memory buffer in the computer. This is often referred to as "device-to-memory DMA" and is illustrated in Figures 1a and 1b. Typical applications are tape drive interfaces, disk drive interfaces, local area network interfaces, and high speed communication interfaces. The DMA controller in the IBM PC is of this type.

The DMA controller in the IBM PC/AT can also be used for "memory- to-memory" DMA. Rather than transfer data from a single source to a block of memory, it can transfer data from one

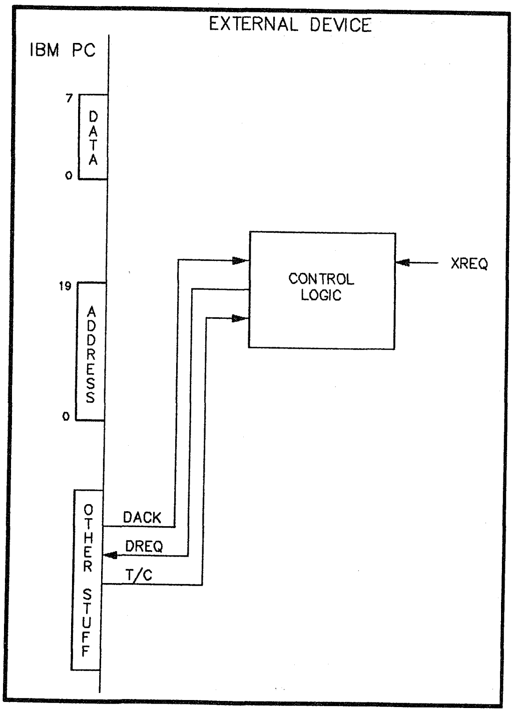

FIGURE 2a. Memory-to-Memory DMA Block Diagram.

contiguous block of memory to another, as illustrated in Figures 2a and 2b. This is useful in graphics controllers, for example, where one may want to transfer a block of memory into a screen buffer.

The device-to-memory DMA technique works fine for most data processing applications. In a data acquisition system, however, it limits

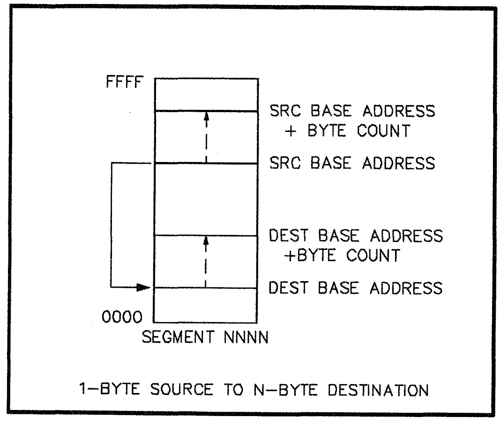

FIGURE 2b. Memory-to-Memory DMA Memory Diagram.

one to one device per DMA channel. That device must be designed to provide the handshaking required for DMA, in addition to the signals required to operate in a non-DMA mode. The typical approach using the classical device-to-memory DMA technique for data acquisition is to "hard- wire" a single A/D converter for both DMA and programmed transfer. Usually, the converter has some sort of sequential scanner on its input, allowing multiple channels. The channels to be sampled in the data acquisition run, then, have to be sequential. Some boards provide a "scan-list" memory for the scanner that will allow the sampling of non-sequential channels.

Memory-to-memory DMA doesn't provide much help for data acquisition. It typically transfers a large block of memory from one location to another. Both blocks are the same size, and consist of contiguous addresses. For data acquisition, we need to transfer a large group of relatively small "frames" of random memory or I/O addresses to a large block of contiguous memory. This type of DMA has not existed until now.

A BETTER WAY

A new patent-pending DMA technique has been developed which is targeted directly at efficient DMA transfer for data acquisition systems. The technique has been implemented on the PCI-20041C-3 High Performance Carrier for IBM PCs and compatibles. Using this system, any data type (i.e. digital, analog, counter, etc.) can be put under DMA control simultaneously with any other type. The memory-mapped Carrier occupies a 1kbyte block in the host computer's address space (Figure 3). The board can hold three memory-mapped data-acquisition modules of various descriptions. Each module is allocated 256 bytes of the available 1K. Additionally, the Carrier itself is allocated 256 bytes for its own control functions. All of the functions of both the Carrier and the modules behave as though they were memory locations in the IBM PC. To read the results of an A/D conversion, for example, one would simply read the two memory locations in the Carrier's address space which contain the two

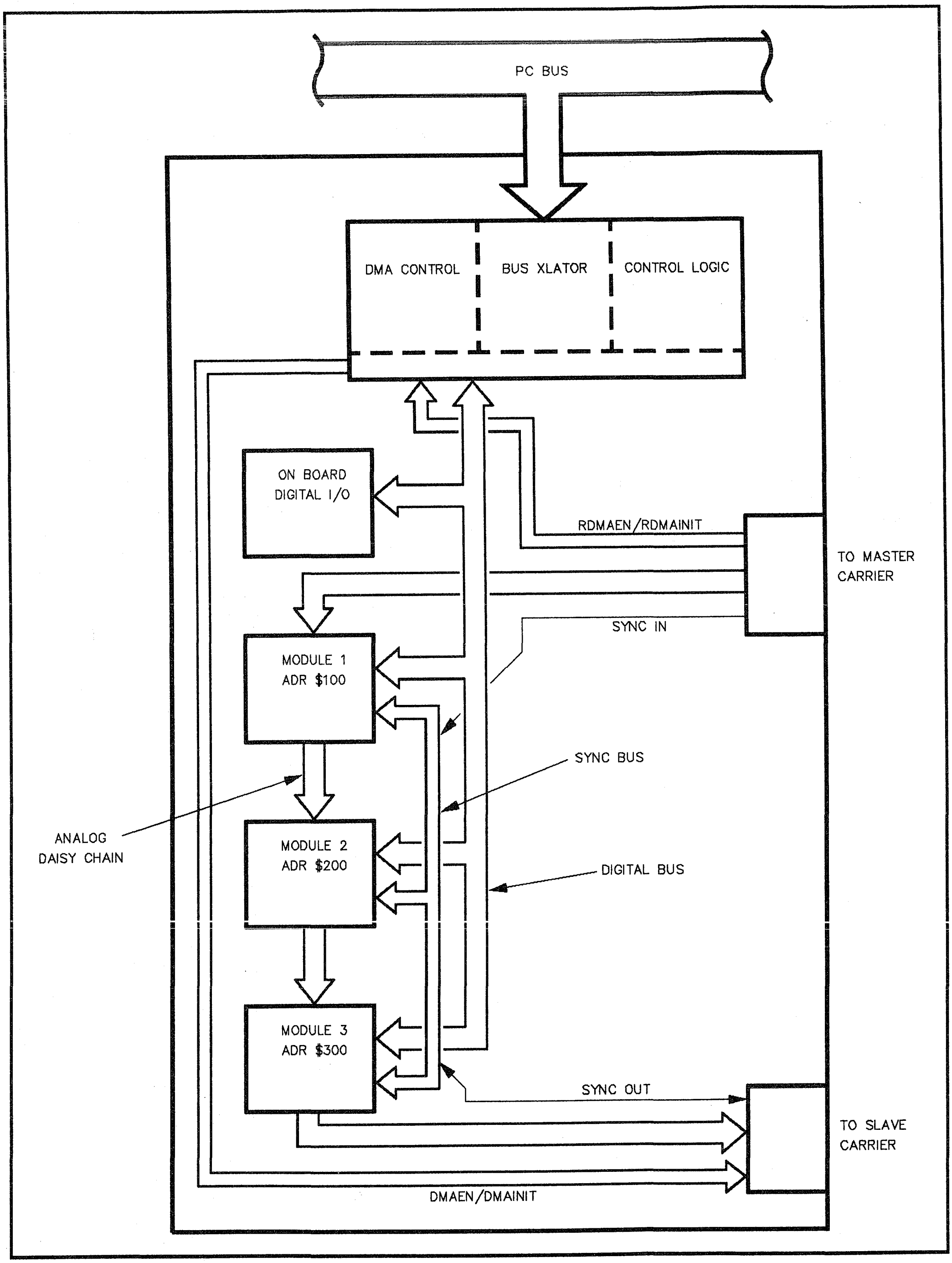

FIGURE 3. PCI-20041C-3 High Performance Carrier.

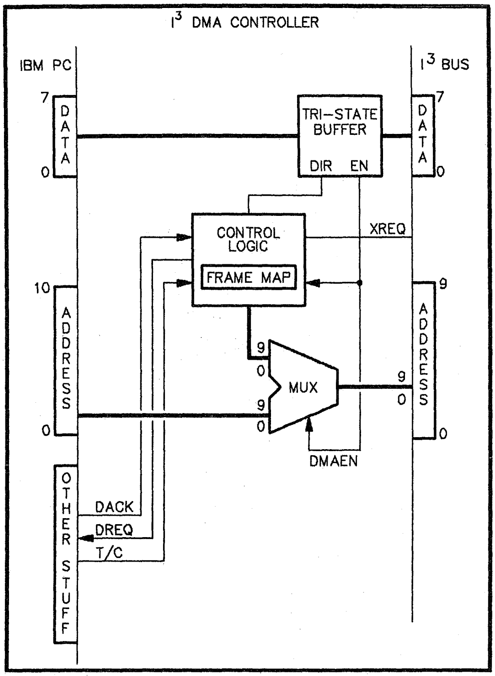

FIGURE 4a. I^3 Bus-to-Memory DMA Block Diagram.

bytes of the conversion. To output a digital I/O byte, merely write the desired value to the address corresponding to the digital I/O byte.

The DMA technique starts with the PC's internal DMA controller, and is illustrated in Figure 4a. Prior to any transfers, it must be programmed to perform a normal DMA sequence. This means programming it for the number of bytes to be transferred, the direction of transfer, the base address of the data to be transferred, and a few other more esoteric things. The IBM PC's controller is a classic device-to-memory controller, so it transfers one byte from the data bus to memory on each DMA cycle. The external device is responsible for insuring that the byte appears on the data bus at exactly the right moment.

The Carrier works with the three DMA signals available on the PC's bus, shown in Figure 5. The first, DREQ, is issued by the Carrier to indicate that the data to be transferred should be put on the PC's data bus (or taken from it, depending on the direction of the transfer). The third signal, T/C, indicates that all the bytes that the controller was programmed for have been transferred. The PC's DMA controller takes care of putting the correct address on its own address bus so that the byte on the data bus falls into the correct memory location. From the PC's vantage point, this looks like classical, straightforward device-to-memory DMA.

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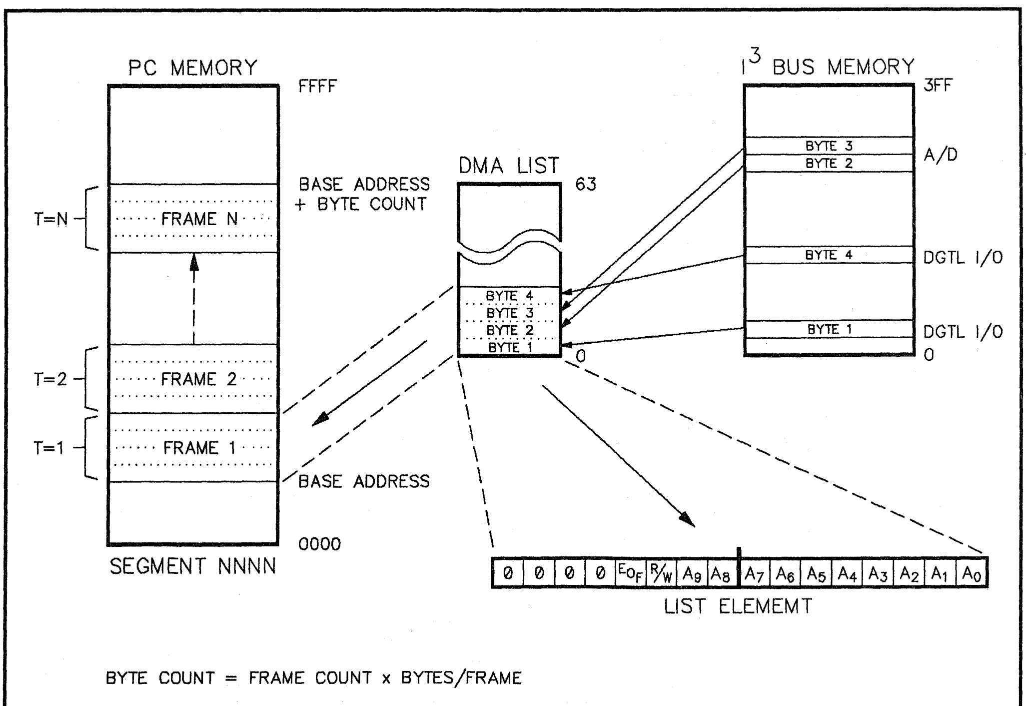

FIGURE 4b. I^3 Bus-to-Memory DMA Memory Diagram.

THE BIG DIFFERENCE

128 bytes of the 256 allotted to the PCI-20041C-3 Carrier's functions are set aside as a DMA "frame map", implemented as a dual-ported memory. The frame map is shown in Figures 4a and 5. This is the key element of the system, and the thing that makes it different. In this map is stored a list of the addresses of all the bytes to be transferred in each DMA frame. For example, if one wanted to acquire data from an analog channel, one byte of digital I/O, and the contents of a 16-bit counter, then one would store the addresses of these items in the map.

In this example, the first two entries in the list would be the addresses of the low and high order bytes of a 12-bit A/D converter module, the third entry would be the address of the digital I/O port, and the last two entries would be the addresses of the low and high bytes of the digital counter. So, the **data** in the list memory is the **address** of the byte to be transferred. Figure 4a shows a logical block diagram of this technique, while Figure 4b shows the resulting memory map.

Each list entry contains the ten-bit address which uniquely identifies a byte in the Carrier's 1Kbyte address space, a Read/Write bit to identify the direction of transfer, and an End of Frame flag to identify the last element of the list. To the host computer, the list looks like a sequential group of memory locations which are read from or written to in the normal fashion. The IBM PC, then sees the list as 128 8-bit memory locations.

The list memory is dual ported. That is, it can be accessed from two independent sources. One source is obviously the host computer, and the other source is the on-board list controller, "E" in Figure 5. Any time the host computer writes to or reads from the list memory, it is the accessing source. Whenever a DMA transfer is called for, the list controller becomes the accessing source.

During each DMA cycle, the list controller controls the address of the list memory, pointing to one frame element. The contents of that frame element in the list becomes the address of the byte to be transferred for that DMA cycle through tri-state buffer F in Figure 5. At the end of each DMA cycle, the list controller increments the list address by one. This causes the controller to point to the next list element for the next transfer. If the End of Frame flag is set in the list memory's data, then the controller resets the list address to zero for the next transfer.

During the DMA transfer (i.e., as long as DACK from the computer is true), the Carrier switches control of the I^3 address bus from the IBM PC to the frame list. It does this by disabling buffer C and enabling buffer F in Figure 5. The **data** of the list memory becomes the **address** to the I^3 bus. As far as the I^3 bus is concerned, a normal memory transfer is occurring,. The contents of the byte which is pointed to by the I^3 address bus is placed on the bus in the normal fashion. On the PC's side of the system, the final destination of that byte is waiting on the PC's address bus. When the DMA cycle is complete, the list controller switches control of the I^3 address bus back to the PC, and increments the frame list's address counter so that it points to the next element in the list for the

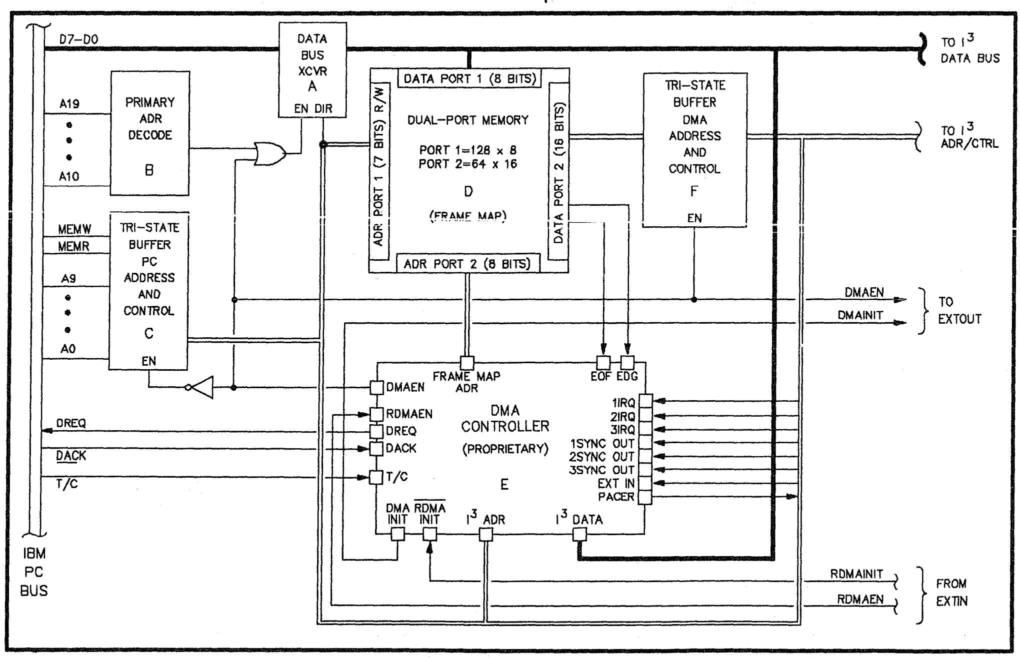

FIGURE 5. DMA System Block Diagram.

next transfer. If the End of Frame flag is set, then the address counter is reset at the end of the transfer so that the list controller is again pointing to the first list element for the next transfer.

The list controller is started by a transaction request signal (XREQ). This signal can come from a variety of places in the system. Each time the XREQ signal is received by the list controller, it will issue one DREQ to the PC and complete the ensuing DMA cycle for each element in the list. So, the transfer of one entire frame of data becomes one indivisible event to the system.

The net result of this scheme is that the list of elements to be transferred by the DMA sequence can be any length up to 64 items, and the addresses of those items can be totally random —they don't have to be sequential at all. The PC believes it is doing normal device-to-memory DMA, and the I^3 bus devices believe they are doing normal programmed transfers. Only the Carrier's DMA controller, E in Figure 5, really knows what is going on.

START/STOP

The system also solves one other problem which is normally encountered in DMA-driven data acquisition. In most data processing applications, the DMA transfer process can be started and stopped by software. If, for example, the computer is transferring one sector buffer from a disk drive to memory, it can totally control the timing of the process. It can start when the computer tells it to, and stop when the data is transferred. In a data acquisition system, this is not always the case.

Data acquisition events tend not to be as well-behaved as disk-drive transfers are. They occur asynchronously and the computer has to react to them quickly. Suppose, for example, that it's wanted to monitor a strain gage attached to a steel rod. The steel rod is to be flexed, and one is interested in the strains occurring just before the rod breaks. Obviously, one must acquire data at high speed both before, during, and after breakage. The only problem is that the exact moment of breakage can't be accurately predicted, so it's difficult to know when to start taking data. If one starts too soon, memory fills up before the event of interest occurs. If one waits too long, he misses the "pre-trigger" data.

This problem is easily solved by specialized start/stop hardware on the Carrier —items J, K, L and M on Figure 6. The Carrier's control circuitry supports four different methods of starting and stopping DMA. They are:

Mode 1: Start on trigger event after delay, stop on software command.

Mode 2: Start on software command, stop on terminal count.

Mode 3: Start on software command, stop on trigger event after delay.

Mode 4: Start on software command, stop on software command.

Mode 2 is the one used for most data processing applications. The other modes are useful only for data acquisition. Mode 2 is typically the only mode employed in the IBM PC. In data acquisition, it is useful for capturing a block of

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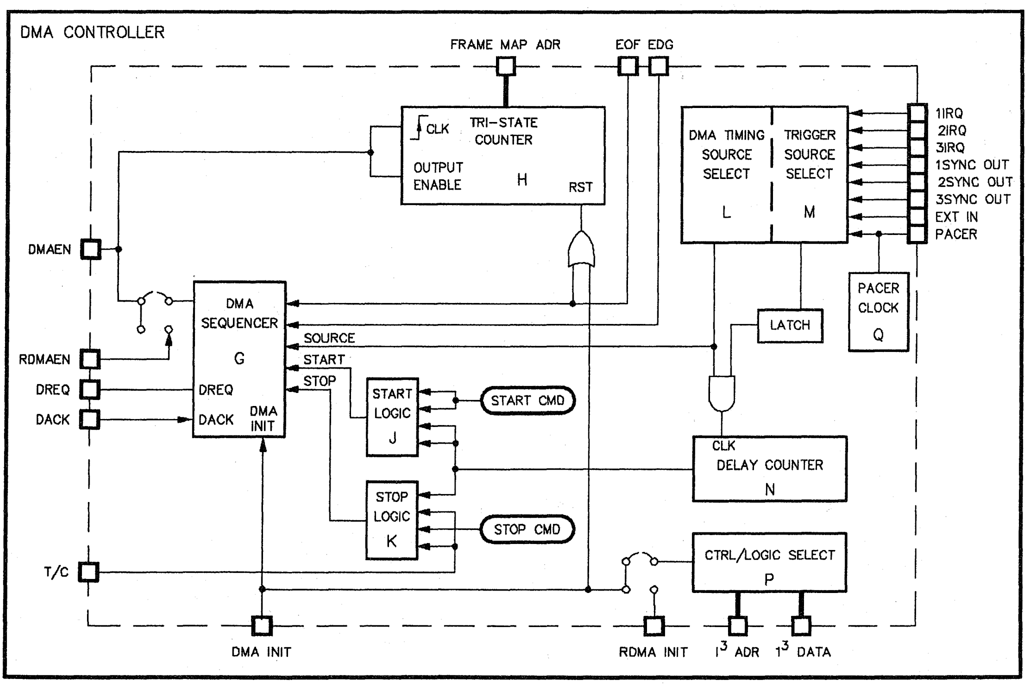

FIGURE 6. DMA Controller Block Diagram.

data at a regular rate from a repetitive signal to be used for digital signal processing, for example. In this case, it is not important for the acquisition to be synchronized to anything.

Modes 1 and 4 are most useful for DMA output. They both involve the use of a circular buffer. In both cases, when the DMA controller has transferred all the bytes in the DMA buffer, it resets its pointers and starts over again. Using either Mode 1 or Mode 4, then, one could build an analog waveform in memory, and then continuously output it through a D/A converter module to develop an arbitrary waveform.

Mode 3 is the most useful for most data acquisition applications, and is the one best used to solve the problem above. Using a circular buffer, Mode 3 provides both pre-trigger and post-trigger information — just right for this application.

There are two significant types of events implied by the four DMA modes above. The first is the trigger event.

This is the event which starts or stops the whole series of DMA transactions which comprise a data acquisition "run". The second is the timing source event. This is the source of the XREQ signal which causes each individual frame to be transmitted.

Both of these two signals can come independently from any one of eight sources in the system under software control. The sources are:

- The Syncout signal of any of the three Modules.
- The IRQ0 signal of any of the three Modules.
- The on-board pacer clock.
- The External Syncout from another Carrier.

Here's how to solve the problem of the breaking bar:

First, the modules required are the PCI-20019M High Speed A/D Module, and the PCI-20020M Trigger Alarm Module. Also, the PCI- 20046S and PCI-20047S software packages will ease the software burden.

It is assumed that the strain gage signal is externally conditioned to a voltage between at least ±2.5V. This can be done with the PCI-20044T Active Signal Conditioner, for example. The output of the strain gage amplifier is connected to the inputs of both the A/D and the Trigger/Alarm.

The PCI-20046/47S allows control of the system by using simple calls from high-level language programs —BASIC, Turbo Pascal, C, or ASYST.

Using PCI-20046-47S, the Trigger/Alarm is programmed to trigger when the strain exceeds a threshold. Presumably, when the rod breaks, the strain gage voltage will suddenly increase. The internal pacer clock is programmed for the desired sample rate — say 80kHz. With jumper selections, this also becomes the start convert signal for the PCI-20019M.

Using PCI-20047S, we will set up the DMA transfer. The IRQ0 output of the A/D indicates that a conversion is complete, so it could be used for the timing source event for frame transfers. The IRQ0 output of the Trigger/Alarm module is selected as the trigger event. Also, we will select Mode 3 to give both pre- and post-trigger data. Finally, we need to program the system to monitor the appropriate A/D channel. All of these selections are made through the "Configure DMA" (CNF.DMA) call of PCI-20047S. It handles setting up all of the hardware on the Carrier, programming the frame map, and programming the PC's DMA controller.

DMA.RUN call will set the number of frames to be acquired, and the trigger delay in frames. This call handles programming the PC's DMA controller for the proper operation, and actually begins the DMA transfer. For our example, we will acquire 10,000 frames, and set the delay to 1000 frames. Thus, our total buffer will consist of 10,000 A/D readings, and the last 1000 will be post-trigger data. After executing this call, data is being acquired by DMA at 80K samples per second.

The machine which bends the rod can now be started, and the data acquisition occurs automatically, filling up the PC's buffer in a circular fashion. When the rod finally breaks, the Trigger/Alarm module will issue the trigger event signal. The delay counter will then count 1000 more A/D samples, and stop the DMA process. The data in the buffer now represents 9000 samples of pre-trigger data, and 1000 samples of post-trigger data.

Suppose one would like to put a turns counter on the lead screw of the bending machine so that he could correlate screw position with strain. The modifications required to accomplish this are quite simple.

First, add an incremental shaft encoder to output TTL pulses with the turning of the lead screw. Next, add a PCI-20007M-1 Counter/Timer Module to the system. Then, connect the output of the shaft encoder to the clock input of one of the counters on the PCI-20007M-1. The counters on this module are 16-bit counters, so each requires two memory bytes.

Code to initialize the counters must be added to the setup program. The channel number of the counter used is added to the CNF.DMA call. This call will double the PC DMA controller's byte count to account for the two extra bytes of the counter, and extend the size of each from from two to four bytes.

Now, after the data acquisition run, the first two bytes in each frame are the two bytes from the A/D converter, and the last two are the two bytes of the counter. The first 9000 frames are still pre-trigger data, and the last 1000 frames are post-trigger data.

This technique represents a quantum leap in power and flexibility for personal-computer-driven data acquisition. It provides answers to most of the standard data acquisition problems — precise timing; mixed data types; accurate, event-driven starting and stopping; and pre- and post-trigger data capture capability.

Section 4
Data Conversion Principles

As discussed earlier, digital computers, powerful as they are, speak a very limited "language." Most real-world signals are not in a format (for example: amplitude, level, timing) that can be directly accepted by the computer. It is the data acquisition system that performs the translation function. Internal to the data acquisition unit, there are a variety of data acquisition components that facilitate the translation operations. These include: analog-to-digital (A/D) converters, multiplexers, sample/holds, amplifiers, counter/timers and some more specialized functions.

Perhaps the most important feature of a data acquisition product is that it brings together these sophisticated functions in a compatible, integrated system. Given the companion software that is available, the user can take advantage of the latest technology without being intimately familiar with the internal details. When selecting a system, however, it is useful to have a basic understanding of data acquisition principles.

Analog Input Systems

The fundamental function of an analog input system is to convert the analog signals into a corresponding digital format. It is the "analog-to-Digital Converter" (A/D) that transforms the original analog information into computer-readable data (digital, binary code). In addition to the A/D, several other components may be required to obtain optimum performance. These can include: an amplifier, a sample/hold, a multiplexer and signal conditioning elements.

Analog-to-Digital Converters - A significant number of different types of A/D converters exists today. Among these, a few stand out as the most widely used: successive approximation, integrating and parallel (flash) converters. While flash converters are the fastest, they are also the most expensive. Complexity generally limits these devices to low-resolution (8 bits or less) applications. Most data acquisition tasks usually require a minimum of 12-bit resolution. It is predictable that higher resolution converters are not only more expensive but they are usually slower. Therefore, it makes sense to carefully consider the requirements before making a "resolution" decision.

A good starting point is the input sensor or transducer. Some sensors have very wide dynamic ranges. Dynamic range is the span, or difference, between the maximum full scale signal level and the lowest detectable signal. There is not necessarily a good correlation between sensor accuracy and dynamic range. For example, a 0.5% accurate transducer can have a dynamic range of more than 80dB. This requires a system with at least 12-bit resolution. To maintain maximum dynamic range, some applications may require 14- to 16-bit resolution. Amplifying a low-level signal by 10 or 100 increases the effective resolution by more than 3 and 6 bits respectively. Starting with a 12-bit converter this results in 15 to 18 bits of dynamic range. A related technique is described in Section 9, under "Getting Increased Resolution From A 12-bit A/D Converter".

A 12-bit system provides a resolution of one part in 4096 (2^{12}) or approximately 0.025% of full scale. 16 bits corresponds to one part in 65536 (2}16) or approximately 0.0015% of full scale. Therefore, resolution not only determines dynamic range but it also limits overall system accuracy. On the other hand, increasing a system's resolution cannot benefit its accuracy if other components such as the amplifier or sample/hold are the limiting factor.

When an input signal change is smaller than the system's minimum resolution, then that "event" will go undetected. For instance, when using a 12-bit A/D converter (without any preamplification), any signal change that does not exceed 2.44 millivolts on the 10 volt range will not be "seen" by the data acquisition system. In contrast, if the signal is first amplified by 1000 before conversion, the resolution could be increased to 2.44 **microvolts** (in the absence of noise).

For speeds above 100 samples/second the successive approximation converter is most popular. In fact, speeds above 100K samples/second are attainable. Binary weighted "guesses" are compared to the actual input signal until a match is achieved. It is essential that the input signal remain constant during the course of the successive comparisons or very significant errors can result. This requires the use of a sample/hold circuit, as described below.

When high speed is not required, an "integrating" A/D converter can give 12-, 14- or even 16-bit resolution at low cost. Sampling speed is typically on the order of 3 to 50 conversions per second. As the name implies, this converter averages any input signal variations during the conversion cycle. This feature inherently filters input noise. Linearity and overall accuracy are generally better than in the other A/D converters.

Accuracy is an important measure of an analog input system. It defines the total error in any particular reading. For example, a data acquisition system specified as accurate to 0.05% of full scale on the 10 volt range, would exhibit a worst-case error of 5 millivolts (10V * 0.0005). If the system is specified as 0.1% accurate on the +/-10 millivolt range (for example the A/D on the +/-10V range and the PGA in a gain of 1K) the system would exhibit a worst-case error of 20 microvolts referred to the input (20mV * 0.001). In assessing the value of a data acquisition system, the accuracy specification requires careful scrutiny. Be sure the accuracy is specified for the input range of interest.

Amplifiers - Analog input signals can vary in amplitude over a very wide range. The A/D converter, however, requires a "high-level" signal in order to perform at its best. In many systems an amplifier is provided to boost possible "low-level" signals to the desired amplitude. Ideally, the input amplifier will have several gain choices available, all under software control. This device is usually called a programmable gain amplifier (PGA). However, cost and performance trade-offs sometimes dictate that the gain of the amplifier should be "manually" adjusted. Manual adjustment refers to the selection of a resistor or a jumper.

A simple analog input stage is shown in Figure 4.1. Remember, the amplifier shown in this diagram may not be required in every application. As shown, this circuit can accommodate only one input channel. One way of measuring

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several channels would be to duplicate the A/D converter and amplifier for each input signal. However, there is a less expensive way described below.

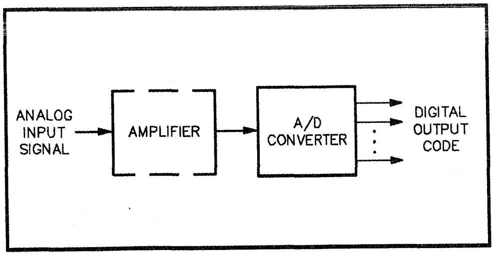

FIGURE 4.1. An Analog Input Channel

Multiplexers - The multiplexer (Mux) shown in Figure 4.2 is simply a switch arrangement that allows many input channels to be serviced by one amplifier and A/D. Software can control these switches to select any one channel for processing at a given time. This approach offers considerable cost savings over separate amplifiers and A/Ds. Since the amplifier and A/D are being shared, the speed of analog acquisition will be reduced. To a first approximation, the rated "speed" of the amplifier and A/D will be divided by the number of input channels serviced. "Throughput" is often defined as the "single-channel speed" multiplied by the number of channels.

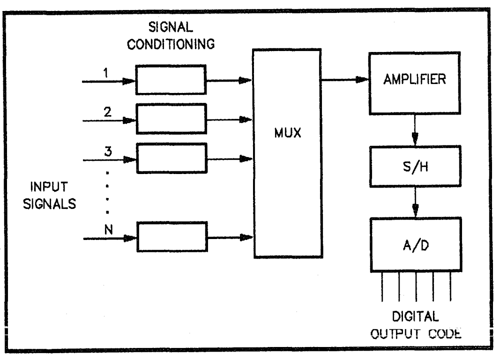

FIGURE 4.2. A Complete Analog Input Subsystem.

Sample/Hold - In general, an analog input signal can be changing with time. That is, the input could be an AC signal whose amplitude varies continuously. Successive approximation A/D converters require that the input amplitude not change during the conversion cycle. The function of the Sample/Hold (S/H) is to "grab" the present value of the signal just before the beginning of an A/D conversion. This level is held constant, despite a changing input, until the A/D conversion is complete. This feature allows the accurate conversion of high-frequency signals.

Time Multiplexing - The system described in Figure 4.2 shares the amplifier, S/H and A/D converter between the various input channels. The user selects the desired sample rate to fit the given application. If each channel is to be read "R" times per second, then the Mux must scan at "n" times this rate (where "n" is the number of channels to be read). Clearly, the S/H and A/D must be fast enough to allow a complete conversion in less than 1/(R · n) seconds.

We must be careful not to be misled by the speed specifications of the individual components in the system. "Conversion time" defines only the speed of the A/D converter, which is only part of the total time required to measure a given channel. In order to understand the true speed of a system we must know either the "per channel sample rate" or "throughput rate", and the conditions under which it was specified (for example, throughput is a strong function of the amplifier gain).

Ideally, all of the input channels will be read at the same time, every I/R seconds. However, time multiplexing inherently generates a "skew" or time difference between each channel's reading. If the Mux, S/H and A/D combinations are "fast enough", then it may appear that the channels are being read at the "same" instant. Some applications are very sensitive to time skew, such as the measurement of instantaneous electrical power (I · V), or relative position of mechanical components. Given the fastest A/D converters available, there are still many applications that cannot tolerate the time difference between readings resulting from sequential readings. In critical applications the technique of "Simultaneous Sample & Hold" can further reduce time skew by a factor of 100 to 1000 times.

The simultaneous sample/hold architecture is ideal for applications in which the phase and time relationships of multiple input channels are critical to the given investigation. For example, if the system in Figure 4.2 were sequentially scanning four analog inputs at a throughput of 89K samples/second, the time elapsing between conversions would be 11.25 microseconds. About 45 microseconds will be required to digitize all four channels. This represents a 162-degree phase shift between the first and fourth channel at a 10kHz signal frequency (45us/100us · 360 deg). In contrast, the simultaneous sample/hold system in Figure 4.3 can capture all four channels within about 10 nanoseconds of each other, representing a phase shift of less than 0.04 degrees at 10kHz.

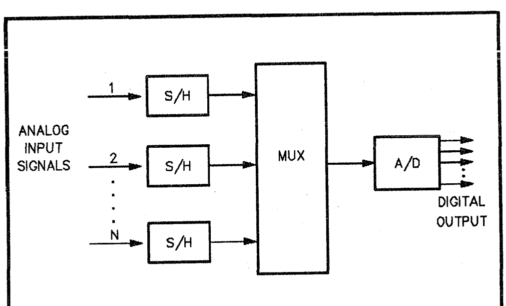

FIGURE 4.3. Simultaneous Sample & Hold Systems.

In addition to phase and time relationships, this technique is particularly useful for applications in which cross-correlation functions must be calculated. Prime examples include: speech research, materials and structural dynamics testing, three-phase electrical power measurements, geophysical signal analysis, and automatic test equipment (ATE) on production lines.

Signal Conditioning - Even with the high-quality components mentioned above, it may be desirable to preprocess the input signals. This task is called signal conditioning, and is often divided into two categories. "Active" signal conditioning can include amplification and isolation, while "passive" signal conditioning includes voltage division, surge suppression, current-to-voltage conversion and filtering.

The maximum signal amplitude that can be applied to an amplifier or A/D converter is usually +/-10 volts. Resistive dividers can be used to scale virtually any voltage level down to this acceptable range. Thus, monitoring 48 volts or 480 volts is entirely practical. It is important to consider that the multiplexer and other electronic components can be permanently damaged if signals above 15 volts make direct connection to these devices. The addition of clamping devices such as zeners or MOVs to the signal conditioning network can insure protection against possible input faults or surges.

It is sometimes desirable to preamplify low-level signals (1mV to 1V) outside the main DA&C enclosure to maintain maximum signal-to-noise ratio. One form of this kind of signal conditioning is the "two-wire transmitter." Transmitters not only amplify the input signal but can also provide isolation, linearization, cold- junction compensation and conversion to a high-level current (typically 4 to 20 milliamps). Current transmission allows signals to be sent up to several thousand feet (1500 meters) without significant loss of accuracy. While voltage signals are rapidly attenuated by the resistance of the connecting wires, current signals are not. In a current loop, the voltage drop due to wire resistance is compensated for by the compliance of the current source. That is, the voltage across the current source automatically adjusts to maintain the desired current level.

When signals are represented by currents, it is a simple matter to convert them to voltage signals with a resistor. Values of 250 to 500 ohms are most common (producing 5 to 10 volt signals, for 4 to 20mA currents).

Of all the signal conditioning categories, filtering is the most widely needed, most widely used and most widely misunderstood. Simply stated, filtering is used to separate desired signals from undesired signals. Undesired signals include: noise, AC line frequency pick-up, radio/TV station interference, and signal frequencies above 1/2 the sampling frequency. Generally, a low- pass filter is employed to control these unwanted sources of error, by excluding the portion of the frequency spectrum where desired signals to not exist. When input signal frequency components above 1/2 the sampling frequency are allowed at the input to the A/D converter, a phenomenon known as "aliasing" occurs. This results in the generation of spurious signals within the frequency range of interest that can not be distinguished from real information. Hence, serious errors in the interpretation of the data can occur. This discussion of signal conditioning is intended only to suggest the need for this type of consideration. More detail will be offered in Section 8 on "Signal Conditioning."

Single-Ended vs Differential Signals - Analog signals can be configured as either single-ended or differential inputs. Single-ended inputs all share a common return or ground line. Only the "high" ends of the signals are connected through the multiplexer to the amplifier. The "low" ends of the signals return to the amplifier through the system ground connections. That is, both the signal source and the input to the amplifier are referenced to ground. This arrangement works fine as long as the ground potential difference is very small. Problems arise when there is a large difference in ground potentials. This causes extraneous currents to flow (a "ground loop") which can generate errors. The main advantage of single-ended inputs is the low per-channel cost. Only one multiplexer switch is required to handle each input channel.

A differential arrangement allows both the non-inverting (+) and the inverting (-) inputs of the amplifier to make connections to both ends of the actual signal source. In this way, any ground-loop induced voltage appears as a common-mode signal and is rejected by the differential properties of the amplifier. While differential connections can greatly reduce the effects of ground loops, they require two multiplexer switches per channel. Thus a 32-channel, single-ended system can handle only 16 differential inputs. In addition, while a simple op-amp can be used for single-ended inputs, an instrumentation type amplifier is required for differential inputs.

In some applications the so-called "pseudo-differential" connection can be employed. This is actually a single-ended connection in which one of the inputs is connected to the common ground return point of the input signals. Thus, this channel measures the ground-loop induced voltage which can then be corrected for in the software. This technique is useful when all of the input signals are referenced to the same ground potential.

Instrumentation Amplifiers (IA) - As suggested above, the instrumentation amplifier is a differential input gain block that presents a very high impedance at both the + and - input terminals. The common-mode rejection characteristics attenuate the effects of ground loops, AC power line pick-up and noise- induced error signals. Thus, the IA is especially useful for measuring low-level signals. When the IA has software- programmable gain, it is known as a PGIA (programmable gain instrumentation amplifier). Because virtually all programmable gain amplifiers in DA&C systems are IAs, we simply refer to PGIAs as PGAs.

Ideally the input impedance, common-mode rejection and bandwidth amplifiers would be infinite. In addition, input current and offset voltage would be zero. This implies that the measuring circuit does not influence the signal source. However, real amplifiers do have finite input impedance and input current characteristics as well as offset voltage (Vos). Offset voltage refers to the amplifier's output voltage when zero input is applied (inputs are shorted). Actually, Vos is the input voltage that must be applied to the +/- input of the amplifier to make the output voltage zero. Offset voltage is due to small mismatches in the characteristics of components in the amplifier's input stages. While most amplifiers have provisions for trimming the offset to zero, this is not done without sacrificing other parameters. For example, trimming Vos often generates an additional amount of offset drift (Vos change with temperature) and other non-ideal effects. Vos can be compensated for in the software. The PCI-20000 has built-in provisions for offset correction.

In most cases it is the input current that is potentially most troublesome. Two terms are used to describe input current: bias current (Ib) and offset current (Ios). Bias current refers to the current flowing into (or out of) either the + or the - terminal of the amplifier. Offset current is the difference between the + and - bias currents. In principle, the distinction is important because Ios can be much smaller than Ib. These non- ideal currents interact with the signal source impedance to produce an additional offset voltage term. When the source impedance is balanced, that is, equal at both + and - inputs, it is only Ios that generates an error.

It is essential that an external conductive path exists between the input terminals of the amplifier and its power supply ground. In addition, the resistance of this path must be small enough so that the resulting offset voltage (Ib * Rs) does not interfere with the amplifier's performance. In the extreme case where the inputs are left floating (no external return resistance), the amplifier is likely to reside in a nonlinear or otherwise unusable state. As a general rule, single-ended inputs do not require attention to the bias current return resistance. This is because one side of the input is directly connected to ground and the other input has a return path through the signal source. In contrast, differential connections almost always require the user to provide an external return resistance path. Normally the DA&C system's "termination panels" have provisions for these resistors. Typically, values of 100K or 1 Megohm are used.

Analog Outputs

In many applications analog output signals are required. These signals are used to drive chart recorders, to provide feedback in closed-loop control and to initiate a variety of other tasks. Common analog output ranges include ±5V, ±10V, 0-10V and 4-20mA.

When operating in the voltage output mode, most D/A converters can supply up to 5 or 10mA of load current. However, some multiple output systems have ratings as low as 1mA. This is not usually a limitation, because the majority of these applications call for driving high impedances. When large loads such as positioners, valves, lamps and motors are to be controlled, power amplifiers or current boosters are required. Most DA&C systems do not include high power analog drivers within the standard configuration.

Digital Inputs and Outputs

Most data acquisition systems are able to accept and generate TTL level signals (0 to 5 volts). However, applications often require an interface for other discrete voltage levels. Higher voltage and current outputs are also required to control devices such as solenoids, motors and relays.

A number of standard signal termination panels is available to facilitate the connection of the field wires to the DA&C system. These termination panels have provisions for screw terminal connections, signal conditioning, channel status indicators (LEDs), voltage dividers and isolators. Thus, the monitoring and control of high DC levels, along with AC line voltage circuits, are readily accomplished.

These features will be described in more detail in the Signal Conditioning Section of this handbook.

Pulse and Frequency Inputs and Outputs - A variety of counting, timing and frequency measuring applications exists. Other applications require that devices be turned on and off for precise time periods. All of these functions can be provided by "counter/timer" (C/T) circuits. The system's counter/timers are optimized for pulse applications including frequency measurement and time-base generation. Counters are characterized by the number of input events that can be accumulated and by their maximum input frequency. Most systems employ 16-bit counters that can accumulate pulses at frequencies up to 8 megahertz. Up to 65536 (2^{16}) events can be accumulated before the counter overflows. The counters are all independent of each other and can be used to count events, measure frequency or act as frequency dividers. The pulse generators (rate generators) are software programmable over a very wide range of frequencies and duty cycles. A rate generator is often used to provide the precise time base required for accurate data acquisition.

The digital counters available in most DA&C systems accept TTL level signals and can be used to accumulate the number of input pulses. Counting can be started from a defined initial value and the counter can be configured to automatically reset to this value after it has been read. Internally, the counter actually decrements or subtracts a count for each input pulse. However, software can easily interpret the counter's data as a sum or difference from an arbitrary starting point. When a 16-bit counter exceeds 65535 or the initial count value (whichever is smaller) an overflow occurs generating a digital output. This signal can be used to activate external events. Of great significance is that the next input pulses simply cause the counter to decrement from 65535. Thus, if overflows are detected and accounted for, total counts of any size can be accumulated in the software.

Frequency measurements using counters can be accomplished in different ways depending upon the application. When the unknown frequency is a TTL signal, it can be applied directly to the counter circuit. Analog signals with an amplitude of at least 100mV can be converted to TTL levels with the PCI-20000's Trigger/Alarm module (PCI-20020M-1). Voltage dividers using resistors and/or zener diodes or opto-isolators can be used to scale down high-level signals. When using any kind of signal conditioning before the counter input, consideration should be given to possible resulting speed limitations.

Two distinct options exist for measuring high or low frequencies. The first method counts a known clock generator for the period of the unknown input signal. This provides high resolution for low- frequency signals, while minimizing the time required for the measurement. Generally this is used for frequencies below 10Hz. The second method counts cycles of the unknown input signal for a fixed time interval. The advantage of this technique is that it allows measurements beyond 8MHz. It is easy to implement an auto-ranging algorithm that optimizes resolution over a very wide frequency range.

Section 5
Software Techniques

Section 3 briefly discussed the role of DOS and other Operating Systems. Everyone knows that a computer is made to perform a useful task by "programming" it with a series of instructions. At the chip level, the system can respond only to the most primitive digital commands: an input is High or Low (On or Off, I or O). Semiconductor circuits do not understand "Add", "Multiply", "Read" or "Print". They can understand that a given voltage is, or is not, present at an input. So ultimately, all communication with a computer is in terms of digital ones and zeros. In the beginning, only this "Machine Language" existed. Programming was slow, error prone (even more so than now!), difficult to maintain, and was approached only by specialists.

The invention of "Compilers" changed everything for the better. A compiler accepts (understands) alphanumeric inputs and translates them into machine-readable code. Sensible combinations of alphanumeric inputs (acronyms or other recognizable words) are defined to be equivalent to a pattern of digital inputs. Thus, the compiler (an intermediate program) provides a more practical human interface. Assembly language is the first step above machine code. An "assembler" is a low-level compiler that converts assembly language into machine code. The resulting code works with DOS and BIOS (defined in Section 3) to further simplify a specific programming task. Be assured that, for most of us, Assembly language is not simple. It is, however, much more manageable than machine code.

What else can be done to improve the situation? Languages such as BASIC can now come into play. These "High-Level" languages perform still more complex operations while presenting an additional degree of recognizable English (still dominated by jargon and special syntax, however). Each of the many high-level languages has been fine-tuned to excel in particular areas. BASIC is best known for the ease with which it can be learned and used. Other languages (C, PASCAL, etc.) are recognized for their execution speed and program maintainability.

As was explained earlier, the use of a high-level language requires that a compiler be used to translate the written program into machine code. So-called "Compiled" languages are converted before run-time and executed in that form (i.e., C and PASCAL). The entire program must be debugged as a whole. "Interpreted" languages are "incrementally compiled (i.e., BASIC). That is, as *each line* of the original code is read, it is then converted and executed. This permits a single program line to be written and tested independently.

One sometimes gets the feeling that the differences between computer languages are smaller than they are made out to be.

Imagine asking an international gathering to select the best, single, spoken language for all to use! Similar disagreements about the "best" computer language also exist.

Software makes the computer-based data acquisition and control system operational. A low-cost, powerful hardware system is of little value without appropriate software.

Personal-computer-based data acquisition systems have been designed so that users have the opportunity to write specialized programs for data acquisition, storage, display, logging, and control in high-level languages. When software is provided with a data acquisition system, it should make these tasks as simple as possible for the user.

Three classes of software are generally available for PC-based DA&C systems: tutorial and program development tools, function subroutine libraries, and complete "turn-key" applications packages. Often the turn-key packages are menu-driven.

Program development tools and function libraries are packages designed to allow users to write their own unique applications software. They usually include "drivers" that provide the interface to the I/O hardware. These packages make it very easy to write programs in high-level languages such as BASIC, C, TURBO PASCAL and ASYST. This type of programming is very flexible and is useful for general purposes.

Complete applications packages are designed to get the system going immediately, usually with no programming required. However, some of these packages offer users the facilities to enhance or modify the software to meet their own needs. Normally, this type of product is directed at a specific type of application. As a result these packages are often quite structured and less flexible than are the other classes of software.

Third-party software is that vast collection of "generic" software products designed by independent companies to serve hardware built by others. Some well-known products include LABTECH Notebook, ONSPEC and LOTUS 1-2-3. These and many other software packages provide data collection, analysis, plotting, and control capabilities. In Section 9 of this handbook are several examples of third-party software being used with PCI products. Section 12 lists additional programs.

Many, if not most, data acquisition and control applications depend upon the timely execution of read/write operations. When speed and/or timing are critical, three techniques for software control should be considered: "polling", "interrupts" and "direct memory access" (DMA).

As would be expected, each has its special merits and requirements. Polling is the simplest method for detecting a unique condition and then taking action. This involves a software loop that contains all of the required measurement, analysis, decision-making algorithms and planned actions. The data acquisition program periodically tests the system's clock or external trigger input to sense a transition. Whenever a transition occurs, the program then samples each of the inputs and stores their values in a "frame". A frame is simply a list that contains the values representing the specified inputs at a given time. The frames can be stored in RAM, disk or other types of memory. Each time the program senses a clock "tick", the inputs are scanned and converted, and a new frame is added to memory. In this mode, the IBM PC can support a data acquisition rate of about 54kHz, while the PC/AT can support about 89kHz. On the other hand, the design of the PC is such that potentially significant variations (or jitter) in timing can occur. In the IBM PC, jitter of approximately 12 microseconds is not uncommon. In addition, the PC is continuously busy when the polling loop is operational, and hence no other tasks can be serviced. When an application can not tolerate these characteristics, interrupt techniques may be indicated.

Interrupts do provide a means of tightly controlling the timing of events, while allowing the processing of more than one task. Multitasking systems are also known as "foreground/background" systems. One way of putting data acquisition in the background is to relegate it to an interrupt routine. The clock or external timing signal, rather than being polled continuously, is used to generate an interrupt to the computer. Whenever the interrupt occurs, the computer suspends current activity and executes an "interrupt service routine". The interrupt service routine in this case might be a short program which acquires one frame of data, and stores it in memory. The computer can perform other operations in the foreground while collecting data in the background. Whenever a clock tick or external interrupt occurs, the computer will automatically stop the foreground processing, acquire the data, and then resume where it left off.

The reaction speed of the interrupt system is much slower than that of a well-written polling loop. This results because the interrupt mechanism in most computers involves a significant amount of software overhead. Speed, for an IBM PC, is about 4kHz in the interrupt mode. Also, the software complexity of interrupts can be significant. In most cases the programmer must be prepared to write a substantial amount of assembly language code. In contrast, most polled systems can be written in a high- level language. Interrupts are useful in situations where the acquisition rate is slow, timing accuracy is not a priority, and background operation is important. When the amount of time required to service an interrupt is small, compared to the rate at which the interrupts can occur, then this technique yields excellent results. These factors should make it clear that careful thought is warranted before making a polling/interrupt question.

DMA is the hardware/software technique that allows the highest speed transfer of data, to or from random access memory (RAM). Given the potentially more expensive hardware, DMA can provide the means to read or write data at precise times without restricting the microprocessor's tasks. For example, the PCI-20000 system, under DMA control, can read or write any combination of analog, digital or counter/timer data to or from RAM at 360K bytes/second. This is accomplished by taking minimal time from the other tasks of the microprocessor. The amount of time required to respond to a DMA request is very small compared to the time required to service an interrupt. This makes the goal of foreground/background operation, at high speed, possible. For additional information about DMA, please refer to Section 3 of this handbook.

Section 6
Field Signals and Transducers

A good DA&C system does everything practical to simplify the handling of a wide variety of field signals. However, it is helpful for the user to have a basic knowledge of the types of signals that the system may be called upon to read or generate. This section reviews what the most common signals consist of, and shows how the DA&C system deals with them.

Transducers - Whatever the phenomena detected or the device controlled, "transducers" play a vital role in the DA&C system. It is the transducer that makes the transition between the physical and the electrical world. Remember that data acquisition and control can involve both input and output signals. Input signals can represent force, temperature, flow, displacement, count, speed, level, pH, light intensity, etc.. Output signals can control valves, relays, lamps, horns, motors, etc.. The electrical equivalents produced by input transducers are most commonly in the form of voltage, current, charge, resistance or capacitance. As shown later, the process of "Signal Conditioning" will further convert these basic signals into voltage signals. This is important because the major interior blocks of the DA&C system can only deal with voltage signals.

Signal Types - It is necessary to further define three types of voltage signals: analog, digital and pulse. While all signals are assumed to be changing with time, analog signals are the only ones to have information contained in their incremental variations in amplitude. The pulse signals referred to here are similar to the digital signals in many respects. Both digital and pulse signals are of uniform amplitude, and are represented by only two possible values (high and low). Typically, these high and low levels are approximately 5 and 0 volts respectively (TTL levels). The actual allowable ranges for TTL signals are:

low level = 0V to 0.8V
high level = 2.0V to 5.0V

However, other levels including 110 or 220 VAC (line voltage) can be accommodated.

So, with analog it is important "how" high the signal is, while with digital it matters only "if" the signal is high or low (on or off, true or false). The distinction between digital and pulse signals lies in the information conveyed and the type of data acquisition hardware utilized. Digital signals are sometimes called "discrete" signals. A given digital "bit" is one channel of the DA&C system's digital port. While all digital signals have the potential to be changing states at high speed, information is usually contained in the static state of a bit or group of bits, at a given time. In contrast, pulse information is usually contained in the number of state transitions that have occurred or in the rate at which the state transitions are occurring (pulses/second). Refer to Figure 6.1 for a look at the differences between analog and digital signals.

Analog signals will be transformed into a digital representation (binary number) by the system's analog-to-digital converter (A/D). When analog outputs are required, they will be generated by the system's digital-to-analog converters (D/A). Analog inputs usually come from some type of preamplifier where the primary sensor signal has been conditioned and amplified for presentation to the data acquisition system. Most preconditioned signals are of a relatively high amplitude, in the range of ±1 to ±10 Volts. However, many primary sensors, such as thermocouples, photovoltaic cells, piezoelectric sensors and biomedical sensors produce small signals that may have a full scale range of only 10 millivolts. A quality data acquisition system must handle both high- and low-level signals with equal ease and accuracy.

Thermocouples - The thermocouple (TC) is so common for temperature measurement in industry and science, that it will be given special treatment. Physically, a TC is a junction of two dissimilar metals. This junction produces a thermal EMF proportional to the temperature of the junction (Seebeck effect). Temperatures of -200°C to +4000°C can be measured. The output voltage is usually in the range of -10 to +50 millivolts and has an average sensitivity of 10 to 50 microvolts/°C depending upon the TC used. Many thermocouple types, using different combinations of metal alloys, are in wide use. For convenience, alphabetic letter designations have been given to the most common.

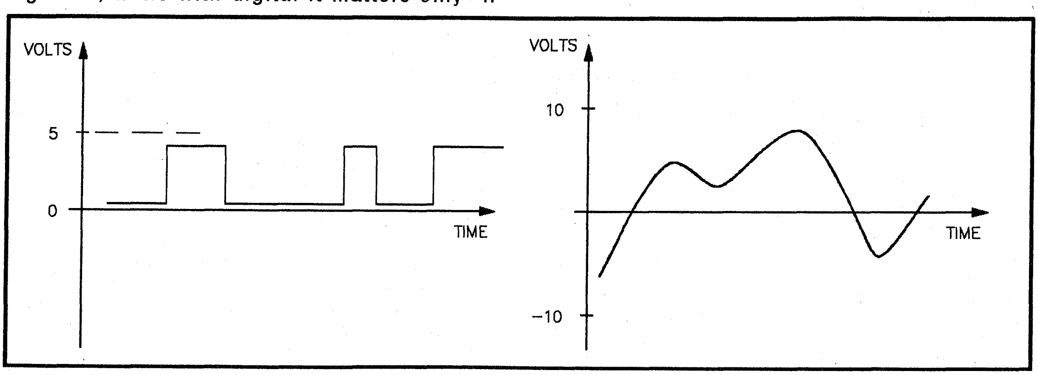

FIGURE 6.1. Digital and Analog Signals.

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These include:

J	Iron	-Constantan	(Fe-C)
K	Chrome	-Alumel	(Ch-Al)
T	Copper	-Constantan	(Cu-C)

Tungsten, rhodium and platinum are also popular metals, particularly at very high temperatures.

While TCs are both low in cost and very rugged, they are not without their limitations and applications problems. Accuracy is generally limited to 1-3% due to material and manufacturing variations. In addition, response time is slow (on the order of several seconds) and both nonlinearity and multiple junction phenomena must be compensated.

The Law of the Junction - A single thermocouple junction generates a voltage proportional to temperature:

Equation 6.1 $V = k\ (t)$,

where "k" is the Seebeck coefficient, defining a particular metal-metal junction and "t" is in degrees Kelvin.

We cannot measure this Seebeck voltage directly. When we connect the TC to a measuring system, the connection leads themselves create a new thermoelectric circuit. As an example, let us connect a voltmeter to a copper-constantan (Type T) thermocouple as in Figure 6.2.

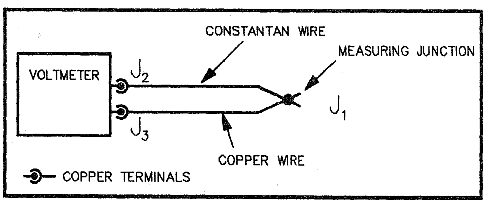

FIGURE 6.2. The Thermocouple Measurement Problem--Extra Junctions.

We would like the voltmeter to read only V_1 (of J_1) but by connecting the voltmeter in an attempt to measure the output of Junction J_1, we have created two more metallic junctions: J_2 and J_3. Since J_3 is a copper-to-copper junction, it creates no thermal EMF ($V_3=0$) but J_2 is a copper-to-constantan junction which will add an EMF (V_2) in opposition to V_1. As a result the voltmeter reading, V_v, will be proportional to the temperature difference between J_1 and J_2. This means that we can't find the temperature at J_1 unless we first know the temperature at J_2.

One way to establish the temperature of J_2 is to physically put the junction into an ice bath, forcing its temperature to 0°C. This defines J_2 as a Reference Junction (t_2 - t_{ref}), and therefore:

Equation 6.2 $V_v = (V_1 - V_{ref}) = k\ (t_1 - t_{ref})$

Note that even under these conditions (see Equation 6.1), V_{ref} is not 0 volts. The Seebeck relationship is based upon the Kelvin (absolute zero) scale. It is also important to remember that k is highly nonlinear with respect to temperature. However, we are fortunate that tables have been compiled that yield not only V_{ref} at any temperature, but more directly, V_v when t_{ref} is 0°C. These tables take variations in k into account and can provide t_1 directly in terms of V_v, assuming that t_{ref} is at 0°C. Note that both the measuring and reference junctions are both Cu-C.

As we have seen on this example. a copper-constantan TC is a special case because the copper wire is the same metal as the voltmeter terminals. It is interesting to look at a more general example using iron-constantan (Type J). The iron wire increases the number of dissimilar metal junctions in the circuit, as J_3 becomes a Cu-Fe thermocouple junction. However, it can be shown that if the Cu-Fe and the Cu-C junctions (at the termination panel) are at the same temperature, the resulting EMF is equivalent to a single Fe-C junction. This allows us to again use Equation 6.2, noting that both the measuring and reference junctions are of the same materials (Fe-C, in this case). Again, it is very important that both "parasitic" junctions be held at the same reference temperature. This can be aided by making all connections on an isothermal (same temperature) block.

Clearly, the requirement of an ice bath is undesirable for many practical reasons. Taking our analysis to the next logical step, we are reminded that Equation 6.2 does not require that t_{ref} be at any special temperature. It is only required that the reference temperature be accurately known. If we can measure the temperature of the isothermal block (the reference junction) independently, we can use this information to compute the unknown temperature, t_1.

Devices like thermistors, RTDs, and semiconductor sensors provide us with a way to measure the absolute temperature of the reference junction. Therefore, under computer control, we simply:

1) Measure t_{ref} and compute the equivalent TC voltages for the parasitic junctions (V_{ref}).

2) Measure V_v and subtract V_{ref} to find V_1.

3) Convert V_1 to the desired temperature t_1.

This procedure is known as software "cold-junction" compensation, because it relies upon the computer to account for the effects of the reference junction.

If we already have a device that measures absolute temperature (such as RTDs, thermistors and IC sensors), why do we bother with a thermocouple that requires cold-junction compensation? First, thermocouples can be used over a very wide range of temperatures, while the other devices are useful over a more limited range. Secondly, they are much more rugged than the competitive devices, as evidenced by the fact that thermocouples are often welded into a metal part or clamped under a screw. Thirdly, they can be constructed in the desired lengths in the field, either by soldering or welding. In short, thermocouples are the lowest cost, most versatile temperature transducer available. Since the DA&C system can perform the entire task of cold-junction compensation and voltage-to-temperature conversion, using a thermocouple becomes as easy as connecting a pair of wires.

When selecting a thermocouple, the following factors should be taken into account:

Type J **Lowest cost**, Highest sensitivity, Moderate accuracy. Should not be used above 760°C because of severe decalibration.

Type K Moderate cost, Moderate sensitivity, Low accuracy, **High temperature range**. Can be used to 1372°C due to is high resistance to oxidation.

Type T Moderate cost, Moderate sensitivity, High accuracy. **Very useful at low temperatures**. Because one lead is copper, cold junction compensation is not required when making differential temperature measurements with two back-to-back TCs.

For J, K and T type thermocouples, the "red" colored lead is always the negative terminal.

Thermistors - The thermistor is a metal oxide or semiconductor device that changes resistance with temperature. While positive temperature coefficient devices are available, most units exhibit a negative slope. This temperature coefficient can be as large as several percent per degree Celsius. This makes it possible to resolve smaller changes than with other devices (0.01°C). The accuracy of thermistors is typically 10 times better than than of thermocouples, yielding to ±0.1°C under some conditions. Only the platinum RTD has better accuracy. The physically small size and high nominal resistance are significant advantages. Small size yields a fast response while the high resistance makes any error, due to lead-wire resistance, small.

Along with the high sensitivity goes a high degree of nonlinearity. However, several manufacturers offer devices that have excellent conformance to published tables. While an individual unit exhibits a third-order logarithmic relationship, combinations of positive and negative slope devices can be made to have highly linear relationships. These units can be used from -50 to +100°C. In addition to the limited temperature range, attention must be given to the fragile nature of these devices. Careful mounting and handling must be used to avoid accuracy-destroying stress or catastrophic crushing.

Since it is basically a resistor, a thermistor can be read in several ways. These include current excitation (read a voltage) and voltage excitation (a voltage divider is formed with a fixed resistor). In either case, current must be passed through the measuring device. This will generate internal power dissipation than can produce an error-causing temperature rise. As a general rule, the self-heat error associated with this device can be estimated by dividing the proposed internal power dissipation by 8 milliwatts (yielding rise in °C). This rule applies to small bead thermistors in a conductive environment (like oil or water).

In all cases, excitation levels must be held to a very low level to achieve high accuracy.

Resistance Temperature Detectors (RTDs) - As Thermistors, RTDs exhibit a changing resistance with temperature. Several different metals can be used to produce RTDs, but for a number of reasons, platinum has proven to be the most widely used. One notable exception to this rule is tungsten, which does find applications at very high temperatures. RTDs always have a positive temperature coefficient, with a small nonlinearity. For accurate measurements a third-order polynomial correction should be applied. Many data acquisition systems provide this built-in linearization capability.

Most RTDs are of either wire-wound or metal-film designs. The film design offers faster response time, lower cost and higher resistance values than the wire-wound types. The more massive wire-wound designs are more stable with time. High resistance is desirable because of the potential for lead-wire induced errors. However, even the so-called high resistance units require careful attention to lead-wire effects. Because of the excitation current required to produce a measurable signal, self-heating can also be a factor. However, the dissipation constant of an RTD is about ten times that of a thermistor. In this case, an estimate of the temperature rise (in °C) can be found by dividing the internal power dissipation by 80 milliwatts. Again, this is a general rule that applies to small RTDs in a conductive fluid like oil or water.

Most platinum RTDs are built with 100 or 200 ohm elements. 100 ohm metal-film devices seem to be the most popular. These units have sensitivities of about +0.4 ohms°C. The combination of low sensor resistance and low sensitivity suggests the use of a bridge type of measuring configuration.

Solid State Temperature Sensors - These devices are derived from modern silicon integrated circuit technology, and are often referred to as Si sensors. They consist of electronic circuits that exploit the temperature characteristics of active semiconductor junctions. Versions are available with either current or voltage outputs. In both cases the outputs are directly proportional to temperature. Not only is the output linear but it is of a relatively high level, making the interpretation very easy. The most common type generates 1 microamp per degree Kelvin (298 microamps at 25°C). This can be externally converted to a voltage by using a known resistor. The usable temperature range is -50 to +150°C. The stability and accuracy of these devices are good enough to provide readings within ±0.5°C. It is easy to obtain 0.1°C resolution.

Strain, Pressure, Force, Position, Displacement and Level - These and many other types of transducers are often characterized by their responses to physical movement. Crystal and resistive strain gages, linear voltage displacement transducers (LVDTs), slidewires (resistive potentiometers), and capacitive sensors are among the most common. While each of these sensors is based upon very different principles, the ultimate output signals are ordinary voltages, currents or impedances. These signals are directly or indirectly represented by analog voltage levels. Hence, the techniques described in this handbook can be applied to these types of transducers. Sensors that require external excitation present an accuracy dilemma. Invariably, higher excitation levels yield greater transducer output. However, this also leads to internal power dissipation that can cause errors even in mechanical devices. An optimum excitationlevel exists for each type of device. If additional information about a specific transducer is desired, reference to the manufacturer's data sheet or to one of the available texts is suggested.

Flow, Speed and Count - Flow and speed can be measured in several ways. These include resistive, piezoelectric and thermal techniques. As discussed previously, these methods ultimately generate analog voltage signals. Transducers such as shaft encoders, paddle wheels (turbine), and both optical and magnetic pickups typically have digital or pulse outputs. The desired speed, rate or number of events can be determined by using digital counting or frequency measurement techniques. The methods for acquiring analog, pulse and frequency signals are covered elsewhere in this handbook.

Light Intensity and Chemical Action - These parameters are often encountered in density, spectroscopy and pH measurements. The transducers are characterized as having very high output impedance. The light-activated devices typically are modeled as current sources, while the chemical devices look like voltage sources with high series resistance. In most cases, the raw signals from these types of transducers can not be directly processed by standard DA&C systems. Even the excellent characteristics of the modern PGAs discussed earlier are inadequate in these specialized applications. However, many transducer manufacturers include the necessary preprocessing as an integral part of their product. When they do, the signals are then high-level voltages or currents which can be read as outlined elsewhere in this handbook (Section 4).

Low-level currents are often preprocessed with an FET input op- amp operating as a current-to-voltage converter (transimpedance amplifier). As suggested earlier, all amplifiers have finite input bias currents that can produce errors. FET input amplifiers have bias currents that are often below 1 picoamp (10 to 100 femtoamp units are available), which makes them useful for the majority of practical applications.

High impedance voltage sources are also preamplified with FET input amplifiers. In this case the op-amp is configured as a non-inverting voltage amplifier. This can yield input impedances on the order of 10^{14} ohms, which satisfies most high impedance transducer applications.

Detailed information about selecting and applying FET amplifiers can be found in the Burr-Brown components data book, as well as in several Burr-Brown textbooks and application notes.

Resistance - Resistance signals arrive at the data acquisition system from primary sensors such as strain gages and RTDs. A resistance sensor is usually measured as part of a Wheatstone "bridge" circuit. A bridge is a symmetrical, four-element circuit that enhances the system's ability to detect small changes in the sensor. The sensor can occupy 1, 2 or 4 arms of the bridge, with any remaining arms being filled with fixed resistors. A differential voltage signal is developed across the arms of the bridge when the sensing resistors vary from their nominal values as a result of temperature or strain.

Transducer excitation, as well as provisions for the insertion of bridge-completion components, can be provided on signal "termination panels". While both voltage and current excitation can be used, current excitation is generally more desirable. This is because current excitation provides a more linear output response, making the data interpretation easier. The PCI-20000 system provides adjustable current sources that can be optimized for the type of transducer being measured.

The diagrams below show some of the more common configurations for resistive bridge elements. Bridge-completion resistors should be of very high precision (typically 0.05%). Stability is actually the most important characteristic of the bridge- completion elements. Initial inaccuracies can be calibrated out, but instability always appears as an error. More information about bridge circuits and their transfer functions can be found in the Burr-Brown textbook series.

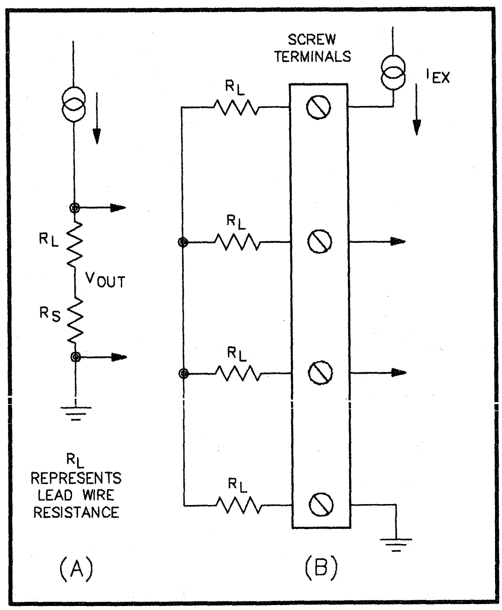

FIGURE 6.3. Measuring a Resistive Device.

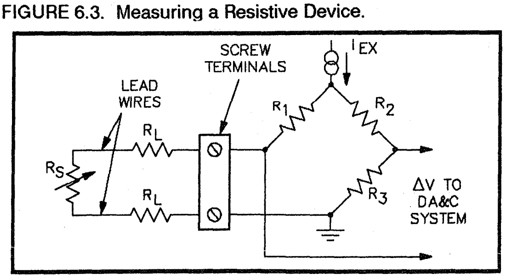

FIGURE 6.4. A Two-Wire Bridge Configuration.

Transducers, such as strain gages and RTDs, have relatively low sensitivity. That is, the change in resistance is small for a given change in the input parameter. Simply measuring the change in voltage (due to a current excitation) across the device is difficult. Not only is the change in voltage small, but it is "riding" on the device's quiescent (I · R) voltage. The quiescent voltage greatly limits the amplification that can be used to amplify the voltage change. Let us explore this concept in more detail. Fundamentally, a DA&C system can measure only voltage. Fortunately, as has been suggested, all other types of signals can be transformed into voltages. To convert a changing resistance, we need only to "excite" it with a current. The voltage across the resistance is then (I · R). Figure 6.3(A) shows the basic idea.

A real application might involve a 100-ohm platinum RTD. To control internal self-heating, the excitation level is usually limited to 2mA. Given that the sensitivity of this type of device is about +0.4 ohms/°C, the output will be about 0.8mV/°C. This is indeed a small signal that will require amplification. It would be useful to multiply the signal by 100 to 1000 times to make best use of the A/D's full-scale range (typically, 5 or 10V). However, the quiescent voltage across the RTD is (2mA · 100 ohms) = .2V. This limits the maximum gain to 10. Thus, in a 12-bit system, the smallest detectable temperature change is about 0.5°C. In contrast, the bridge circuits shown balance out the fixed or quiescent voltage drop, allowing greater magnification of the difference signal. This allows the detection of changes as small as 0.005°C.

The effects of lead-wire resistance should also be considered. The output voltage is proportional to the sum of the RTD resistance and the connecting wire resistance (R_L). In many applications this "wire error" can be very significant. Figure 6.3(B) suggests a solution. This is the so-called Kelvin or four-terminal connection. Wire resistance cannot be eliminated, but this measurement technique greatly reduces the effects. The idea is to connect two wires to each end of the measuring device. One lead carries the excitation current and the other senses the terminal voltage. Current in the sense or measurement lead is very small and can be assumed to be zero. This is because the DA&C system has a very high input impedance. Thus, no voltage drop occurs in the sensing lines. Note that under these conditions the drops in the excitation lines are not in the measurement circuit.

The most common resistive sensors are of the one- and four-element types. Both the two-wire and three-wire bridge configurations are intended to monitor single-element transducers. These are transducers that are represented by a single resistor that is exposed to, or is sensitive to, the measured parameter. In the four-element circuit, all four of the resistors react to the measured parameter. As might be expected, this configuration offers four times the sensitivity of a single-element bridge. In addition, the four-element bridge offers the most linear response.

The two-wire bridge is very simple, but has the potential to be adversely affected by the series resistance of the connecting wires. As can be seen in Figure 6.4, the lead-wire resistance is indistinguishable from the transducer's resistance. Hence, this circuit is not usually employed in precision applications.

While the three-wire bridge requires an additional wire to be run to the sensor, several very important advantages are gained. If we make the reasonable assumption that the two wires bringing current to the sensor are of the same material and length, many of the potential error terms cancel. In Figure 6.5, it can be visualized that one lead resistance is in the top arm of the bridge while the other lead resistance is in the lower arm. The result is that most of the lead-wire effects are cancelled. However, when long leads (generally, over 10 feet) are used or the highest possible precision is desired, software correction of the lead effects can be employed. The resistance of the sense wire is of little significance because the current that flows in this lead is very small. Owing to the lead-wire error cancellation and the available computational power of the PC, this configuration is ideal for most DA&C applications.

Figure 6.6 shows a four-element bridge circuit. Here, the connecting lead wires do not introduce any significant error terms Both of the power supply connecting wires are in series with a current source and hence do not affect the excitation level. A complete bridge does not have any connecting wires in a series with the individual sensing resistors. As suggested above, this circuit has the highest sensitivity, the best linearity, and does not require bridge-completion resistors. Unfortunately, the complex manufacturing process for this type of sensor does result in relatively high cost.

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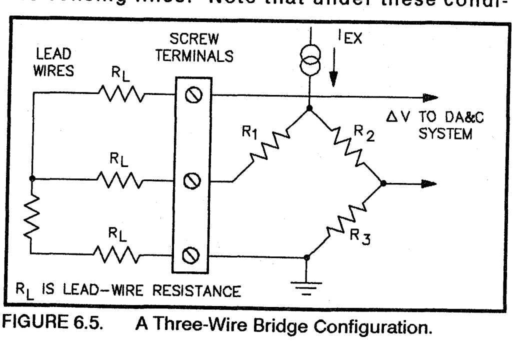

FIGURE 6.5. A Three-Wire Bridge Configuration.

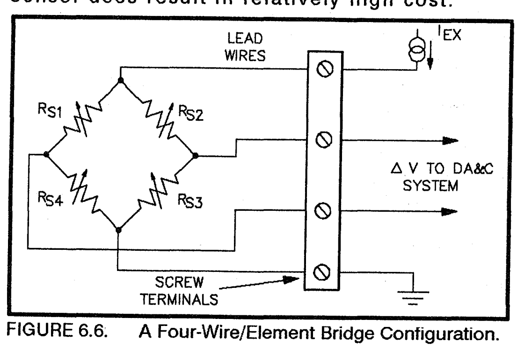

FIGURE 6.6. A Four-Wire/Element Bridge Configuration.

Section 7
Wiring & Noise Considerations

It is a fact that signals entering a data acquisition system will include unwanted noise. Whether this noise is troublesome depends upon the signal-to-noise ratio and the specific application. In general, it is desirable to minimize noise to achieve high accuracy. Digital signals are relatively immune to noise because of their discrete (and high-level) nature. In contrast, analog signals are directly influenced by relatively low-level disturbances. The major noise transfer mechanisms include conductive, inductive (magnetic), and capacitive coupling. For example:

- The switching of high-current loads in nearby wiring can induce noise signals by magnetic coupling (transformer action).
- Signal wires running close to AC power cables can pick up 50/60Hz noise by capacitive coupling.
- Allowing more than one power or signal return path can produce ground loops that inject errors by conduction.

Conduction involves current flow through ohmic paths (direct contact), rather than inductance or capacitance.

Interference via capacitive or magnetic mechanisms usually requires that the disturbing source be close to the affected circuit. At high frequencies, however, radiated emissions (electromagnetic signals) can be propagated over long distances.

In all cases, the noise level induced will depend upon the several factors that can be user influenced.

- Signal source "output impedance" (the input impedance to the data acquisition system).
- Signal source "load impedance" (the input impedance to the data acquisition system).
- Lead-wire; length, shielding and grounding.
- Proximity to noise source(s).
- Signal and noise amplitude.

Transducers that can be modeled by a current source are inherently less sensitive to magnetically induced noise pickup than are voltage-driven devices. An error voltage coupled magnetically into the connecting wires appears in series with the signal source. This has the effect of modulating the voltage across the transducer. However, if the transducer approaches "ideal" current-source characteristics, no significant change in the signal current will result.

When the transducer appears as a voltage source (regardless of impedance), the magnetically induced errors add directly to the signal source without attenuation.

Errors also are caused by capacitive coupling in both current and voltage transducer circuits. With capacitive coupling, a voltage divider is formed by the coupling capacitor and the load impedance. The error signal induced is proportional to $2\pi f \cdot RC$, where R is the load resistor, C is the coupling capacitance and f is the interfering frequency. Clearly, the smaller the capacitance (or frequency), the smaller is the induced error voltage. However, reducing the resistance only improves voltage type transducer circuits.

Example:

> Assume that the interfering signal is a 110V AC, 60Hz power line, the equivalent coupling capacitance is 100pF and the terminating resistance is 250Ω (typical for a 4-20mA current loop). The resulting induced error voltage will be about 1mV, which is less than 1 LSB in a 12-bit, 10V system.
>
> If the load impedance were 100KΩ, as it could be in a voltage input application, the induced error could be much larger. The equivalent R seen by the interfering source depends upon not only the load impedance but also the source impedance and the distributed nature of the connecting wires. Under worst-case conditions, where the wire inductance separates the load and source impedances, the induced error could be as large as 0.4V. This represents about an 8% full- scale error.

Even though current type signals are usually converted to a voltage at the input to the data acquisition system, with a low value resistor, this does not improve noise performance. This is because both the noise and transducer signals are proportional to the same load impedance.

Before panic totally overwhelms the reader, it should be pointed out that this example does not take advantage of —or benefit from — shielding, grounding and filtering techniques.

Most noise problems can be solved by close attention to a few grounding and shielding principles:

- Do not confuse ground and return paths.
- Minimize wiring inductance.
- Minimize ground currents.
- Limit antennas.
- Maintain balanced networks where possible.

This sounds simple enough, but what is involved?

To begin with, redefine some common terms. A ground is NOT a signal or power supply return path. A ground wire connects equipment to earth for safety reasons, to prevent accidental contact with dangerous voltages. Ground lines do not normally carry current. Return lines are an active part of a circuit, carrying power or signal currents. This is depicted in Figure 7.1. Care should be taken to distinguish between grounds and returns and to avoid more than one connection between the two.

To be effective, return paths should have the lowest possible impedance. Someone once said that the shortest distance between two points is a straight line. But, in geography it's not true and it's not generally true in electronics either. Current does not take the shortest path, rather it takes the path of least resistance (really, least impedance). Return impedance is usually dominated by the path inductance. Wiring inductance is proportional to the area inside the loop formed by the current-carrying path. Therefore, impedance is minimized by providing a return path that matches or overlaps the forward signal path. Note that this may not be the shortest or most direct route. This concept is fundamental to insuring proper system interconnections.

Three different grounding and connection techniques are suggested in Figure 7.2. The circuit in Figure 7.2A allows the signal return line to be grounded at each chassis. This may look like a good idea from a safety standpoint. However, if a difference in potential exists between the two grounds, a ground current must flow. This current multiplied by the wire impedance results in an error voltage, e_e. Thus, the voltage applied to the amplifier is not V_1, but $V_1 + e_e$. This may be acceptable in those applications where the signal voltage is much greater than the difference in the ground potentials.

When the signal level is small and a significant difference in ground potentials exists, the connection in Figure 7.2B is more desirable. Note that the return wire is not grounded at the amplifier and ground current can not flow in the signal wires. Any difference in ground potential appears, to the amplifier, as a common-mode voltage (CMV). In most circuits the effects of CMV are very small, as long as the signal voltage plus CMV is less than 10V (10V is the linear range for most amplifiers). Additional information about common-mode rejection and single- ended versus differential amplifiers can be found in the handbook section "Data Conversion Principles".

If cost is not a limitation, Figure 7.2C offers the highest performance under all conditions. Injecting an isolator into the signal path faithfully conveys V_1 to the amplifier while interrupting all direct paths. In this configuration multiple ground connections can be tolerated along with several hundred volts between the input and output circuits. Additional information on both analog and digital isolators can be found in the section on signal conditioning. Related product data sheets are included in the PCI-20000 system configuration and data sheets section.

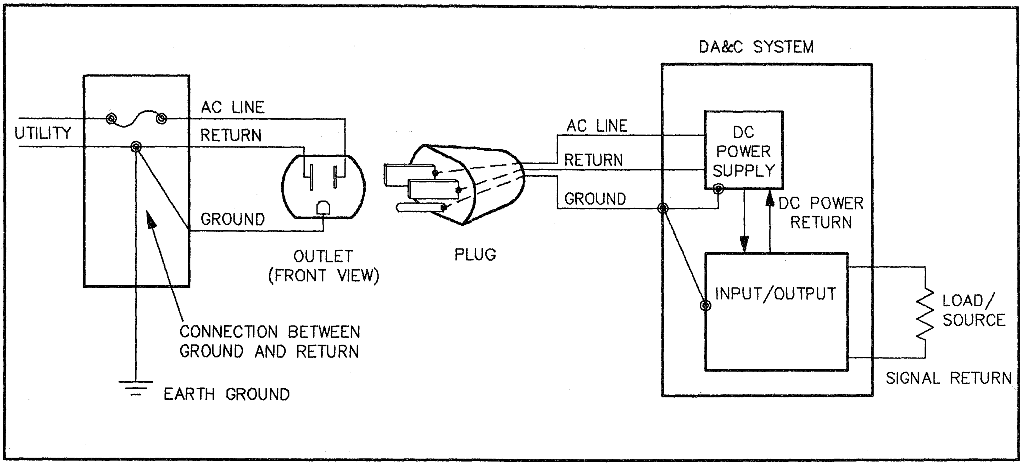

FIGURE 7.1. The Differences Between Ground and Return Conductors.

Cable Types - What kind of wire should be used to interconnect a system? We must first emphasize that a single piece of wire is not generally useful. Circuits consist of complete paths, so we will refer to pairs of wires in this discussion. Basically, four kinds of wire are fundamental: the plain pair, shielded pair, twisted pair and coaxial cable. All the the coaxial (coax) wires are said to be balanced. Coax differs from the others in that the return line surrounds the central conductor. Technically, we should not call the outer conductor a shield because it carries signal current. It is significant that the forward and return path conductors do not model the same. In contrast a shielded pair is surrounded by a separate conductor (properly called a shield) that does not carry signal current.

Figure 7.3 suggests a simple model for a differential signal connection. The attributes of the signal source have been split to model the influence of a common-mode voltage (CMV). Focus on the effect of forward and return path symmetry in the cable. Assuming that the amplifier is perfect, it will respond only to the difference between V_a and V_b. Superposition allows us to analyze each half of the cable model separately and then to add the results. Z_1 is usually dominated by series inductance, while Z_2 is dominated by parallel capacitance. In any case, Z_1 and Z_2 form a voltage divider. If the dividers in both legs of the cable are identical, $V_a - V_b$ will not be influenced by CMV. If, however, the capacitance represented by Z_2 is different in the two paths, a differential voltage will result and the amplifierwill be unable to distinguish the resulting CM error from a change in V_s.

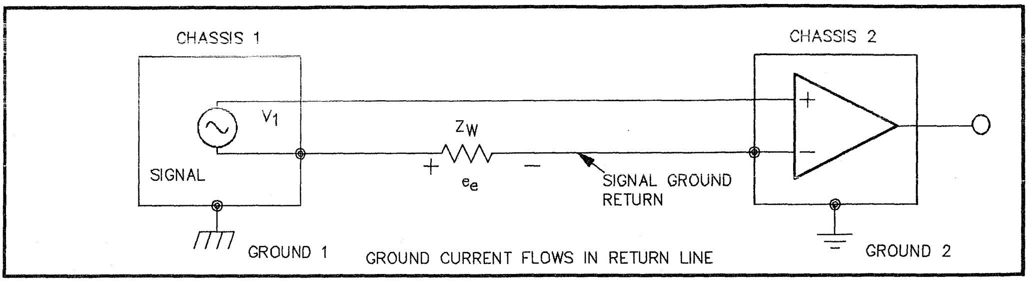

FIGURE 7.2A. A Single-Ended Connection.

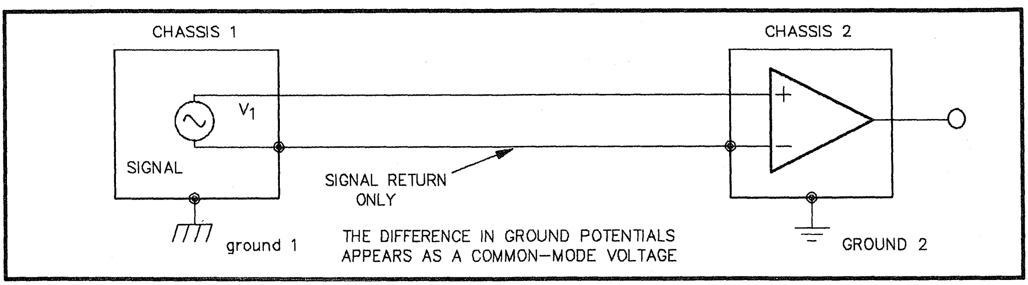

FIGURE 7.2B. A Differential Connection.

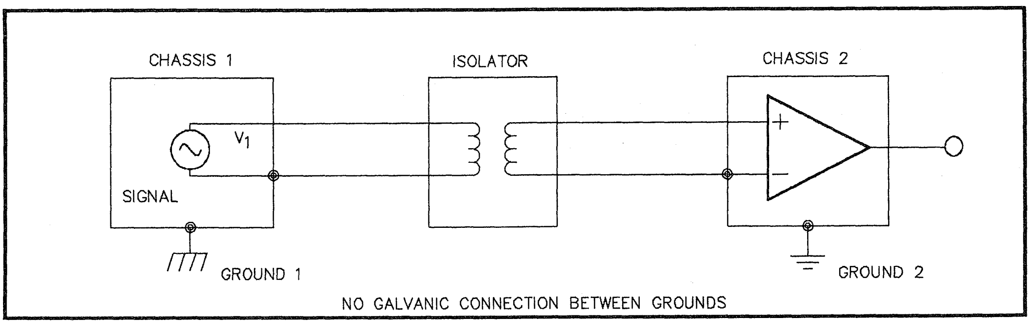

FIGURE 7.2C. An Isolated Connection.

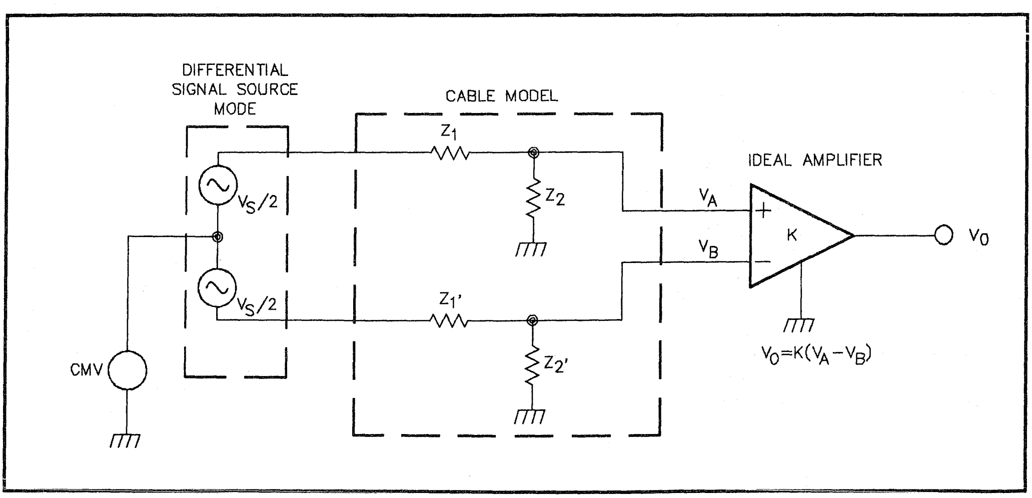

FIGURE 7.3. Influence of Cable Connectors on Common-Mode Signal Performance.

Coax offers a very different capacitance between each of its conductors and ground. Not only does the outer conductor surround the inner, but it is also connected to ground. Thus, coax is intended for single-ended applications only. Note that even perfectly balanced cables can still attenuate differential signals.

Sometimes even a single-ended source is best measured with a differential amplifier. Refer again to Figure 7.2B. To maintain a high rejection of any ground difference potential, balanced cables are required.

One method or reducing errors, due to capacitive coupling, is to employ a "shield". Generally, there is little that can be done to reduce the actual capacitance (wire length and physical location are factors, however). Nevertheless, placing a conductive material (at ground potential) between the signal wires and the interference source is very useful. The shield blocks the interfering current and directs it to the ground. Depending upon how "complete" the shield is, attenuations of more than 60dB are attainable. When using shielded wire, it is very important to connect only one end of the shield to ground. The connection should be made at the DA&C system end of the cable (input amplifier, etc.). Connecting both ends of the shield can generate significant error by inducing ground-loop currents.

A shield can work in three different ways:

- "Bypassing" capacitively coupled electric fields
- "Absorbing" magnetic fields
- "Reflecting" radiated electromagnetic fields.

Another approach is to use twisted pairs. Twisted-pair cables offer several advantages. Twisting of the wires insures a homogenous distribution of capacitances. Both capacitances to ground and to extraneous sources are balanced. This is effective in reducing capacitive coupling while maintaining high common-mode rejection. From the perspective of both capacitive and magnetic interference, errors are induced equally into both wires. The result is a significant error cancellation.

The use of shielded and/or twisted-pair wire is suggested whenever low-level signals are involved. With low impedance sensors, the largest gage connecting wires that are practical should be used to reduce lead-wire resistance effects. On the other hand, large connecting wires that are physically near thermal sensing elements tend to carry heat away from the source, generating measurement errors. This is known as thermal shunting, and it can be very significant in some applications.

The previous discussion concentrated on cables making single interconnections. Multi-conductor cables, for connecting several circuits, are also available in similar forms (i.e., twisted pairs, shielded pairs, etc.). Both round and flat (ribbon) cables are widely used. Because of the close proximity of the different pairs in a multi-conductor cable, they are more susceptible to "crosstalk". Crosstalk is interference caused by the inadvertent coupling of internal signals via capacitive or inductive means.

Again, twisted pairs are very effective. Other methods include connecting alternate wires as return lines, running a ground plane under the conductors or using a full shield around the cable.

Still another noise source, not yet mentioned, is that of triboeletric induction. This refers to the generation of noise voltage due to friction. All commonly used insulators can produce a static discharge when moved across a dissimilar material. Fortunately, the effect is very slight in most cases. However, it should not be ignored as a possible source of noise when motion of the cables or vibration of the system is involved. Special low-noise cables are available that employ graphite lubricants between the inner surfaces to reduce friction.

The key to designing low-noise circuits is recognizing potential interference sources and taking appropriate preventive measures. Figure 7.4 can be useful when troubleshooting an existing system.

After proper wiring, shielding and grounding techniques have been applied, input filtering can be used to further improve the signal-to-noise ratio. However, filtering should never be relied upon as a fix for improper wiring or installation.

7

Cable Length Guidelines - What is the maximum allowable cable length? There is no direct answer to this question. The number of factors relating to this subject are overwhelming. Signal source type, signal level, cable type, noise source type(s), noise intensity, distance between the cable and the noise source(s), noise frequency, signal frequency range and required accuracy are just some of the variables to consider. However, experience has given us a "feel" for what often works. For example:

Analog, Current Source Type Signals -

Given: 4-20mA signal, Shielded wire, Bandwidth limited to 10Hz, Accuracy required is 0.5%, "Average", industrial noise levels.

Cable lengths of 1000 to 5000 feet (300 to 1500 meters) have been used successfully.

Analog, Voltage Source Type Signals -

± 1 to ± 10 volt signal, Shielded wire, Bandwidth limited to 10Hz, Accuracy required is 0.5%. "Average", industrial noise levels.

Cable lengths of 50 to 300 feet (15 to 90 meters) have been used successfully.

Analog, Voltage Source Type Signals -

Given: 10mV to 1volt signal, Shielded wire, Bandwidth limited to 10Hz, Accuracy required is 0.5%. "Average", industrial noise levels.

Cable lengths of 5 to 100 feet (1.5 to 30 meters) have been used successfully.

OBSERVATION	SUSPECT	POSSIBLE SOLUTION	NOTES
Noise a function of cable location	Capacitive coupline Inductive coupling	Use shielded or twisted pair Reduce loop area, use twisted pair or metal shield	A B
Average value of noise Is not zero	Conductive paths or ground loops.	Faulty cable or other leakage. Eliminate multiple ground connections.	C
Is zero	Capacitvie coupling	Use shielded or twisted pair	A
Shield inserted Ground significant Ground insignificant	Capacitive coupling Inductive coupling	Use shielded or twisted pair Reduce loop area, use twisted pair or metal shield	A B
Increasing load Reduces error Increases error	Capacitive coupling Inductive coupling	Use shielded or twisted pair Reduce loop area, use twisted pair or metal shield	A B
Dominat feature Low frequency	60Hz AC line, motor, etc.	(1) Use shielded or twisted pair. (2) Reduce loop area; use twisted pair or metal shield. (3) Faulty cable or other leakage; eliminate multiple ground connections.	
High frequency	Electromagnetic radiation	Comlete shield	D
Noise a function of cable movement	Tribolectric effect	Rigid or lubricated cable	
Noise is "white" or 1/f	Electronic amp, etc.	Not a cable problem	

NOTES: (A) Connect shield to noise return point and check for floating shields.
(B) Nonferrous shields are good only at high frequencies. Use MuMetal shields at low frequencies.
(C) Could be capacitive coupling with parasitic rectification, i.e., nonlinear effects.
(D) Look for circuit element whose size is on the order of the noise wavelength (antennas). Openings or cracks in the chassis or shields with a dimension bigger than the noise wavelength/20 should be eliminated.

FIGURE 7.4. Troubleshooting Guide for Noise.

Digital, TTL Type Signals -

Ground-plane type cable, "Average", industrial noise levels.

Cable lengths of 10 to 100 feet (3 to 30 meters) have been used successfully.

Ground-Plane cable reduces signal reflections, ringing and RFI. Special termination networks may be required to maintain signal integrity and minimize RFI. If "squaring circuits" (Schmidt triggers) are used to restore the attenuated high frequency signals, improved performance can be realized.

Remember, this information is offered as "typical" of what might be encountered. The actual length allowed in a particular application could be quite different.

The following relationships are offered as an aid to visualizing the influence of the most significant factors determining cable length. These relationships show **how** the various parameters affect cable length. These relationships are **not equations**, and will not allow the calculation of cable length.

For Current Source Type Signals:

Allowable length is proportional to

$$\frac{I_s\ D_n\ C_f}{f_n\ A\ N_i}$$

For Voltage Source Type Signals:

Allowable length is proportional to

$$\frac{V_s\ D_n\ C_f}{f_n\ A\ N_i\ R_L}$$

Where:

I_s or V_s equals the signal level,
C_f equals the coupling factor which is inversely proportional to the effectiveness of any shielding or twisting of the wires.
D_n equals the distance to the noise source,
f_n equals the noise frequency,
A equals the required accuracy,
N_i equals the noise source intensity, and
R_L equals the equivalent resistance to ground at the signal input.

Section 8 Signal Conditioning

We are all familiar with the old cliche "a chain is only as strong as its weakest link." As suggested in Figure 1.1, a DA&C system is made up of several links. It is common to partition the system at the transducer/signal conditioning interface. That is, the transducer is considered to be the signal source. Because signal conditioning effects the quality of the input signal, the ultimate performance of the system can be greatly influenced by the type of conditioning employed. Signal conditioning can include current-to-voltage conversion, scaling, filtering, isolation and amplification. Optimum signal conditioning is important to maintain the highest overall accuracy. Signal conditioning can be physically installed at a number of locations including the signal source, the termination panel, or the data acquisition board (at the amplifier input or A/D). Usually it is most convenient and hence most common to use the termination panel. A large variety of standard PCI signal-conditioning termination panels are available. Both "passive" and "active" panels support a wide range of digital and analog applications. All panels provide for field wiring connections through convenient screw terminals. Passive panels are designed to accommodate the most common R, L, C and diode arrangements. This allows the user to configure voltage dividers, filters, surge suppressors, etc. The active panels also provide for filtering, programmable differential amplification, bridge completion, bridge excitation, cold junction compensation and optional isolation. Figure 8.1 suggests two of the many termination panel styles. Shielded ribbon cables are used to bring the termination panel's input/output signals to the data acquisition electronics (board, module, or carrier).

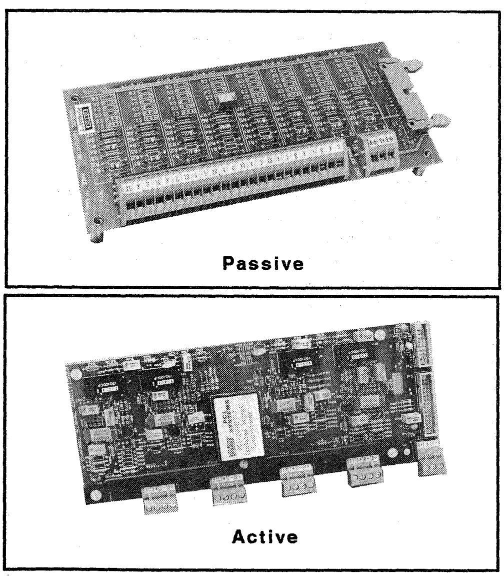

Figure 8.1. Examples of Passive and Active Termination

Input Buffering -- The input characteristics (bias current, impedance, offset voltage, bandwidth, slew rate, etc.) of the DA&C system place limits on the range of signals that can be accurately measured. Some transducers, including piezoelectric and pH, exhibit a very high output impedance. Under these conditions, direct connection to the DA&C system (normally presenting a "moderate" input impedance) can result in measurement errors. These applications require that a special, high input impedance, amplifier be incorporated to buffer the connection between the signal and the actual measuring device. Figure 8.2 suggests a type of buffer circuit that can be used.

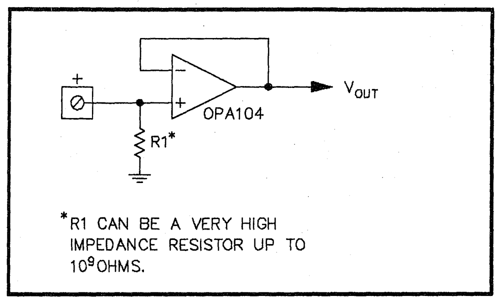

Figure 8.2. A very high input impedance buffer circuit.

Current Conversion -- The need to measure input current is quite common in DA&C systems. The outputs from remote sensors are often converted to high-level, 4 to 20mA signals at the source. This task is easily accomplished with a wide variety of "transmitters". At the measurement system, current is easily converted back to a voltage with a simple resistor. See Figure 8.3. Values of 250 to 500 ohms are often used to provide voltage ranges of 1-5 volts and 2-10 volts, respectively for a 4-20mA signal. The largest resistor that does not cause an over-range condition should be employed. This insures the maximum resolution. Stability of the resistor is essential, however, the exact value is not im-

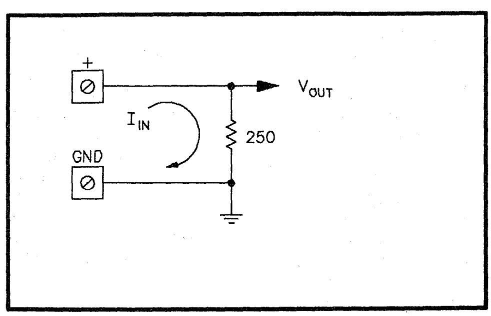

Figure 8.3. 4-20mA input conversion circuit (single-ended).

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portant. Most systems have software provisions for calibrating the measurement sensitivity of each channel at the time of installation. Low-cost, .1%, metal-film resistors are usually adequate.

The technique of using only a resistor to convert from current to voltage does have limitations. If, for example, we wish to measure a 1uA level, a resistor of approximately 5Meg ohms will be required. Unfortunately, the use of high value resistors leads to potentially large errors due to noise and "measuring system loading". The input stage to the DA&C system always includes a device that presents a small but finite current (input bias current) that must be absorbed by the signal source. This bias current (typically around 10nA) also flows through the conversion resistor and is indistinguishable from the signal current. Therefore, when very low currents must be measured, a different technique is employed. Figure 8.4 suggests an active circuit that utilizes a precision FET-input amplifier to minimize the bias current problem. Both the simple resistor and FET amplifier circuits require the same resistor value for a given current level. However, in the later circuit the DA&C system's bias current is supplied by the amplifier and does not effect the measurement accuracy. A wide range of low bias current amplifiers are available for special applications. With the amplifier shown, currents as low as 10pA can be read reliably.

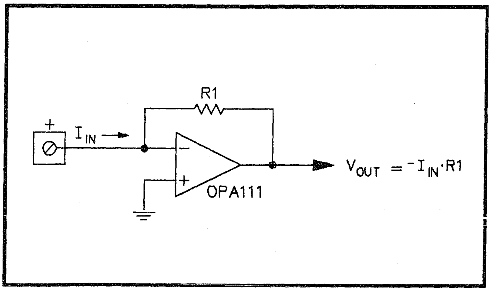
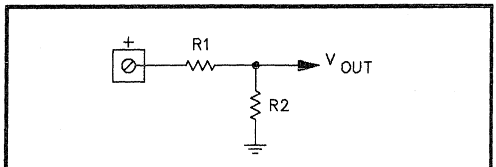


Figure 8.4. A current-to-voltage converter circuit suitable for very low current levels.

Analog Signal Scaling -- A/D converters are designed to operate with "high-level" input signals. Common A/D ranges include 0-10, ±5, and ±10 volts. When an input signal is below 1 volt, resolution, noise and accuracy are degraded. Under these circumstances it is often appropriate to amplify the signal before the A/D converter. Some A/D boards, carriers, and modules have amplifiers built-in. With a gain of 1000, signals as small as 1mV can be accurately processed. When on-board amplifiers are not available or additional gain is required, "active" termination panels can be employed. Two types of panels are applicable, one with amplifiers installed at the factory and one that allows the user to install almost any type of circuit desired. Please refer to the termination section of this handbook for more information.

In addition to an input signal being too small, it is possible that it might be too large. Remember that most converters accept a maximum of 10 volts at their input. We might want to measure 12, 48 or 100 volts. Fortunately, it is a simple matter to reduce high levels with a resistive voltage divider network. Figure 8.5 is appropriate for most analog signals. In selecting R1 and R2, there are practical factors to consider. Making R1 large can introduce limitations on signal bandwidth, due to the low-pass filter produced by R1 and the parasitic capacitance (Cp) in parallel with R2. In some applications the network bandwidth can be extended by placing a capacitor (Cs) across R1. The value should be selected to make the time constant R1·Cs equal to R2·Cp. In addition, the equation assumes that the source (signal) impedance is very low compared to the series combination of R1 and R2 (R1+R2). From this prospective, R1 and R2 should be as large as possible.



$$V_{OUT} = V_{IN}\left(\frac{R_1}{R_1 + R_2}\right)$$

Figure 8.5. Resistive voltage divider to reduce large analog input signals to below 10 volts.

Low-Pass Filtering -- By averaging a series of incoming data points, we effectively increase the signal-to-noise ratio. Given the speed and math capabilities of modern DA&C systems, averaging is readily employed. Averaging will be most effective in reducing the effects of random, non-periodic noise. It is less effective in

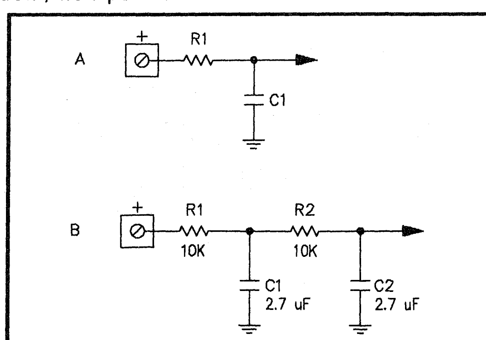


Figure 8.6. One and two-pole low-pass filters.

dealing with 50/60Hz or other periodic noise sources. It is important to remember that all noise filtering techniques, whether hardware or software, are designed to filter specific types of noise. PCI-20000 signal termination panels have provisions for the user to install a variety of filters. The most common types are represented by the one and two pole passive filters shown in Figure 8.6. Figure 8.6B is an example of an effective, single-ended, double-pole circuit to attenuate 50/60Hz noise. The filter has a -6dB cutoff at about 1Hz while attenuating 60Hz about 52dB (380 times).

Figure 8.7 suggests a differential, two-pole, low-pass filter. In contrast to the circuits in Figure 8.6, this can be used in balanced applications. Note that any mismatch of the attenuation in the top and bottom path will result in a degradation of the system common-mode rejection ratio, CMRR (see Section 7). Therefore, the resistors and capacitors should be carefully matched to each other. If it is given that all of the resistors and capacitors are of equal values, the pole position (f_1) for this differential two-section filter is:

$$f_1 = 0.03/(R \cdot C)$$

and the approximate attenuation ratio ($r = V_{in}/V_{out}$), at a given frequency (f_x), is:

$$r = \left[\frac{f_x \cdot R \cdot C}{.088} + 1\right]^2$$

and also,

$$r = \left[\frac{.3 f_x}{f_1} + 1\right]^2$$

$$dB = 20 \log (r)$$

The equations for a single-ended, single-pole filter are:

$$f_1 = \frac{.159}{R \cdot C}, \quad r = \frac{f_x \cdot R \cdot C}{.159} + 1$$

and also, $$r = \frac{f_x}{f_1} + 1$$

The above equations assume that the source impedance is much less than R, and that the load impedance is much larger than R.

For filter applications, monolithic-ceramic type capacitors have been found to be very useful. They possess very high density (small in size for a given capacitance), have low leakage and are non-polar. Values up to 4.7uF at 50V are commonly available from Sprague, Centralab and others.

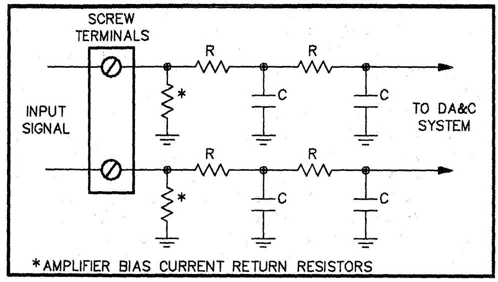


Figure 8.7. A two-pole, differential, low-pass filter.

Filters have special significance in computerized DA&C systems beyond noise reduction. Such system generally employ sampled-data techniques. This implies that while data is recorded on a regular basis, it is not taken continuously. That is, there are gaps between the data points. Thus, when the data is interpreted, certain assumptions must be made about what the data is doing between the known points. In most cases it is assumed that the gaps contain information that falls on a straight line drawn between the known data points. This is known as linear interpolation. When this type of presumption is not sufficiently accurate, the logical recourse is to increase the sampling rate. This makes the gaps smaller by adding additional "real" data points. Nyquist has provided us with a firm theoretical foundation upon which to deal with sampled data. In the simplest of terms, he states that a signal must be sampled at a minimum of two times the highest input frequency.

With pulse waveforms there can easily be very significant harmonics far beyond the repetition rate. Frequencies out to $1/t_r$ are often important (t_r is the pulse rise time). The danger of under-sampling is that erroneous conclusions can be drawn about the input signal. It is not simply a matter of overlooking something, but of reaching totally wrong conclusions about the basic makeup of the data. See Figure 8.8 for an example. Note that sampling a pure sine wave (containing only the fundamental frequency) at a rate in violation of the Nyquist criterion leads to meaningless results. In this example, it suggests the presence of a totally nonexistent signal. This phenomenon is known as "aliasing".

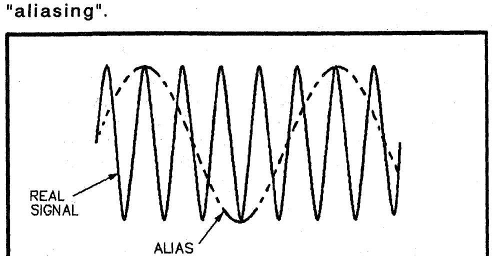


Figure 8.8. Aliasing Because of an Insufficient Sampling Rate.

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Given that there are practical limits to the maximum sampling rate, another action must be taken to insure that the input signal does cause a violation of the Nyquist criterion. This involves the use of an input filter (anti-aliasing filter) to limit high frequencies. In the ideal case, this filter would have infinite rejection beyond the cutoff frequency. This would allow the filter to be set at exactly one half the sampling rate, providing maximum bandwidth without danger of aliasing. Because perfect filters are not available, however, an appropriate compromise must be made between the allowed system bandwidth and sampling speed. The required accuracy for a given system will greatly influence the necessary bandwidth reduction. In applications using simple passive filters, the sampling frequency might have to be 5 to 10 times the filter corner frequency (the signal bandwidth). Using high-order active filters might require a bandwidth reduction of only two or three.

High-order active filters are very desirable in anti-aliasing applications. While offering excellent performance, they are physically large and expensive compared to simpler filters. Complete, ninth-order elliptic designs are available in a number of configurations. This type of filter has very steep roll-off (attenuation) while maintaining nearly constant gain in the passband (±0.2dB is common). In selecting elliptic filters you must be sure to choose a unit that has a stop-band attenuation greater than the resolution of the systems A/D converter. For example, a 12-bit converter has a resolution of one part in 4096. This corresponds to a dynamic range of 72dB. Therefore, the filter used should attenuate all undesired frequencies by more than 72dB. Fixed-frequency filter modules, as well as switch and software programmable units, can be purchased from various manufactures including Frequency Devices in Haverhill, MA. Several of the modular elliptic filters can be installed directly on the PCI-20024T series termination panels.

Many (perhaps most) applications can be satisfied by, low cost, one or two-pole passive filters. In low or moderate bandwidth applications, simple filters can be used in conjunction with "over-sampling". Over-sampling involves reading the input at a sufficiently high rate to account for the non-ideal filter characteristics. Depending upon the termination panel selected, accommodations for one, two or three pole filters can be provided.

In summary, filtering is intended to attenuate unavoidable noise and to limit bandwidth to comply with the Nyquist sampling theorem (the maximum signal frequency must be limited to half of the sampling frequency). It must always be remembered that filtering is not intended as a substitute for proper wiring and shielding techniques.

Analog Isolation -- Analog isolation as well as digital isolation can be used to protect people and equipment from contact with high voltages. Other applications include the breaking of ground loops or the removal of large common-mode signals. For example, if a thermocouple is connected to a motor armature, it could be at 240V above ground. However, the TC output voltage might be only 30mV. The 30mV (the actual signal) is a differential signal because it is applied to the + and - inputs of the data acquisition channel. On the other hand, the 240V appears not as a differential signal, but as a signal common to both + and - inputs. Common-mode voltages are referenced to the power supply ground. Standard analog input channels can only accept up to a 10V common-mode signal while remaining linear. Voltages above 30V are likely to damage the input components. In the thermocouple example above, an analog isolator would separate the desired differential signal from the unwanted common-mode voltage.

Three major types of analog isolators are in wide use today: capacitively coupled, transformer coupled, and optically coupled. The so-called "flying capacitor" isolator is widely used because of its low cost. However, its mechanical relay design causes the system to be slow, and to have a poor mean-time-to-failure. As the cost of alternative methods declines, the trend is for mechanical systems to give way to electronic solutions. Transformer-coupled devices offer the highest level of electrical performance available today. Unfortunately, the high isolation voltage and high accuracy are associated with very high cost. In some application areas, such as medical patient monitoring, this cost is well justified. Generally, in the commercial/industrial world, the lower-cost optical isolators are more appropriate.

For use in DA&C systems, optical isolators offer high performance at moderate cost. This type of technology provides a wide range of isolation features. It is desirable to keep all potentially high voltage signals outside the personal computer. For this reason, both digital and analog isolation should be provided on external termination panels. In addition to isolation, analog panels should also provide differential input gain stages, bridge-completion and excitation circuitry, as well as passive signal conditioning capabilities. Provisions for thermocouples, RTDs, strain gages and pressure transducers are also included in better systems.

More information on analog isolators can be found by referring to the PCI-20042T series later in this handbook.

Surge Protection -- When a system can be subjected to unintentional high-voltage inputs, it is required that protection be provided to avoid possible destruction of the equipment. High-voltage inputs can be induced from: lightning, magnetic fields, static electricity, and accidental contact with power lines, to name just a few sources.

Figure 8.9 suggests two different protection networks. Both circuits offer transient (short duration) as well as steady state protection. Circuit "A" can tolerate continuous inputs of up to 45 volts. When the overload disappears, the signal path automatically returns to normal. Circuit "B" is useful for continuous overloads of up to 280 volts (limited by physical distances on the termination panel). However, sustained overloads to this circuit will cause the fuse to open (protecting the protection circuit). A disadvantage of this network is that the fuse must be replaced before the signal path is again active.

The resistor (or fuse in circuit "B") and MOV forms a voltage clamp to insure that transients will not get to the inputs of the DA&C system. MOVs are "metal oxide varistors". They are semiconductor devices that can react very quickly to absorb high energy spikes. Good results have been recorded with the General Industries SCL15C TransZorb MOV. Consideration should be given to the possible leakage current of the MOVs. If the series R is large, the leakage could appear as a significant temperature- dependent offset voltage (I·R). In the circuits shown, the resulting offset voltage will be insignificant (less than 1LSB).

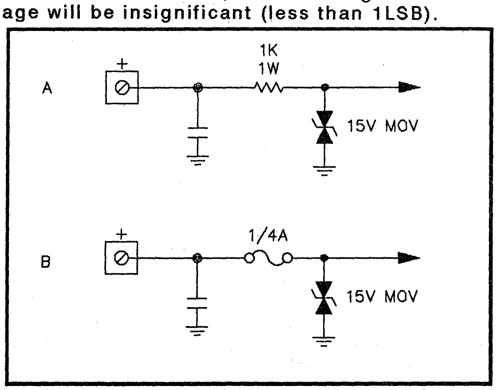


Figure 8.9. Representative input protection networks.

The capacitors help to suppress high frequency transients. In some applications they must be rated for high voltage because transients in power stations or other noisy environments can exceed 1000V. The values should be as large as physically possible, and these capacitors should be positioned as close as possible to the signal entry point of the system. Capacitors with low series impedance at high frequencies should be selected. This requirement eliminates electrolytic-type capacitors. If the input signal can change polarity, polarized capacitors must be avoided.

Thermocouples -- Thermocouples were discussed in Section 6. However, because they produce low-level (-10mV to +50mV) differential signals, they deserve special attention. In addition to the filtering and surge protection techniques described above, Figure 8.10 shows how to implement open thermocouple detection. This can be important in both monitoring and control applications. Particularly at high temperature, thermocouples are subject to mechanical fatigue leading to broken wires. Unfortunately, an open thermocouple results in a measurement of zero volts (not including cold-junction compensation) which could represent a legitimate temperature. Including R1 and R2 in the signal conditioning circuit eliminates this ambiguity. R2 (10K), connected to the positive input terminal, provides the traditional bias current return path required in all differential applications. A similar resistor is not required on the negative terminal because it's bias current can flow through the low impedance of the thermocouple, to R2, and on to ground. The addition of R1 (10Meg connected to +V), produces a small current that has negligible effect on a normal measurement. However, if the thermocouple should break, the negative terminal is forced to +V, simulating a negative full- scale signal (usually representing a -50mV input). This voltage is outside

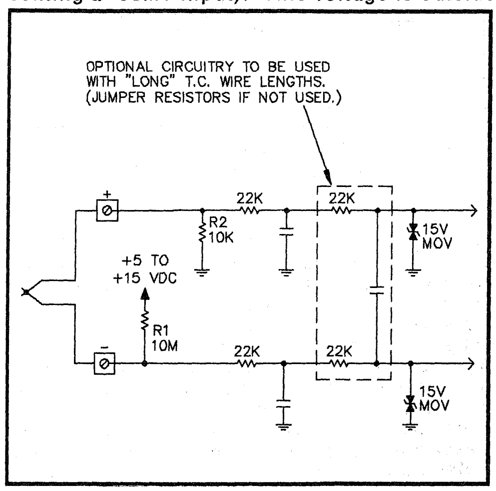


Figure 8.10. Complete thermocouple signal conditioning.

of the expected range and can thus be identified in software as a open thermocouple.

Digital Signal Scaling -- For large digital signals the circuit in Figure 8.11 can be used to produce TTL compatible levels. It is generally true that most digital acquisition products require "fast" input level transitions to insure reliable operation. Usually, transitions faster than 10uS are adequate. The 10pF capacitor in Figure 8.11 is included to help preserve the high frequency components present in the input signal. However, if a given input is not fast enough, it can be made TTL compatible with the Schmitt trigger circuit shown in Figure 8.12. These networks are compatible with all PCI digital and counter input products.

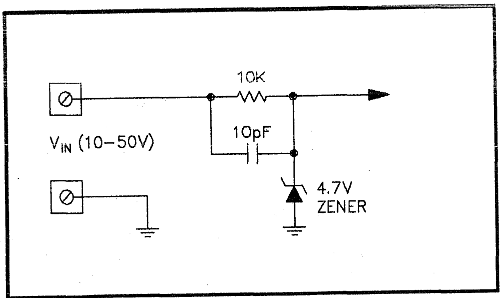


Figure 8.11. Circuit to convert large digital signals to TTL compatible levels.

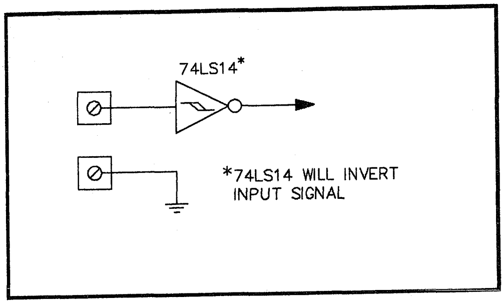


Figure 8.12. Schmitt trigger circuit to "speed-up" slow input signals. The input levels must be TTL compat ible.

Digital Isolation -- When driving heavier loads than a TTL output is rated for, digital isolation modules can be used. These devices convert a standard TTL input via power transistors or triacs to switch high voltage/high current, AC or DC signals. Optical isolation provides high voltage separation between the load and the DA&C system, without using mechanical relays. Other modules are designed to monitor digital input signals while breaking the galvanic connection between the signal source and the measuring equipment. The modules not only isolate, but also convert the inputs to standard TTL levels that can be read by the DA&C system's digital input channels. Isolation is useful for safety, equipment protection and ground-loop interruption. Each module supports a single channel, allowing the flexibility to mix the various types when configuring a system. Special termination panels are available that accommodate either 8 or 16 isolated modules.

There are six optically isolated PCI modules in four basic groups: AC input, AC output, DC input, and DC output. The AC models are intended to monitor and control 120V and 240V power lines. Line voltage inputs can be directly connected to these devices. Actually, DC input models can accommodate almost any AC or DC input level with the choice of an appropriate series resistor. The DC output devices are rated for up to 60V. Both the AC and DC models can switch loads up to 3A.

More information on this family of opto-isolators is available by referring to the PCI-1100 series in this handbook.

Contact Sensing -- When interfacing to relay or switch contacts, a "pull-up" current must be provided. The pull-up current converts the opening and closing of the contacts to TTL levels. Because all metal surfaces tend to oxidize with time, poor relay contacts can result. This oxidation can be cleaned away by passing a minimum current through the relay contacts. Both level generation and contact wetting can be accomplished by connecting resistors between the input lines and the +5V power supply. This can be implemented on the signal termination panel as shown in Figure 8.13. A value of 250 ohms for R_1 will provide 20mA of wetting current, which is usually enough to keep most contacts free of oxide build-up. R2 and C1 function as a debounce filter to reduce erroneous inputs due to the mechanical bouncing of the contacts. When the switch is open, the system sees +5V. When the switch is closed, the input is 0V. This satisfies the TTL requirements of the system.

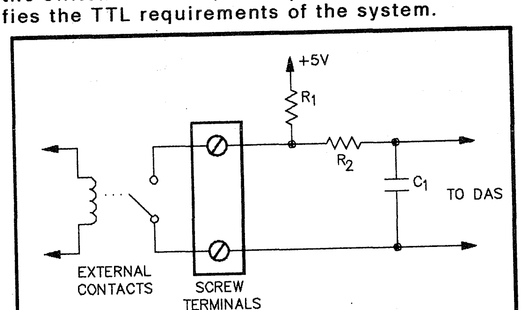


Figure 8.13. Contact Sensing and Wetting.

Relay Driving -- Figure 8.14 shows how a TTL output is connected to drive an external relay coil. The diode, D1, protects the internal circuit against the inductive "kickback" from the relay coil. Without the diode, the resulting high-voltage spikes will damage the digital port. Note that the direction or polarity of the diode must be as shown in the diagram. Protection diodes must be able to respond very quickly and be able to safely absorb the coil's energy. Most standard "switching" diodes fill these needs.

When large relays, contactors, solenoids or motors are involved, an additional driver or intermediate switching network can be employed.

Motor Control -- Many different types of motors are in common use today. When it comes to controlling these devices, specialized circuits are often required. Some applications, however, require only on-off operations. These can simply be driven by digital output ports, usually through optical isolators (load up to 3A) or with various types of contractors (relays).

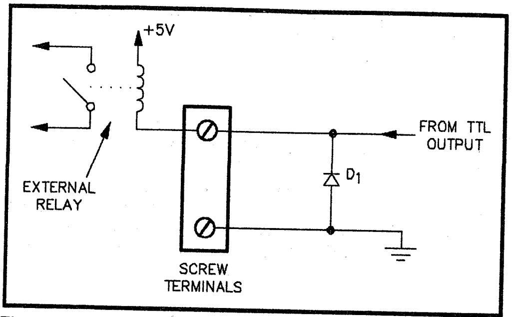


Figure 8.14. Relay Driving Circuit.

In general, when variable speed is desired, either analog or digital outputs from the DA&C system are used to manipulate the motor through an external controller. A wide range of both AC and DC controllers is available from KB Electronics (Brooklyn, NY), and others.

Stepper-type motors are of particular interest in robotics, process control, instrumentation and manufacturing. They allow precise control of rotation, angular position, speed and direction. While several different types of stepping motors exist, the permanent-magnet design is perhaps the most common. The permanent magnets are attached to the rotor of the motor. Four separate windings are arranged around the stator. By pulsing DC current into the windings in a particular sequence, forces are generated to produce rotation. To continue rotation, current is switched to successive windings. When no coils are energized, the shaft is held in its last position by the magnets. In some applications these motors can be driven directly (via opto relays) by one of the DA&C system's digital output ports. The user would provide the required software to produce the desired pulses in proper sequence. The software burden could be reduced by driving the motor with a specially designed interface device. These units accept a few digital input lines representing the desired speed, rotation, direction and acceleration, etc. A full range of both motors and interfaces is available from companies such as Airpak Corporation (Cheshire, CT), Superior Electric (Bristol, CT) and others.

8

Section 9

APPLICATIONS, TOOLS & TECHNIQUES

INTRODUCTION

This section includes a collection of articles that address a number of important principles and techniques. The fundamentals presented earlier are now linked to available hardware and software products. In some cases it is appropriate to first have a basic knowledge of the specific hardware and/or software items before studying these notes.

When this is the case, detailed information can be found in the, product sections of this handbook. A complete description, including specifications and system configuration information, for all PCI products will be found. Please refer to the Tab Index, Model Number Index or Subject Index to locate the desired product section.

TABLE OF CONTENTS

PROGRAMMING YOUR PC FOR DATA ACQUISITION APPLICATIONS USING IBM PC, PC/XT, PC/AT AND COMPATIBLE MACHINES

SOME USEFUL TECHNIQUES

- Establishing a Time-Base from the PC's clock
- Time-Stamping
- Converting the raw data to a LOTUS readable file
- Writing the data to disk

INTRODUCTION

In most data acquisition tasks there are three basic steps:

1) Acquire the data
2) Process, manipulate or analyze the data
3) Present the data in tabular, graphical or report format.

Using the PCI-20000 System, extensive programming experience is not needed to acquire or manipulate data. This Application Note will demonstrate how to read a given Channel at predetermined intervals and to write a permanent record of this data to disk. As is often required, the data will also be "Time-Stamped". This means that the data will be recorded along with the corresponding Time-of-Day.

Manipulating and presenting the data can get "involved" and as a result, may require considerable effort. Fortunately, a number of software products exist that bridge the gap between the raw data and sophisticated analysis and presentation capabilities. One such package is LOTUS SYMPHONY. SYMPHONY integrates word-processing and spreadsheet functions. The spreadsheet portion is called LOTUS 1-2-3, and it provides both analysis and graphics features. This note shows how easy it is to transform data files into a format that can be read by LOTUS. The technique shown is general and can be applied to any language. An example is included using BASIC.

EXAMPLE

In the example that follows, a PCI-20000 system consisting of a PCI-20001C-1 Carrier and a PCI-20002M-1 Data Acquisition Module is used to acquire analog input data and place it into an array. The complete program is shown in Listing 1. The first portion of the program makes use of the PCI-20046S-1 Software drivers. These drivers "isolate" the programmer from having to have a complete understanding of the data acquisition hardware. They handle the details of setting multiplexers, programmable gain amplifiers, sample-holds and A/D converters. Programming READ, WRITE and many other functions are reduced to invoking simple "CALL" statements. In many cases, it is required that data be taken at defined, regular intervals. The sample program includes both a time-base generator and a time-stamping routine. The maximum data acquisition rate, using this technique, is limited by the timing jitter generated by the PC. This timing uncertainty is about 10 milliseconds; therefore, the practical maximum data rate might be about 1 reading per second (1% timing accuracy). Having acquired the data, the program writes the data to a LOTUS readable file. Listing 2 is an example of such a file. This data can be presented graphically by LOTUS as shown in Figure 1.

BACKGROUND

In this example, two BASIC functions are used to implement the timing and time-stamping features. They are TIMER and TIME$, respectively. TIMER returns the number of seconds elapsed since system start-up, or since last midnight if a real-time clock is installed in the computer. TIME$ returns TIMER's value formatted in "hh:mm:ss".

Getting data into the LOTUS format is actually very straightforward. There are only a few simple rules to remember:

RULE 1: The data file must have a .PRN extension.

RULE 2: String type (literal) information must be contained in quotes (" "). Numbers (non-literals) must not be contained in quotes.

RULE 3: Entries that are to be on the same row in LOTUS 1-2-3 must be separated by commas in the file.

RULE 4: Each line must end with Carriage-Return, Line-Feed characters. <CR> = 13 (Dec) and <LF> = 10 (Dec).

RULE 5: The data file must end with and END OF FILE character. <EOF> = 26 (Dec).

Following these rules is especially easy when programming in BASIC. BASIC's built-in WRITE# function automatically adheres to Rules 2, 4 and 5. Therefore, <CR>, <LF>, and <EOF> characters are automatically inserted.

Functions of Program Lines in Listing 1

70	Merges the PCI Header files containing the definition and location of the drivers.
1030 to 1070	Variable declarations. These parameters can be altered to suit unique requirements.
1110 to 1120	Defines array sizes.
1160 to 1170	Initializes the PCI-20000 software and hardware.
1210 to 1260	Acquires the data and stores it in arrays.
1300	Opens the disk filed (it must have a .PRN extension to be read by LOTUS).
1340 to 1420	Shows how to write the PCI-20000 data to the file.
1400	Converts the raw A/D data to volts.
1410	Writing data. Notice the comma separators for multiple-row data.
1460	Closing the file.

To use this program simply LOAD it, define the variables in lines 1030 to 1070, connect an input to the channel defined by CHANNO, and RUN it. The program will create a file named FILENAME$, that can be read by LOTUS. Once data is inside the LOTUS environment, all of the features and power of this product are available.

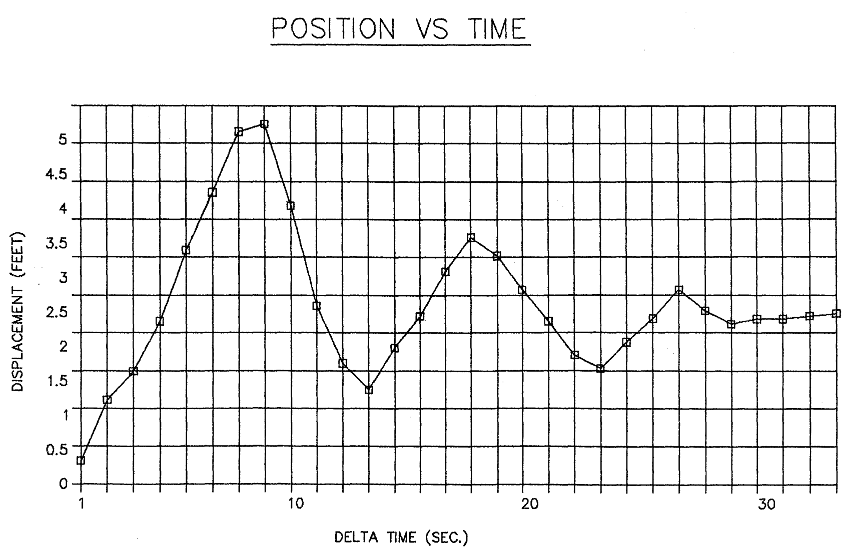


Figure 1. An example of a LOTUS 1-2-3 Graph.

LISTING 1. A BASIC Program to Acquire Analog Data and Write it to a LOTUS Readable Disk File.

```
10      ' Sample Program to Demonstrate:  Interfacing Data-Files to
20      ' LOTUS 1-2-3, Writing files to Disk & Generating Time-bases.
30      '
40      ' The System:  PCI-20002M-1  A/D Module (+/- 10 V range)
50      ' -----------  PCI-20046S-1  Software Drivers
60      '
70      CHAIN MERGE "PCIHEAD.BAS", 100, ALL
80      '
1000    ' Define program variables.
1010    ' The following terms can be changed to suit requirements.
1020    '
1030    FILENAME$ = "A:SAMPLES.PRN" ' Name of file to receive data.
1040    PASSES    = 30              ' Number of data points to take.
1050    CARSEG    = &HD000          ' Base address of carrier in RAM.
1060    CHANNO    = 0               ' Channel number to read.
1070    FINTERVAL = 11              ' Interval between reading in sec.
1080    '
1090    ' Declare array sizes.
1100    '
1110    DIM  VALUES(PASSES)
1120    DIM  TIMESTAMP$(PASSES)
1130    '
1140    ' Initialize the PCI-20000 Hardware and Software
1150    '
1160    CALL SYSINIT
1170    CALL INIT(CARSEG)
1180    '
1190    ' Acquire the data (Analog & Time) and save in arrays.
1200    '
1210    FOR I = 1 TO PASSES
1220      FTIME = TIMER                             ' Initialize the timer.
1230      IF (FTIME+FINTERVAL) > TIMER THEN GO TO 1230 ' Delay for interval.
1240      CALL READ.CH(AI, CHANNO, VALUES (I))      ' Read the analog input.
1250      TIMESTAMP$(I) = TIME$                     ' Get and save time stamp.
1260    NEXT I
1270    '
1280    ' Open the data file.
1290    '
1300    OPEN FILENAME$ FOR OUTPUT AS #1
1310    '
1320    ' Write header information to the file.
1330    '
1340    WRITE #1,"READING","TIME INTERVAL","TIME OF DAY","VOLTAGE"
1350    WRITE #1,"
1360    '
1370    ' Write the data from the arrays to the disk file.
1380    '
1390    FOR I = 1 TO PASSES
1400      FVOLTS = VALUES(I)/4096!*20!-10!        ' Convert data to volts.
1410      WRITE #1,I*FINTERVAL,TIMESTAMP$(I),FVOLTS ' Write data to the fine.
1420    NEXT I
1430    '
1440    ' Close the data file.
1450    '
1460    CLOSE #1
```

LISTING 2. Sample LOTUS Readable Data File.

```
"READING","TIME INTERVAL","TIME OF DAY","VOLTAGE"
"                                                  "

1,1,"12:51:30",2.260742
2,2,"12:51:32",2.822266
3,3,"12:51:33",3.759766
4,4,"12:51:34",4.84375
5,5,"12:51:35",4.467774
6,6,"12:51:36",3.754883
7,7,"12:51:37",3.183594
8,8,"12:51:38",2.661133
9,9,"12:51:39",2.084961
10,10,"12:51:40",1.171875
11,11,"12:51:41",.5322266
12,12,"12:51:42",0
13,13,"12:51:43",.4394532
14,14,"12:51:44",1.230469
15,15,"12:51:45",2.050781
16,16,"12:51:46",2.851563
17,17,"12:51:47",2.939453
18,18,"12:51:48",2.431641
19,19,"12:51"49",1.99707
20,20,"12:51:50",1.367188
21,21,"12:51:51",1.21582
22,22,"12:51:52",1.811524
23,23,"12:51:53",2.407227
24,24,"12:51:54",2.993164
25,25,"12:51:56",3.15918
26,26,"12:51:57",2.700195
27,27,"12:51:58",2.25586
28,28,"12:51:59",1.938477
29,29,"12:52:00",2.15332
30,30,"12:52:01",2.636719
```


GRAPHING WITH LOTUS 1-2-3

There are often instances when it is desirable to produce a graphic display of recorded data. This can have many uses including notebook entries, reports and presentations. Most data acquisition systems do not inherently have plotting capabilities. However, most can be interfaced to appropriate software which can perform this function. Some products, such as the ControLOGraph, can generate useful graphs directly, In specific applications when detailed control over plot format, size, labeling or other characteristics is desired, it is sometimes helpful to call upon the extensive plotting features of LOTUS 1-2-3.

This application note assumes that the reader has a basic working knowledge of 1-2-3. Presented here is a menu-driven "macro" (once installed) that reads a given data file and plots the results. The details of the plot characteristics are easily customized by the user. Naturally, the input data file must be in an appropriate LOTUS-readable format. The requirements for such a file are defined in the preceding applications note, *Programming Your PC for Data Acquisition Applications*. File conversion techniques are also described.

The following steps are required to use the macro:

- Enter the macro as shown in Listing 1. Be sure to start with the first entry, "\G", in cell AA1
- Name the macro as follows: /RNC\G<enter> AB6 <enter>
- To run the macro, type: Alt-G

The user will be prompted for the name of the data file to be plotted and the graph title.

Listing 2 shows a simple example of a data file as read from the PCI ControLOGraph . Note that the ControLOGraph automatically generates the output file in the correct format, so that no conversion is required. Figure 1 suggests just one of the possible ways that this data could be presented.

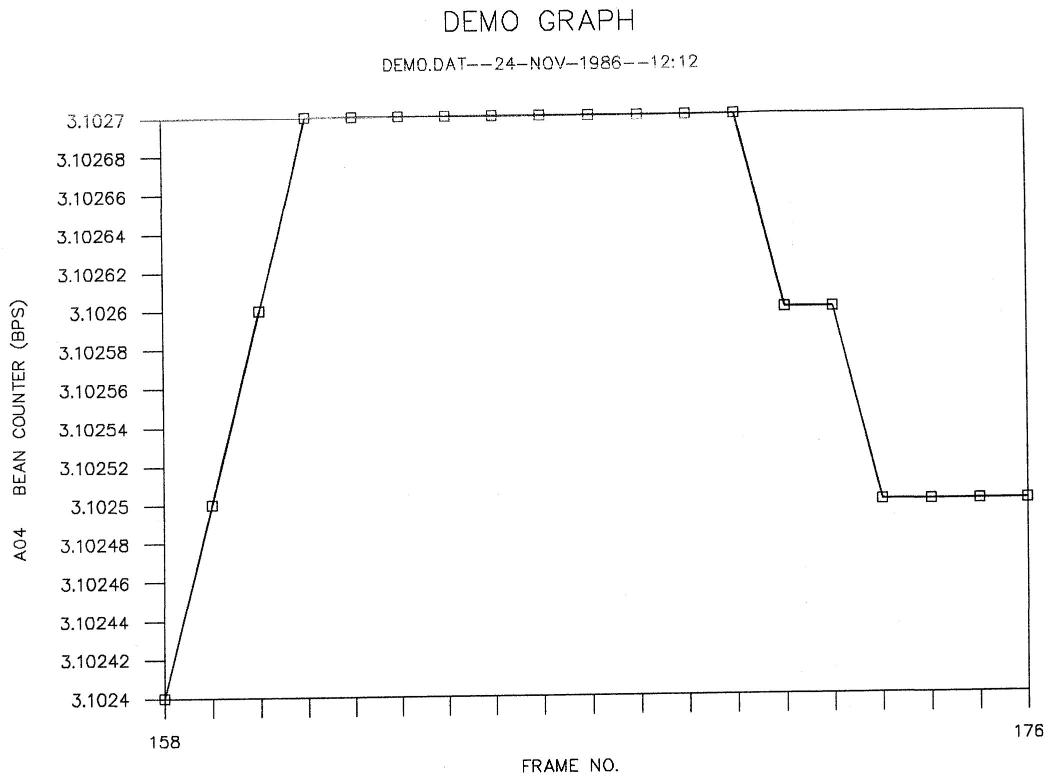


FIGURE 1. A Sample Lotus Plot.

Listing #1

\G THIS MACRO AUTOMATICALLY PRODUCES A GRAPH FROM A ControLOGraph DATA

```
LSTBLROW      29
LSTDTROW      30
BLNKCELL
              {HOME}                      MOVE TO CELL A1
              /RNLRAA3..AA140~            NAME RANGES TO BE USED
              /RNCFNAME~AE81~             CREATE FNAME
              /RNCGTITLE~AF100~           CREATE GTITLE
              /RNCMESSAGE~AE123~          CREATE MESSAGE
              {GOTO}FILENAME~             MOVE TO THE FILENAME PROMPT MENU
              {GOTO}FNAME                 MOVE TO THE FNAME FIELD
              {?}                         GET THE FILENAME
              /CFNAME~GETFILE~            COPY THE ENTERED FILENAME
              {GOTO}GRPHTITLE~            MOVE TO THE GRAPH TITLE PROMPT MENU
              {GOTO}GTITLE~               MOVE TO THE GTITLE FIELD
              {?}                         GET THE TITLE
              /CGTITLE~GPHTITLE~          COPY THE ENTERED TITLE
              {HOME}                      MOVE TO CELL A1
              /FIN                        READ IN THE DATA
GETFILE       DEMO
              ~
              /CLSTBLROW~BLRANGE~         COPY LSTBLROW TO BLRANGE
              {GOTO} BLRANGE~             MOVE CURSOR TO DTRANGE
              {EDIT} {CALC} {HOME}'~      MAKE THE VALUE A STRING
              /CBLNKCELL~E13..E           COPY BLANKS INTO THE RANGE
```

```
BLRANGE     29
            ~
            /CLSTDTROW~DTRANGE~          COPY LSTDTROW TO DTRANGE
            {GOTO}DTRANGE~               MOVE CURSOR TO DTRANGE
            {EDIT} {CLAC} {HOME}'~       MAKE THE VALUE A STRING
            {GOTO}FILENAME~              MOVE CURSOR TO FILENAME
            {GOTO}FNAME                  MOVE CURSOR TO FNAME FIELD
            /CDTRANGE~ARANGE~            COPY DTRANGE TO ARANGE
            /CB8~DFNAME                  COPY DATA FILE NAME
            /CB3~DFDATE~                 COPY DATA FILE DATE
            /CB4~DFTIME~                 COPY DATA FILE TIME
            /CE11~XTITLE~                COPY X TITLE
            /CA7~YTITLE~                 COPY Y TITLE
            /CB7~Y1TITLE~                COPY Y1 TITLE
            /CC7~Y2TITLE~                COPY Y2 TITLE
            /GRG                         CLEAR THE GRAPH PARAMETERS
            XE12..3                      DEFINE THE X DATA
DTRANGE     30
            ~
            AD12..D                      DEFINE THE A DATA
ARANGE      30
            ~
            OTF                          DEFINE THE FIRST TITLE
GPHTITLE    DEMO GRAPH
            ~
            TS                           DEFINE THE SECOND TITLE
DFNAME      DEMO.DAT
DFDATE      24-NOV-1986
DFTIME      12:12
            ~
            TX                           DEFINE THE X TITLE
XTITLE      FrameNo
            ~
            TY                           DEFINE THE Y TITLE
Y1TITLE       BEAN COUNTER
Y2TITLE     (BPS    )
            ~
            QV{ESC} {ESC}                DISPLAY THE GRAPH
            {GOTO}ENDMSG~                MOVE TO THE ENDING MESSAGE
            {GOTO}MESSAGE~
```

9

Continuation of Listing #1.

```
FILENAME   ENTER THE ControLOGraph .PRN FILE TO BE GRAPHED
                              DEMO

GRPHTITLE  ENTER THE GRAPH TITLE:  DEMO GRAPH
```

ENDMSG

ALT-G EXECUTES THE MACRO AGAIN

Note: Figures above are not shown actual size. Create box to fill entire screen.

Listing #2.

```
"AC"
"PCI ControLOGraph"
"ASCII File Date = ","24-NOV-1986"
"ASCII File Time = ","12:12"
"Trigger Frame No = ",13
"Origin Frame No = ",1
"A04 "," BEAN COUNTER "," (BPS )"
"Acquisition Data File = ","DEMO.DAT"
"Total Points Written = ",44
"Trigger Relative Time"
"Date", "Time", "tX Values", "tY Values", "FrameNo"
"31-DEC-1985","23:55:28.4"," 0000:36:15.0", 3.1024E+00,158
"31-DEC-1985","23:55:43.4"," 0000:36:30:0", 3.1025E+00,159
"31-DEC-1985","23:55:58.4"," 0000:36:45.0", 3.1026E+00,160
"31-DEC-1986","23:56:13.4"," 0000:37:00.0", 3.1027E+00,161
"31-DEC-1985","23:56:28.4"," 0000:37:15.0", 3.1027E+00,162
"31-DEC-1985","23:56:43.4"," 0000:37:30.0". 3.1027E+00.163
"31-DEC-1985","23:56:58.4"," 0000:37:45.0", 3.1027E+00,164
"31-DEC-1985","23:57:13.4"," 0000:38:00.0", 3.1027E+00,165
"31-DEC-1985","23:57:28.4"," 0000"38:15.0", 3.1027E+00,166
"31-DEC-1985","23:57:43.4"," 0000:38:30.0", 3.1027E+00,167
"31-DEC-1985","23:57:58.4"," 0000:38:45.0", 3.1027E+00,168
"31-DEC-1985","23:58:13.4"," 0000:39:00.0", 3.1027E+00,169
"31-DEC-1985","23:58:28.4"," 0000:39:15.0", 3.1027E+00,170
"31-DEC-1985","23:58:43.4"," 0000:39:30.0", 3.1026E+00,171
"31-DEC-1985","23:58:58.4"," 0000:39:45.0", 3.1026E+00,172
"31-DEC-1985","23:59:13.4"," 0000:40:00.0", 3.1025E+00,173
"31-DEC-1985","23:59:28.4"," 0000:40:15.0", 3.1025E+00,174
"31-DEC-1985","23:59:43.4"," 0000:40:30.0", 3.1025E+00,175
"31-DEC-1985","23:59:58.4"," 0000"40:45.0", 3.1025E+00,176
"01-JAN-1986","00:00:13.4"," 0000:40:59.9", 3.1024E+00,177
"01-JAN-1986","00:00:28.4"," 0000:41:14.9", 3.1024E+00,178
"01-JAN-1986","00:00:43.4"," 0000:41:29.0", 3.1024E+00,179
"01-JAN-1986","00:00:58.4"," 0000:41:44.9", 3.1024E+00,180
```

DATA ACQUISITION, TEST. MEASUREMENT, ANALYSIS AND CONTROL USING PCI-20040S-1 "LABTECH NOTEBOOK"

INTRODUCTION

PCI-20040S-1 is the model number for the industry standard LABTECH Notebook, designed for PCI products.

LABTECH Notebook is an integrated, general-purpose software package for data acquisition, monitoring, and real-time control (see Figure 1). It runs on the IBM PC, XT, AT and other PC-compatible computers.

Notebook couples to many of the components within the PCI-20000 system including the PCI-20001C, PCI-20041C, and PCI-20098C Series Carriers and the PCI-20002M, PCI-20003M, PCI-20004M, PCI-20005M, PCI-20007M, PCI-20019M, and PCI-20021M Series of Modules.

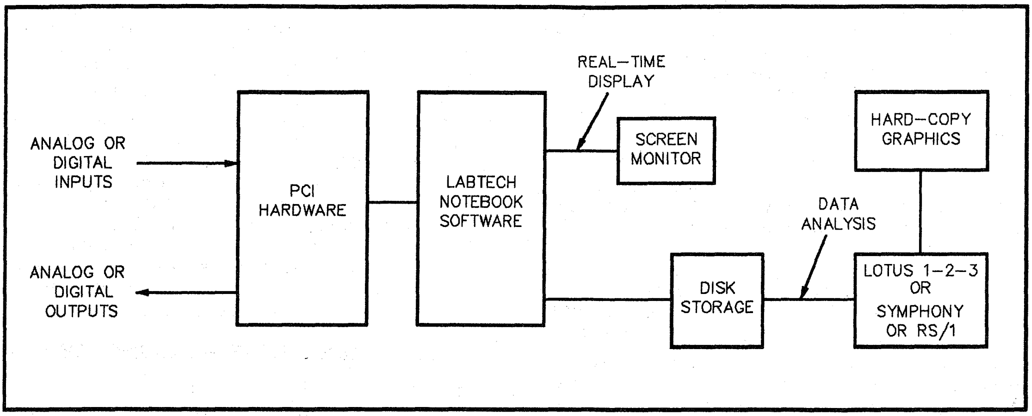


FIGURE 1. A Functional Diagram of LABTECH Notebook.

DATA ACQUISITION AND ANALYSIS USING LABTECH NOTEBOOK

The following example will illustrate the ease with which Notebook can be used to perform data acquisition and analysis tasks.

Imagine that we are performing a series of tests involving a gas contained in a sealed vessel. During the test, a chemical reaction occurs, causing both the pressure and temperature in the vessel to rise. The pressure is measured using a sensor located inside the sealed vessel. At the same time, the temperature both inside and outside the vessel is monitored using thermocouples.

Given this experimental setup, we will use LABTECH Notebook to perform the following tasks:

- First, we will perform a data acquisition run which will last for a period of three seconds, during which data from the sensors will be sampled at a rate of 100Hz.
- Once the pressure data has been taken, its time-derivative will be computed and the maxima of both the pressure and pressure-derivative curves will be found.
- In addition, we will fit the data to a mathematical model of the gas-heating process.
- After the processing is complete, we will create a data-base so that we may catalogue the results of this and subsequent experiments.

SETTING UP AND PERFORMING THE DATA ACQUISITION

Once the data acquisition problem has been defined, we can begin setting up Notebook. First we select the SETUP function from the main menu.

Our setup will be divided into three parts, represented by the first three choices in the SETUP menu: CHANNELS, FILES and DISPLAY. The real-time capabilities of Notebook are divided among these three functions. CHANNELS defines the transfer of data between the PCI hardware and Notebook, FILES is used to setup the transfer of data between Notebook and the disk storage files, and DISPLAY controls Notebook's real-time display.

We will begin by selecting Channels from the SETUP menu. A lower-level menu appears, offering two choices: NORMAL or HIGH- SPEED. Since for our example, data will be taken at a rate of 100Hz, the NORMAL mode will be adequate. Having selected NORMAL, an option table appears on the screen (see Figure 2).

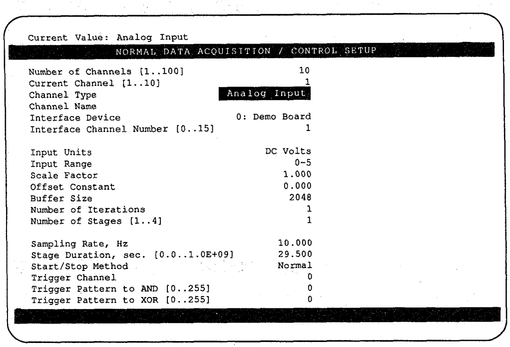


FIGURE 2. The CHANNELS Option Table.

By examining the current values for each of the setup conditions we can determine which need to be changed to conform to our example problem.

The first entry is the Number of Channels. Since we will be taking data from three sources (a pressure sensor and two thermocouples), we will use three of the PCI's channels. In addition, we will use LABTECH's time stamping capability in a fourth channel. We indicate this by entering a 4 in the table.

The next entry is the current channel. We should note here that the screen shows the setup condition entries for only one channel at a time. The entries from other channels are on other "pages". To view the other setup conditions, we will change to the corresponding Page number. In our example, we have three channels. To call up the entries for the second channel, we would change the current page number to two. The screen would then be redrawn to show "Page 2".

The remaining setup conditions are self-explanatory. We are using analog input channels (as opposed to digital inputs), so for Channel Type we will enter the code for A/D. The interface device corresponds to the particular PCI hardware being used for this test (PCI-20000, etc.). Device Channel Number refers to the actual physical channel on the module or board.

We will be using one iteration and one STAGE for our simple example, so the Count and Number of Stage entries will be set to one. The Scale Factor and Offset Constant will be set to convert the voltage output from the sensors to engineering units such as PSI or degrees. As noted above, the Sampling Rate will be 100Hz and the Run Duration will be three seconds.

Let us suppose that our experimental setup involves a switch which initiates the chemical reaction in the sealed vessel, and that the switch is also connected to a digital input of the PCI system. We can use this switch as a trigger for starting the data acquisition. For Starting Method, we choose a Triggered start instead of a Normal or Time-delayed start. The CHANNELS setup is now complete. The resulting option table is shown in Figure 3.

```
Current Value: Analog Input
              NORMAL DATA ACQUISITION / CONTROL SETUP

Number of Channels [1..100]                         4
Current Channel [1..10]                             1
Channel Type                             Analog Input
Channel Name                                 Pressure
Interface Device                          2: PCI-20000
Interface Channel Number [0..15]                    1

Input Units                                  DC Volts
Input Range                                      0-10
Scale Factor                                    4.500
Offset Constant                                12.000
Buffer Size                                      2048
Number of Iterations                                1
Number of Stages [1..4]                             1

Sampling Rate, Hz                             100.000
Stage Duration, sec. [0.0..1.0E+09]             3.000
Start/Stop Method                             Trig On
Trigger Channel                                     0
Trigger Pattern to AND [0..255]                     1
Trigger Pattern to XOR [0..255]                     0
```

FIGURE 3. The CHANNELS Option Table After Setup.

When we leave the option table, the SETUP menu reappears. This time we choose FILES from the menu, and another option table appears.

This option table contains setup conditions which will control the storage of our data on a disk. Again, we enter the values appropriate for the example problem. We will set up one data file for the pressure data, and another data file for both sets of temperature data. To do this, we will enter 2 as the Number of Data Files.

The FILES option table has a "page" system similar to that of the CHANNELS. Here, each page refers to a separate data file. For each data a File Name, Data Storage Mode, and File Header labels will be specified. The data storage mode determines the format in which the data is stored: ASCII Real, ASCII Integer, Binary Real, or Binary Integer.

The Number of Channels entry determines how many channels of data will be placed in a particular data file. In our first data file, data will come from two channels corresponding to time and pressure. In the second data file, there will be two channels providing data, one for each of the thermocouples. After we have entered all the appropriate information, the FILES option table will appear as shown in Figure 4.

All that remains is to set up the real-time display. Upon leaving the FILES option table, we re-enter the SETUP menu, and choose the DISPLAY function. A lower-level menu appears, offering two selections: WINDOWS and TRACES. Each corresponds to an option table. The WINDOWS option table determines the size, number, and color of the graphs to be displayed on the screen during the data acquisition run.

```
Current Value: ASCII Real
                          FILES SETUP

Number of Data Files [0..12]                  2
Current Data File [1..2]                      1
Data File Name                            Pres3
Data Storage Mode                    ASCII Real

Number of Header Lines [0..4]                 4
Header Line 1                     Pressure Data
Header Line 2                           Test #3
Header Line 3                             $DATE
Header Line 4                            Oxygen
Number of Channels in File [0..35]            2
Channel  Number [1..2]                        4        1
Channel Name                               Time Pressure
Channel Units                              Sec.     Psig
Field Width (ASCII Files)                    10       10
Decimal Places (ASCII Real Files)             2        3
```

FIGURE 4. The FILES Option Table After Setup.

TRACES is used to set up the data traces which will be drawn in the windows. We will use WINDOWS first, and set up two windows: one large one, in which we will display the pressure data, and a smaller one, in which data from the two temperature sensors will be displayed.

Once again, we enter an option table. For the first entry, Number of Windows, we enter a 2. The table then breaks out into two columns, one for each window.

We choose position limits for each window. All windows are in the shape of rectangles. The limits determine where the edges of the rectangles will appear on the screen during the data acquisition run. The limits must be in the range from 0 to 1, where 0 represents the left edge of the screen (for the left and right limits) or the bottom edge of the screen (for the lower and upper limits), and 1 represents the right edge or upper edge of the screen.

```
Current Value: 2
                          WINDOW SETUP

Number of Windows [0..15]                        2

              Window Number                      1          2
Left  Limit, x0 [0.0..1.0]                   0.100      0.100
Lower Limit, y0 [0.0..1.0]                   0.100      0.750
Right Limit, x1 [0.0..1.0]                   0.990      0.990
Upper Limit, x0 [0.0..1.0]                   0.600      0.990
Y Axis Title                              Pressure       Temp
X Axis Title                                  Time       Time
Length of Time (X) Axis in sec.              3.000      3.000
X Tic Start Value                            0.000      0.000
X Tic End Value                              3.000      3.000
Number of X Tics [0..11]                         4          4
Y Tic Start Value                            1.000      1.000
Y Tic End Value                              4.000      4.000
Number of Y Tics [0..11]                         4          4
Window Color                                  Blue     Yellow
Scroll Size [0.0..1.0]                       1.000      1.000
```

FIGURE 5. The WINDOWS Option Table After SETUP.

We will also enter the axis scale ranges in this option table, as well as labels for both axes. In addition, the color of each window will be chosen. Up to eight colors are available on systems with color monitors.

The WINDOWS setup is now complete; Figure 5 shows the option table. We may leave this option table and enter the TRACES option table.

Although we have set up only two windows, the Number of Traces for this run is three, since we wish to display the data from the first three channels. In the option table, the Channel Number for each trace will be specified. In addition, we will enter a window number for each trace.

Since we want the pressure trace to appear in the larger, lower window, we enter Window Number 1. The number 1 corresponds to the left-most column of the WINDOWS option table. The two temperature traces will be places in Window Number 2. We will also choose a color for each trace. When this is done, the TRACES option table will appear as shown in Figure 6, and we can return to the SETUP menu.

Current Value: 3

TRACE SETUP

Number of Traces [0..50]	3		
Trace Number	1	2	3
Window Number [1..5]	1	2	2
Line Color	Green	Red	Black
Line Type	Solid	Bold	Solid
Data Point Symbol	None	None	None
Y Channel Number [1..5]	1	2	3
Y Minimum Displayed Value	0.000	0.000	0.000
Y Maximum Displayed Value	10.000	10.000	10.000
Trace Type	T vs Y	T vs Y	T vs Y
For Meters Only:			
Number of Decimal Places	2	2	3
For X vs Y Only:			
X Channel Number [1:5]	1	1	1
X Minimum Displayed Value	0.000	0.000	0.000
X Maximum Displayed Value	4.000	4.000	4.000

FIGURE 6. The TRACES Option Table After Setup.

Now that the entire setup has been completed, we can use VERIFY to perform a global checking routine to insure that setup conditions are consistent between the three SETUP areas. VERIFY displays a summary of the setup condition, and lists inconsistencies between the option tables. For example, if we had asked for a trace from Board 2, Channel 3 in the TRACES option table, but had not entered this channel in the CHANNELS option table, VERIFY would display an error message.

SAVE/RECALL can be used to save the current setup conditions (that is, the contents of the setup files created and used internally by Notebook), or to RECALL a set of setup conditions that has been previously saved.

STARTING THE RUN

LABTECH Notebook is now ready to perform the data acquisition we specified in the problem statement above. To begin the run, we return to the main menu and select the GO function. The screen will clear and two windows will appear on the screen.

Notebook now waits for the trigger we specified in the CHANNELS option table. Once the switch has been thrown, the gas in the sealed vessel will begin to heat up and Notebook will begin to take data. If we had not specified a triggered start, Notebook would have begun to take data after GO was invoked. As the data is taken, it is displayed in the windows on the screen. At the end of the run the data is written to a data filed on the specified disk drive. The resulting display is shown in Figure 7.

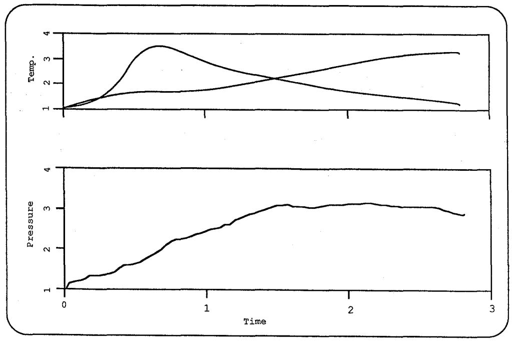


FIGURE 7. The REAL-TIME Display.

DATA MANIPULATION AND GRAPHING

We may now begin analyzing the pressure data we have taken. This can be done in several ways, including adding calculated channels to do the data reduction while the data is being collected. For this example, we will use the Lotus 1-2-3 spreadsheet program. Using 1-2-3 we will set up a single worksheet to perform all our analysis tasks.

The worksheet is a matrix of "cells". Columns are denoted by letters, and rows are denoted by numbers. We may enter numbers, characters, or formulas in the cells using the same method we learned for the SETUP option tables. We move the highlighted rectangle to the appropriate cell using the cursor control keys, then enter the value by typing it and pressing the ENTER key.

The formulas contain variables which are cell addresses (e.g., A4, D23). The displayed value of a cell containing a formula will be the result of that formula when the variables are replaced by the current values of the addressed cells. When the values of these addressed cells change, the displayed value of the formula cell will change accordingly.

A particularly powerful feature is 1-2-3's use of worksheet "templates". A worksheet format can be standardized so that each time it is used, formulas, labels, and graph features will be entered and arranged in the same way.

We will take advantage of this feature in using 1-2-3 to solve our data analysis problem. With the Lotus diskette in place, the 1-2-3 program is invoked directly from Notebook by selecting the ANALYZE function from the main menu.

After 1-2-3 is started, an empty worksheet appears on the screen. We will set up a worksheet template with the following characteristics:

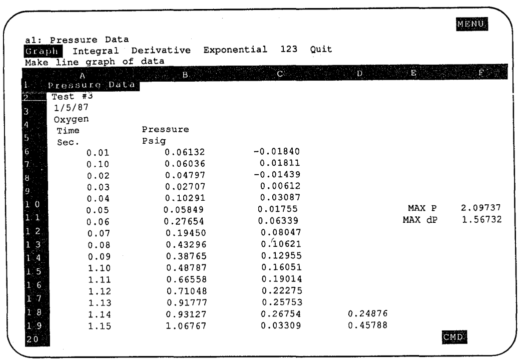
- The left-most two columns will be left empty for now. It is into these columns that the time and pressure data will be imported, once the worksheet is set up.
- In Column C, we place a formula in each cell.

Our aim is to differentiate the pressure data. We will do this by taking the differences between pressure data points and dividing them by the corresponding time differences. If we did this on a point-by-point basis, however, the result would be a very noisy derivative curve.

In the cells of this column, therefore, we will enter a formula to perform a five-point smoothing function. The pressure data will be imported into Column B. To do this, we only need to type a formula into one cell. The 1-2-3 "Copy" command is then used to copy it into each of the other cells in the column.

- In Column D, we will place the appropriate formula in each cell to compute the derivative using the "smoothed" data of Column C.
- Two more values need to be found: the maximum pressure and the maximum pressure derivative value. We will compute these maxima by placing the 1-2-3 "Max" command (with appropriate arguments) in two separate cells in Column E.

Once the template has been set up, we can import our data file into the worksheet. As the data is placed in Column B, the formulas of Columns C, D and E are re-calculated. Column D will now contain the calculated time-derivative of the pressure data. The two cells in Column E will contain the maximum values for the pressure and pressure-derivative data. The filled-in worksheet is shown in Figure 8. These calculated data, along with the rest of the worksheet, can be saved for later use.



MENU

a1: Pressure Data

Graph Integral Derivative Exponential 123 Quit

Make line graph of data

	A	B	C	D	E	F
1	Pressure Data					
2	Test #3					
3	1/5/87					
4	Oxygen					
4	Time	Pressure				
5	Sec.	Psig				
6	0.01	0.06132	-0.01840			
7	0.10	0.06036	0.01811			
8	0.02	0.04797	-0.01439			
9	0.03	0.02707	0.00612			
10	0.04	0.10291	0.03087			
	0.05	0.05849	0.01755		MAX P	2.09737
11	0.06	0.27654	0.06339		MAX dP	1.56732
12	0.07	0.19450	0.08047			
13	0.08	0.43296	0.10621			
14	0.09	0.38765	0.12955			
15	1.10	0.48787	0.16051			
16	1.11	0.66558	0.19014			
17	1.12	0.71048	0.22275			
	1.13	0.91777	0.25753			
18	1.14	0.93127	0.26754	0.24876		
19	1.15	1.06767	0.03309	0.45788		
20						

CMD

FIGURE 8. The Worksheet After a Data File Has Been Imported.

Note that all of these functions — five-point smoothing, differentiation, finding the maxima of the pressure and its derivative — could all have been done with LABTECH using calculated channels (in real-time if desired).

GRAPHING WITH 1-2-3

We can also use 1-2-3 to create a graph of the experimental and calculated data. The time data from Column A will be used for the X axis, and the pressure and pressure derivative data will be plotted against time. 1-2-3 allows the use of different colors or intensities to denote different categories of data. Titles and appropriate labels may also be included. The graph setup conditions can be saved along with the worksheet template.

After this graph has been set up exactly the way we want it, 1-2-3's PrintGraph function may be used to produce a publication quality hard-copy plot of the test results. This hard-copy graph may be plotted on either a dot-matrix printer or a pen plotter. Figure 9 shows the final results, obtained with a multi-color pen plotter.

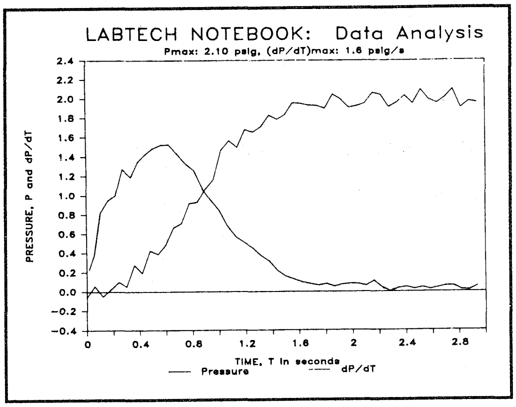


FIGURE 9. The Lotus 1-2-3 Graph.

Our data manipulation and graphing using 1-2-3 are now complete. Note that only one column of data has been brought in from the LABTECH Notebook data file. The derivative and maxima data are computed by 1-2-3 from the raw data.

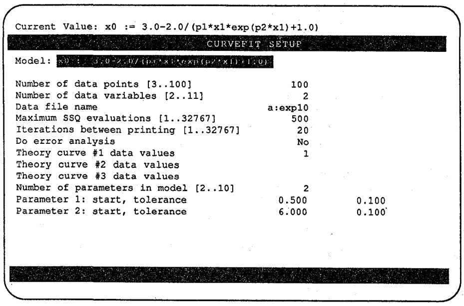
USING LABTECH NOTEBOOK'S CURVE-FITTING FEATURE

Notebook's nonlinear regression function can be used to fit our experimental pressure data to a predetermined mathematical model. For example, suppose we had developed the following model for the increase in gas pressure due to heating:

$$P = RT/V\left(3 - \frac{2/a}{(t+1)\exp(b\,t)}\right)$$

where:
- P = Pressure
- R = Gas Constant
- T = Temperature
- V = Volume
- t = Time
- a, b = Parameters to be determined

We will use LABTECH Notebook to find reasonable values for the parameters, a and b. To invoke the nonlinear regression function, we select CURVE-FIT from Notebook's main menu. A lower-level menu appears, offering two choices: EXECUTE and SETUP. SETUP will be selected first. An option table similar to those we used for the data acquisition setup appears, as shown in Figure 10.


```
Current Value: x0 := 3.0-2.0/(p1*x1*exp(p2*x1)+1.0)
                         CURVEFIT SETUP
Model: x0 := 3.0-2.0/(p1*x1*exp(p2*x1)+1.0)

Number of data points [3..100]                100
Number of data variables [2..11]                2
Data file name                            a:exp10
Maximum SSQ evaluations [1..32767]            500
Iterations between printing [1..32767]         20
Do error analysis                              No
Theory curve #1 data values                     1
Theory curve #2 data values
Theory curve #3 data values
Number of parameters in model [2..10]           2
Parameter 1: start, tolerance               0.500       0.100
Parameter 2: start, tolerance               6.000       0.100
```

FIGURE 10. The CURVE-FIT Option Table.

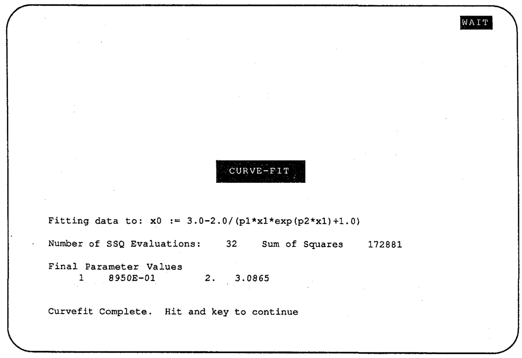
Our theoretical model belongs in the first entry. The entire equation is entered, substituting the variable names with labels X0 through X9, and the parameter names with the labels P1 through P9.

Next, we will enter the number of data points to be used by the curve-fitting routine. During our data acquisition run, we took 100 data points-per-second, for three seconds. Since we intend to use all of these, we will enter 300 here. If we entered the number 200, the first 200 points in the data file would be used, and the last 100 points would be ignored. In addition, the data file name, number of variables, and number of parameters will be entered. There are two variables and two parameters in our model.

For each parameter, a starting value and tolerance will be chosen. CURVE-FIT uses the starting values as initial estimates in its regression routine. The routine will continue until the change in the parameter between iterations is less than the tolerance value. Of course, if the model is not appropriate for the data, the routine may never be able to find appropriate parameter values. For this reason, we will enter a Maximum SSQ (Sum of Squares) Evaluations value. This value determines the maximum number of times CURVE-FIT will repeat the regression routine.

We can also choose to have an error analysis performed on the quality of the fit to the model. The output from this analysis consists of estimates of the parameter standard deviation and a parameter correlation matrix. The Do Error Analysis entry will be set to 1 if we wish to have the routine perform this analysis. The CURVE-FIT setup is now complete. After leaving the option table, we select EXECUTE from the lower-level menu. The routine will begin, and the screen will display parameter information as the routine progresses. CURVE-FIT creates five output files, containing:

- Final values of the parameters, along with estimated standard deviations.
- Experimental data points used by the routine (one column for each variable).
- Theoretical data computed from the model using the final parameter values.
- Final residual values for each of the experimental data points.
- A report containing the results of both the nonlinear regression routine and the error analysis. This file is a readable summary of the regression procedure and results.


```
                                                          WAIT

                          CURVE-FIT

Fitting data to: x0 := 3.0-2.0/(p1*x1*exp(p2*x1)+1.0)

Number of SSQ Evaluations:   32   Sum of Squares   172881

Final Parameter Values
   1   8950E-01       2.   3.0865

Curvefit Complete.  Hit and key to continue
```

FIGURE 11. The CURVE-FIT Screen Display.

The screen output prompts us when CURVE-FIT is finished, and displays the final parameter values, as shown in Figure 11.

We can use Lotus 1-2-3 to create a graph comprising the theoretical and experimental data for our experiment. LABTECH Notebook has an "autostart" template (a worksheet template which is automatically started when the 1-2-3 program is invoked from the main menu) which can be used for this purpose. Figure 12 shows the graph created by this worksheet template using the experimental and theoretical data from our example.

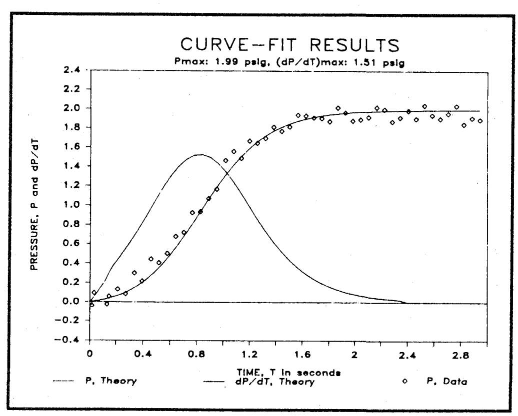


FIGURE 12. 1-2-3 Graph Using CURVE-FIT Output.

9

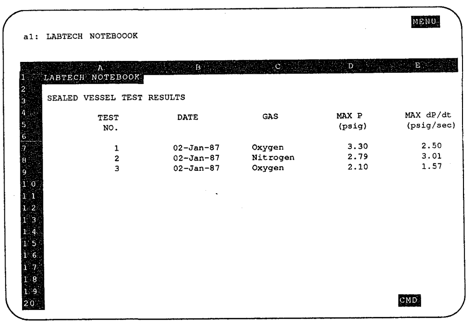
CREATING A DATA BASE OF TEST RESULTS

In a typical laboratory or testing situation, the example above would be only one of many performed in the same testing environment. Unless some means of organizing the output files can be found, the resulting quantity of data files and analysis reports quickly becomes unwieldy.

1-2-3 facilitates the creation of a test result data base. A separate worksheet, such as the one in Figure 13, can be used to store important information for identifying a particular test run.

In the figure, test runs are identified by test number, test data, type of gas used and maximum pressure derivative value.

If the worksheet were to contain a hundred such rows of information, it would be difficult to visually search the table for information about a particular test. In this case, the 1-2-3 Data commands can be used to locate specific test runs on the basis of information in any one of the five columns of our worksheet. For example, if we want to find a test in which the gas used was nitrogen, we use the Data Find command, and 1-2-3 displays the first row in the table with the word "nitrogen" in the gas column. Similarly, if we wish to sort the table by test date, we give the Data Sort command, indicating the test date column as the sorting index, and ask for a sort in ascending order. 1-2-3 will then rearrange the rows in the correct order.



TEST NO.	DATE	GAS	MAX P (psig)	MAX dP/dt (psig/sec)
1	02-Jan-87	Oxygen	3.30	2.50
2	02-Jan-87	Nitrogen	2.79	3.01
3	02-Jan-87	Oxygen	2.10	1.57

FIGURE 13. A Data Base Worksheet.

PRODUCTION LINE TESTING WITH LABTECH NOTEBOOK

Once the setup conditions and data analysis worksheets have been developed, LABTECH Notebook can be configured for production-line testing very easily. All that is required is a very short program written in Notebook's programming option language, MAGIC/L. This program can either be entered at the console and executed immediately, or stored in an autostart file which will be executed when the computer's power is turned on.

A program to collect an entire shift's work of data, say 100 pressure vessel tests, might look like the following:

```
iter100       ;Repeat routine 100 times
    dogo      ;Invoke GO function
    r_123     ;Invoke 1-2-3, perform
               analysis
loop          ;Return to first command
```

This simple program will perform 100 data acquisition runs. Each data acquisition will be automatically triggered by an electrical signal from the production line. After each run, the data files for the run will be immediately analyzed. The results from all the runs will be accumulated in a data base file (using 1-2-3's macro capability), thus completely automating the shift's testing.

CAPTURING AND ANALYZING TRANSIENT WAVEFORMS WITH A PERSONAL COMPUTER

INTRODUCTION

Until recently, the acquisition of transient analog data in the 100Hz to 100kHz region was dominated by storage oscilloscopes and expensive, dedicated, data acquisition systems (DAS). Any non-repetitive phenomenon is a candidate for analysis with this type of system. Some examples include:

- Mechanical shock and vibration studies
- Monitoring the onset of high-speed chemical reactions such as explosions
- Measuring medical signals such as QRS complexes, HIS bundle response, and nerve impulses
- Analyzing audio transients.

In addition to capturing transient signals, some processing oscilloscopes and dedicated DASs also provide a limited level of analysis capability. Usually, however, a computer is required to archive the data, to do special-purpose analysis and to generate graphs and reports. These types of systems are usually linked to a host computer via an RS-232 or IEEE-488 bus. As a result, speed is severely limited. Obviously, it would be far more efficient to have the computer as part of the system that took the data in the first place. The recent availability of powerful, low-cost personal computers (PCs) has enhanced the above methods, but more importantly has opened the door to new techniques.

The PCI-20000 System

State-of-the-art data acquisition systems are now available as board-level products. For example, the PCI-20000 can plug directly inside any IBM-compatible PC, forming the basis of a complete data acquisition, test, measurement and control system. With appropriate software, a package can be put together to acquire, display, measure and analyze transient signals for a fraction of the cost of yesterday's scopes or DASs. Besides the advantage of lower cost, the PCI-20000 approach has greater overall speed and versatility. The system's data acquisition rate can be as high as 180kHz in the PC or PC/AT.

The PCI system is based upon a motherboard, or Carrier approach. The carrier plugs into the computer, and modules plug onto the carrier, adding desired functionality. A large family of modules is available. Up to three modules can plug into a given carrier. Typically, each module performs one data acquisition function such as analog input, analog output, counter/timer, digital input/output, etc. Multiple carriers can be used if required to accommodate a very large application.

Thus, the PCI-20000 combines the high speed of a computer-based product with the flexibility, modularity, and expandability of a plug-in board device.

The Transient Recorder

This describes how to combine the IBM PC (or compatible) with the PCI-20000 to produce a low-cost, high-performance transient data recorder. A complete program listing is included. The features of the transient capture system include:

- Menu driven, no programming required
- 12-bit resolution and linearity
- Sample rates from 150Hz to 50kHz
- Hardware slope and level triggering
- Capture of up to 25,000 samples
- Selection of one of eight channels
- Auto-scaled graphic display
- Data stored and recalled to and from disk

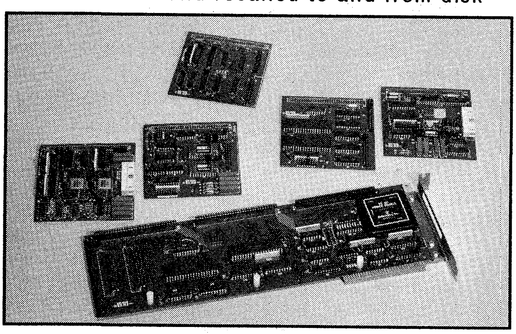


FIGURE 1. The PCI-20000 System.

The hardware (PC and PCI) is combined with a BASIC language program to provide the fundamental capabilities that a transient capture system needs. The system can acquire data, display data, store data to disk, and recall stored data from disk. The data is stored in ASCII format so that it can be manipulated, analyzed and printed by other BASIC programs, or word processors. There is an extensive library of PCI software drivers to interface with the PCI hardware. These drivers make it easy for a programmer to "talk" to the hardware, without being familiar with the details of multiplexers, programmable-gain amplifiers, sample holds, analog-to-digital converters, etc. The program shown here makes wide use of this library.

Software Highlights

The program begins by drawing a box for the graph on the screen, and by displaying the default data acquisition parameters along with the system menu (Figure 2). The data acquisition parameters include:

- Sample rate
- Trigger level and slope
- Channel number
- Amount of data to be taken.

The menu allows you to:

- Exit the program
- Set the acquisition parameters
- Acquire and display a data set with the above parameters
- Execute one of the file operations.

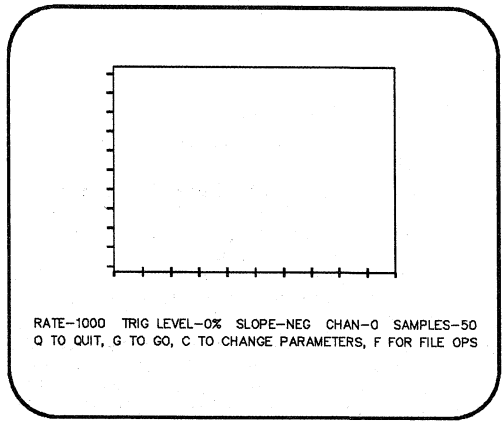


FIGURE 2. System Menu.

If you choose to take data, the system automatically acquires, scales and plots the data on the screen. The autoscale function insures an optimum fit for all of the data on the graph.

If you choose one of the file operations, a second menu is displayed. You can choose to look at the disk directory, store the current data set to a file, recall a data set from a previously stored file, or re-plot the current data set.

Capturing the Data

The hardware and part of the software is dedicated to the task of capturing the transient data. In this type of system, the amount of software which actually interacts with the hardware is small, yielding maximum speed. The majority of the work related to capturing the data is done directly by the hardware. Most of the software is involved in generating the data display and in supporting the menu-driven user interface.

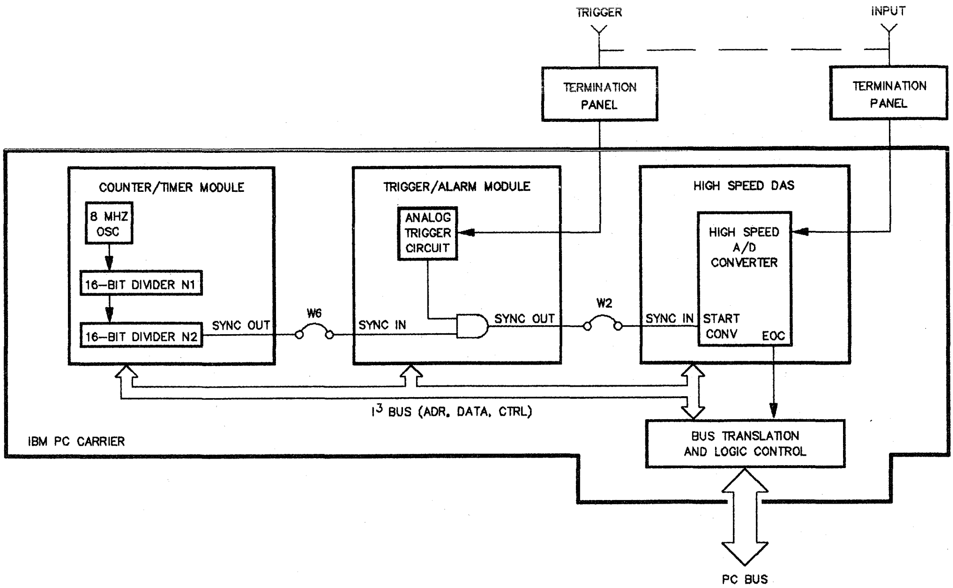


FIGURE 3. System Block Diagram

The fundamental requirements of a useful transient capture system are:

1) **The Ability to Begin Data Capture at the Right Time** — Because the PC has finite memory space, acquiring data at high speed can quickly fill up available memory. Therefore, it is important to be able to "trigger" the beginning of data capture at the point of interest.

2) **The Establishment of a Stable Data Acquisition Rate** —Data is usually time correlated. Many algorithms, such as the FFT, require the exact interval between data points to be known.

In this system, the capture of data begins when the input signal crosses a specified threshold in a given direction (as with an oscilloscope). Once this trigger condition has been met, the acquisition is paced by a crystal-controlled rate generator. Thus, both of the above criteria are met; the slope/level triggering insures that the event of interest is captured, and the crystal-controlled time base insures a stable, jitter-free acquisition rate.

The triggering, timing and data acquisition functions are all available, in hardware, with PCI-20000 Instrument Modules. The hardware is configured by selecting the appropriate modules from the wide variety available, and by plugging them into a carrier. For this high-speed system the choices are:

- PCI-20001C-1 Carrier for the IBM PC
- PCI-20007M-1 Counter/Timer/Rate Generator Modules

—or —

- PCI-20041C-2 High Performance Carrier for the IBM PC

—and —

- PCI-20019M-1 High Speed Data Acquisition Module
- PCI-20020M-1 Trigger/Alarm Module.

Note that if you use the PCI-20041C-2 Carrier, no PCI-20007M Rate Generator module is required. This function is built into the PCI-20041C-2.

To facilitate connecting the input signals to the modules, termination panels and cables are also selected:

- PCI-20057T-1 High Density Analog Termination Panel
- PCI-20012A-1 6-ft Shielded Analog Cables, 2 required.

Finally, the PCI Language Software Support Package mentioned earlier, makes implementing the desired application much easier. While BASIC is used in this example, Turbo Pascal, C, and ASYST are also available.

- PCI-20046S-1 BASIC Language Modular Software Support Package.

Appendix A contains the details on how to configure the individual modules and plug them together. Figure 3 shows a block diagram of the system.

Hardware Description

The carrier contains space for up to three plug-in modules. It also has facilities which allow one module to pass both data and synchronization signals to other modules on the carrier. These unique abilities are made possible by the Intelligent Instrumentation Interface Bus (I^3 Bus, patent pending). Each module has a SYNCIN and a SYNCOUT connection. Jumpers on the carrier determine the source of a module's

SYNCIN and the destination of its SYNCOUT. The ability to pass hardware timing signals from one module to another results in a very close timing relationship between the various modules. This is a key factor in the performance of this system.

As seen below in Figure 3, the Rate Generator's output connects through the Trigger/Alarm Module (via the I^3 Bus) to become the timing source for the Analog Data Acquisition Module (A/D). When the desired input conditions are satisfied, the Trigger/Alarm Module "gates" the Rate Generator signal to the A/D. Once "triggered", the A/D continues to convert the input data at the rate set by the Rate Generator, until the specified amount of data has been gathered.

Operation

While it is the hardware that defines the performance limits of this type of system, its utility and ease of use are defined by the software (program) which drives it. The program presented here provides all of the basic capabilities that a transient recorder must have: data capture, data display, and store/recall (to/from disk) capabilities for post-processing of the data. Many variations on this basic theme are possible. If desired, this program can be used as a model and be easily modified to implement a different approach.

The program makes extensive use of existing machine language subroutines. The subroutines provide a software interface to the hardware, eliminating the requirement that the user "handle" the multiplexers, sample/holds, A/D converters, etc. These routines are found in the PCI-20046S-1 BASIC Language Modular Software Support Package. The routines are loaded (before executing the main program) by running PCI146S_1.COM, provided on the package's distribution disk. Once installed, the subroutines are accessed via BASIC's CALL statements. Running PCI146S_1.COM will load the support routines into memory, and leave them resident. The base address of the routines is stored in the PC at user interrupt vector 60 (hex). This information is used by the program to determine where in memory the routines are located. The "Header" file, which is also provided on the distribution disk, defines the variable names and the other conventions of the subroutine package.

The User Interface

Referring again to Figure 2, we can describe in more detail the user interface portion of the program. Using the single keystrokes indicated on the menu, you can choose to exit the program (quit), start an acquisition using the current parameters (go), change the acquisition parameters (change), or execute a file operation (file).

If you select "q", the program will terminate and return to BASIC.

Selecting "g" causes the system to first acquire a data set using the defined parameters (if none have been specified, the default parameters will be used). The data is then scaled to fit optimally on the graph, and plotted. The minimum and maximum values of both axes along with the value of the first data sample are labeled (see Figure 4). The program assumes that the A/D module is set up for ±10V full scale. If you choose to jumper the module for another range, remember to modify the related equations accordingly. If desired, the program can be changed to prompt the user for the range being used.

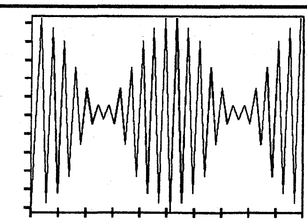


FIGURE 4. Data Display.

If you select "c", the program will erase the graph, redisplay the current parameters, and prompt you to enter new ones. The acquisition parameters which need to be specified are:

- Sample rate (default = 1000 samples per sec.)
- Trigger level (default = 0 volts)
- Trigger slope (default = negative)
- Channel number (default = 0)
- Number of samples (default = 50)

When you have specified all of the parameters, the system will automatically execute a "go" command.

Selecting "f" erases the graph and displays the File Operations menu, as shown in Figure 5. The available options allow you to store the current data set to disk, recall a previously stored data set from disk, plot the current data set, and show the disk directory.

If you select "s", the program will prompt you for a file name, and then will store the current data set, along with the acquisition of parameters to the named file.

FILE OPERATIONS

s to save the current data and setup
r to recall stored data and setup
p to plot current data
d for directory listing
**** Your choice, please****

FIGURE 5. File Operations Menu.

Selecting "r" generates a prompt for a file name. The screen is then erased and the new data set, along with its acquisition parameters, is plotted.

Selecting "d" will list the disk directory so you can see what files are available, while "p" will return you to the main menu, re-plotting the current data set.

The Program Details

The program consists of several well-defined functional blocks (subroutines). Each subroutine is called from one of the two menus, or during initialization. A complete listing of the BASIC source code is shown in Appendix B. The titles and location of each subroutine are listed below:

Line 100	Merge the Header file into the program
Lines 1000 - 1170	Initialization
Lines 1180 - 1410	Main menu routine
Lines 1420 - 1490	Error checking for PCI-20000 system
Lines 1500 - 1650	Disk operations menu
Lines 1660 - 1760	Directory display
Lines 1770 - 2000	Save to disk
Lines 2010 - 2250	Recall from disk
Lines 2260 - 2580	Get input parameters from user
Lines 2590 - 2900	Set up the hardware
Lines 2910 - 3050	Acquire data
Lines 3060 - 3450	Draw the plotting window, and annotate the screen
Lines 3460 - 3570	Calculate Min, Max, Span, and X interval of the data
Lines 3580 - 3860	Scale and plot the data

Since it is impossible to anticipate all the ways that a user might apply this system, a concerted effort was made to write the subroutines so that they could be lifted from this program, and applied elsewhere with a minimum of effort. To this end, the structure was designed so that changes could be made to any one routine with a minimum of side-effects on the others.

Initialization

Line 100 merges the PCI-20046S header file with the main program. This file defines all of the PCI-20046S constants. The first time the program is run, the system merges the header and overwrites Line 100 with a comment. This procedure insures that the latest version of the header file will always be used. Line 1000 defines all variables not beginning with the letter "f" as integer variables. This is a convenient way to make sure that you don't accidentally attempt to send a floating point number to a routine expecting an integer. All of the calls to the PCI-20046S software routines expect their parameters to be integers.

Lines 1040 initializes the PCI-20000 software system, and line 1050 initializes the hardware.

Line 1120 dimensions the data array used in the program. The maximum number of data points allowed in this version is 5000. This number was selected because interpreted BASIC takes a very long time to process and plot large arrays. If larger arrays are desired, it would be a good idea to compile the finished program.

The default values for the data acquisition parameters are set in lines 1130 and 1140. The parameters and values are:

- Sample Rate (FSPS), Initialized to 1000 samples per second
- Trigger Level (FTL), Initialized to 0 volts
- Trigger Slope (S$), Initialized to negative (-)
- Channel Number (AI.CHN(1)), Initialized to channel 0
- Number of Samples (PASSES) Initialized to 50

Line 1150 calls the routine which sets up the hardware with the defined parameters, and line 1160 calls the routine which draws the window that the plot will appear in. Both of these routines will be discussed in detail later.

The Main Menu Routine

This routine uses the INKEY$ function to accept a single-keystroke input from the user. The available choices are displayed by lines 1220 and 1230. Line 1240 accepts the input and lines 1250 through 1280 determine which operation was requested. If the input was not one of the permitted keys, line 1290 beeps and send the computer back to line 1240 for another input.

Lines 1340 through 1400 list the subroutines which do the work of setting parameters, acquiring data and displaying data. Two keys can activate these routines. A "g" will enter at line 1360, acquire a new data set and plot it using the parameters already in force. A "c" enters at line 1340 to first get the new parameters. The code then sets up the hardware and executes a data acquisition. Finally the new data is plotted.

The other two menu choices either activate the File Operations Menu (f) or the program (q).

Getting User-Entered Parameters

If a "c" is typed from the main menu, the Change subroutine is called. The routine begins at line 2290 by clearing the screen, and by reprinting the current set of parameters for reference. The program then prompts you for each of the parameters required, and checks your inputs against limits. A different user interface could be substituted if desired, so long as when you exit from this routine, the variables FSPS, FTL, S$, AI.CHN(1), and PASSES are all set to the desired values.

Setting Up the System

This is the routine which passes the user-supplied inputs to the hardware for the data-acquisition run. Most of the calls to the PCI-20046S-1 Software Support Package are executed from here.

In lines 2670-2700, the Rate Generator Module is set up to deliver a timing signal at a frequency equal to FSPS. The rate generator consists of an 8MHz oscillator followed by two dividers. COUNT1 and COUNT2 set the divide values and hence set the output frequency to the desired value. FSPS = 8MHz/(COUNT1 * COUNT2). In this program, we have arbitrarily set COUNT2 = 2, so that COUNT1 = 4MHz/FSPS. Since both COUNT1 and COUNT2 can assume only integer values, it is possible that the frequency generated will not be exactly that which was requested. Therefore, in line 2690, we compute the actual value of FSPS and display it on the main menu.

Line 2700 contains the actual call to the Software Support Package that writes data to the chips on the Rate Generator Module. The format of this call is representative of all the calls used in this program. The keyword CALL tells the computer to jump to a machine language subroutine. The variable name following the call (in this case CNF.RG) defines the starting address of this particular routine within the subroutine library. This offset is specified in the header file which was CHAIN MERGEd at line 100. Any parameters to be passed to the routine are contained in parentheses following the call name.

Lines 2750-2780 set up the Trigger/Alarm Module. This module tests the trigger input signal against both high and low limits. The limits can be programmed to produce a trigger when the input either enters or leaves the "window" defined by the programmed limits. This establishes the system's trigger level and slope. Because limits are set with eight-bit resolution, a code of zero corresponds to -10V while 255 corresponds to +10 - 1LSB = 9.92V. Line 2750 sets one of the limits to FTL, defining the trigger level. The other limit (S$) is set to 0 for a negative slope or 255 for a positive slope.

Lines 2860-2880 set up the parameters for CNF.HS, the routine which defines the high-speed, block mode, analog acquisition. This high-speed routine will scan a channel list specified by the array AI.CHNS. In this program there is only one analog channel. The variables PAC.TYPE and PAC.CHN specify the signal which is to time the data acquisition. In our case, it will be rate generator channel zero —either the rate generator on the PCI-20007M Module or the built-in pacer clock on the PCI-20041C-2 Carrier, depending on which you are using. The variables TR.TYPE and TR.CHN specify signal which is to trigger the acquisition sequence. In our case, it will be the PCI-20020M-1 Trigger/Alarm Module. The variable HSMODE specifies the type of high-speed acquisition to be performed. Setting it to four specifies total hardware control — the fastest possible mode without DMA. In this mode, the Trigger/Alarm Module prevents rate generator pulses from reaching the PCI-20019M until the trigger conditions have been met. When the trigger occurs, A/D conversions are to be initiated directly by hardware. Thus, the system needs to monitor only the A/D's end-of-conversion signal. Each time "EOC" is true, data is stored in memory.

Getting the Data

Line 2960 is the start of the subroutine which acquires the data, while call HS.RUN actually performs the data acquisition. Once triggered, the HS.RUN routine monitors the A/D for an EOC signal and then stores the data in array Y(I), in the order in which it was taken. After the routine has stored the number of values specified by the variable PASSES, it returns control to BASIC. The variable SEGMNT must be set to 0. It will be used for future versions of the software support.

The data in Y(I) is in complementary offset binary format. Line 3030 converts the array into straight offset binary. A value of 0 corresponds to minus full scale (-10V), and a value of 4095 represents plus full scale (10V - 1LSB = 9.9951V).

Drawing the Box

This subroutine establishes a plotting window of defined size, and draws it on the screen. Other routines automatically scale the data to fit within the window.

Lines 3090 and 3100 clear the screen, erase the function key assignments and set the display to the high-resolution graphics mode.

Line 3150 defines the size and location of the plotting window. With IBM PCs and compatibles, coordinates 0,0 lie at the upper right-hand corner of the screen, while 640,200 is at the lower left. This means that increasing values of Y move the trace toward the bottom of the screen, which is backwards from what most people would expect. The size and location of the window are defined by specifying the upper right-hand corner and the lower left-hand corner of the window with variables TOPX,TOPY and BOTX,BOTY. Specifying the corners like this will take care of the inversion of the Y axis. In this program, you can place the window anywhere on the screen simply by changing the values of these variables. However, depending upon the size and location of the window, you may have to move some text to avoid overlap.

Lines 3190-3230 use the LINE command to draw the box. The variable BORD is used to draw the box two pixels larger, in the Y direction, than the actual size of the data window. This assures that if the data is scaled to exactly fit the defined window, it will never be plotted over the box lines themselves.

Lines 3270-3340 draw tic marks on the X and Y axes to form ten evenly spaced intervals for each axis. The size of the tics is adjustable and is set by XTIC and YTIC.

Lines 3380-3450 establish a text line at line 22 to display the acquisition parameters.

Finding Min and Max Data Values

In order to scale the data to fit the plotting window, this routine goes through all the data to find the highest and lowest data values. This is done in lines 3500-3570.

Line 3550 calculates two important parameters: the span of the A/D counts covered by the data, and the number of Y pixels available in the plotting window. The value of FYFACT tells the plotting routine how many Y pixels each A/D count is worth.

Line 3560 calculates how many pixels represent each sample along the "Y" axis.

Scaling and Plotting the Data

This routine uses the constants computed in the Min/Max routine to autoscale and plot the data. The vertical data to be plotted is in the array Y(I) in the form of A/D counts (integers between 0 and 4095, corresponding to -10V to 9.9951V). To enhance the plot, a line will be drawn from each point in the array to the next. On the time axis, each X coordinate is greater than the previous one by FXINC. The Y increments are computed based upon YSPAN and FYFACT.

Lines 3630-3720 convert the values of the min, max and first data points to volts, and prints them out on the left-hand side of the graph. Line 3960 computes and prints the total elapsed time represented by the graph on the right-hand side, along the X axis. Lines 3700 and 3710 establish the location of the first data point.

The actual scaling and plotting algorithm occupies lines 3760- 3860. For each pass through the loop, the current "new" X,Y point becomes the "old" point for the next pass, resulting in a continuous line being drawn through the data points.

The pixel value of the Y coordinate is computed in line 3770. The expression Y(J)-YMIN yields the distance, in A/D counts, from the smallest value in the array to the current data point. This value is multiplied by FYFACT and then added to the offset BOTY to find the correct Y pixel location on the physical screen.

The File Operations Menu

The File Operations Menu is displayed when "f" is selected on the main menu. The routine allows you to type a single character to select one of several tasks: storing data to disk, retrieving data from disk, viewing the disk directory, or replotting the current data set.

Lines 1530-1600 display the menu choices on the screen and prompt you for a response, while line 1610 uses the INKEY$ function to scan the keyboard for an input. When an input is detected, lines 1620-1650 test for a valid choice. Invalid inputs cause the program to go back to the top of the menu.

The Directory Display

Lines 1690-1760 give you the ability to view the currently active directory of either disk drive A or B. The routine prompts you for a single character choice, and then prints the selected directory using the FILES command. If you are using a hard disk with many sub-directories, you may want to expand this routine.

Storing Data

This routine stores data to disk. Lines 1830 and 1840 prompt you for a filename, and then create that file. Lines 1960-1980 actually store the data to disk from array Y(I). In lines 1880-1920 the user-defined parameters are also written to the above file. This allows the complete display to be reconstructed when data is recalled from disk by the plotting routine.

The order in which the data is stored is as follows:

PASSES	The number of data points to expect in the file.
FSPS	The sample rate at which the data was taken. We need this in order to label the X axis properly.
S$	The trigger slope. Either "pos" or "neg".
FTL	The trigger level.
AI.CHN(1)	The desired channel number.
Y(I)	The data array. Must contain the number of samples indicated by PASSES.

Recalling Data From Disk

This routine prompts you for an existing filename, and reads the data from disk to RAM. It uses the saved parameters to set up the system as it was when the data was originally taken.

Lines 2110-2150 get the user-defined parameters and put them in the appropriate variables. Lines 2190-2210 then write the data points to array Y(I).

Line 2230 calls the setup subroutine which restores the system as directed by the retrieved parameters. At this point, data is in the array Y(I) as if just acquired. Returning to the main menu automatically causes the data to be plotted.

Note than any BASIC program or word processor could have created the data file Y(I), since it is just a list of ASCII characters. This means that data could be entered by hand and then plotted. Alternatively, a program could be written to transfer data from a file created by another data acquisition system. In either case, the data might first have to be manipulated so that the final numbers are in the range from zero to 4095. Also, remember that the parameters must be stored in the order the plotting routine expects, or the system will not function properly.

Converting the Code to Compiled BASIC

Appendix B lists the interpreted BASIC version of this program. While interpreted BASIC is easy to write and debug, it is slow when you need to "crunch" large amounts of data. For this reason, this version of the program limits the data array to a maximum of 5000 points. At an acquisition rate of 50kHz, it would take 0.1 seconds to acquire the 5000 points of data. However, using interpreted BASIC on an IBM PC, it would take 5-1/2 minutes to process and plot the data.

The IBM BASIC Compiler can improve the speed of processing by a significant amount. However, the compiler is not 100% compatible with the interpreter. Therefore, some changes must be made to the program before compiling.

Compiled BASIC does not permit the use of the CHAIN MERGE statement. The first change, then, is to merge the file PCIHEAD.BAS with the interpreted version of the program. The header will then be compiled into the program.

The only other changes that need to be made in the example program involve call statements.

The syntax of a call in interpreted BASIC is as follows:

CALL<name>(<param1>,<param2>,..,
<paramn>).

For example, the call to the CON.RG routine looks like:

CALL CON.RG (CHN, COUNT1, COUNT2)

where: name is CON.RG, and the parameters are CHN, COUNT1, and COUNT2.

To achieve the same meaning with compiled BASIC we have to use the CALL ABSOLUTE statement. The syntax for this is:

CALL ABSOLUTE (<param1>,<param2>,...,
<paramn>,<name>)

Therefore, for each CALL statement in the program we only have to add the keyword, ABSOLUTE, and move the function name to the last item inside the parentheses. Our CON.RG example above would now appear as:

CALL ABSOLUTE (CHN, COUNT1, COUNT2, CON.RG)

The program is designed such that all the calls to the PCI- 20046S-1 Software Support Routines are grouped in three areas: the initialization routine, the system setup subroutine, and the data-taking subroutine.

The lines that need to be changed are detailed in Appendix C.

When this program is compiled, the same 5,000 data points which took 5-1/2 minutes to process under interpreted BASIC now require only 18 seconds. This is an improvement of better than 18 to one. At this speed, larger arrays make sense, and the compiled version of this program can utilize the full data space of BASIC. Users have successfully dimensioned the data array for 25,000 samples.

APPENDIX A

Hardware Configuration

This appendix discusses in detail what data acquisition hardware is required, how to configure the jumpers on the carrier and modules, and how to interconnect the termination panels and cables.

The system is set up to monitor an input in the range of ±10V full scale. For trigger purposes, it will detect when the signal crosses a threshold, and will then initiate digitizing the input signal at a rate of up to 50kHz. The data is automatically stored in RAM. The system uses hardware timing and control to insure the highest possible performance.

The complete list of hardware required is:

PCI-20019M-1 High Speed Data Acquisition Module

PCI-20020M-1 Trigger/Alarm Module

—and either —

PCI-20001C-1 IBM PC Carrier without digital I/O

PCI-20007M-1 Counter/Timer/Rate Generator Module

—or —

PCI-20041C-2 High Performance Carrier.

For convenience in connecting the signals to the modules, termination panels and cables are suggested:

(2) PCI-20057T-1 High Density Analog Termination Panel

(2) PCI-20012A-1 6-ft. Shielded Analog Cable

The Carrier and Modules are configured as follows:

PCI-20001C-1 IBM PC Carrier

Normally, the address switches are set to D0000 (hex). Switches one through six and eight of DIP switch U8 should be in the on position, and switches seven, nine and ten should be off. This establishes the base address of the Carrier card in the PC's memory map. In some circumstances, hardware conflicts may require a different address choice. Please refer to the PCI user manual for instructions.

Install the following jumpers:

W6—SYNCOUT of Module position 3 to SYNCIN of Module position 2.

W2—SYNCOUT of Module Position 2 to SYNCIN of Module position 1.

These two jumpers are the mechanism by which clock pulses are passed from the Counter/Timer Module through the Trigger/Alarm Module to the Data Acquisition Module.

Remove all other user-selectable jumpers (plug-in type jumpers) on the Carrier.

PCI-20007M-1 Counter/Timer/Rate Generator Module

Install the following jumpers:

W10, W12, W14, W16, W18, W20 —All channels software gated.

Remove all other jumpers on the PCI-20007M.

PCI-20041C-2 High Performance Carrier

If you use this Carrier, then no PCI-20007M Module is required, since a rate generator is included on the Carrier. The base address of the Carrier is normally set at D000 (hex) as is the PCI-20001C. The same cautions about hardware address conflicts apply.

Install the following jumpers:

W27 Pacer out to SYNC BUS

W7 SYNC BUS to SYNCIN Module position 2

W4 SYNCOUT Module position 2 to SYNCIN Module position 3

As with the PC20001C, this is the mechanism which routes the clock pulses of the Rate Generator through the Trigger/Alarm Module to the Data Acquisition Module.

All other plug-in jumpers should be removed on the PCI-20041C-2.

PCI-20020M-1 Trigger/Alarm Module

Install the following jumpers:

W7, W9 Select single input from the termination panel.

W19 SYNCIN gated to SYNCOUT when trigger is true.

Remove all other jumpers on the PCI-20020M.

PCI-20019M-1 High Speed Data Acquisition Module

Install the following jumpers:

W2, W4 Set the input range to ±10V.

W8, W9 Start conversion on rising edge of SYNCIN.

9

W11 Single channel mode (disable channel scan).

Remove all other jumpers on the PCI-20019M.

After all the jumpers are set as outlined above, the Modules are installed in the Carrier as follows if the PCI-20001C-1 is used:

- Install the PCI-20019M High Speed DAS in J1 on the Carrier
- Install the PCI-20020M Trigger/Alarm in J2 on the Carrier
- Install the PCI-20007M Rate Generator in J3 on the Carrier.

Plug the other end of the cable coming from the DAS Module into P1 of the PCI-20057T-1 High Density Analog Termination Panel. Likewise, plug the other end of the cable connected to the Trigger/Alarm Module into P2 of the termination panel. Connect your input signal to any of the terminals marked zero through seven, and the ground return to any of the ground terminals in the "Group 1" section of the termination panel.

Normally, the input signal also serves as the trigger. In this case a connection should be made on the termination panel from the selected analog input to the input of the Trigger Module. If an external event is to be used as a trigger, then that signal can be connected to the trigger input. Any signal in the range of ±10V will do. If you are triggering from the input signal, run a jumper from your input channel to terminal eight in the "group 2" section of the termination panel. This is the input to the Trigger/Alarm Module. If you are triggering from an external source, connect the external signal here. The hardware is now set up and ready to acquire data.

If the PCI-20041C-2 is used:

- Install the PCI-20019M High Speed DAS in J3 on the Carrier
- Install the PCI-20020M Trigger/Alarm in J2 on the Carrier.

J2 is the connector nearest to the IBM PC bus connector. After the Modules are plugged in, insert the assembly into the computer (or expansion chassis if you are using one).

It is suggested that the accessory Strain Relief Bracket (PCI-20028A-3) be used to facilitate making cable connections. In this case, run the cables out through the "open" rear port of the PC, next to the Carrier. Plug the cables onto the Trigger/Alarm and DAS Modules. Make sure that the end marked Computer goes to the Modules, otherwise the shielding will not be connected properly. Orient the connectors such that the cable naturally goes from the module toward the rear of the computer, without "doubling back".

APPENDIX B

Transient Capture System Program Listing

```
100 CHAIN MERGE "PCIHEAD.BAS", 100, ALL
1000 DEFINT A-E,G-Z
1010  '
1020  ' Initialize the hardware and software system
1030  '
1040     CALL SYSINIT
1050     SEGMT = &HD000
1060     CALL INIT(SEGMT)
1070 GOSUB 1470  ' check for init errors
1080  '
1090  ' This section of the program sets all the default
1100  ' parameters, and configures the system
1110 '
1120 DIM Y(5000) : EN = 1 : DIM AI.CHN(2)
1130 FSPS = 1000 : FTL = 0 : S$ = "-"
1140 AI.CHN(1) = 0 : PASSES = 50
1150 GOSUB 2590 'set up system
1160 GOSUB 3090 'draw box
1170   '
1180   ' Main menu routine. All action is initiated from here. The
1190   ' various setup, acquire, and plot routines are all arranged
1200   ' as a group of subroutines called from here.
1210   '
1220  LOCATE 24,12 : PRINT " q to quit, g to go, c to change";
1230  PRINT " parameters, f for file ops ";
1240  P$ = INKEY$ : IF P$ - "" THEN 1240
1250  IF P$ = "g" OR P$ = "g" THEN 1360
1260  IF P$ = "c" OR P$ = "C" THEN 1340
1270  IF P$ = "Q" OR P$ = "Q" THEN 1410
1280  IF P$ = "f" OR P$ = "F" THEN 1530
1290  BEEP : GOTO 1240   ' an illegal character was typed.
1300  '
1310  ' There are the subroutine calls which actually do the
1320  ' work.
```

```
1330  '
1340  GOSUB 2290 ' get parameters
1350  GOSUB 2590 ' set up system
1360  GOSUB 2910 ' get the data
1370  GOSUB 3090 ' draw the box
1380  GOSUB 3500 ' find min/max
1390  GOSUB 3630 ' plot the data
1400  GOTO 1180
1410 SCREEN 0,0,0 : END
1420  ' Subroutine to check for errors in the pci20k calls.
1430  ' This call is executed after every pci20k call.
1440  ' All we do is check for nonzero error codes, print them out,
1450  ' and abort. One could be more imaginative if desired.
1460  '
1470 CALL ERR.SYS(Z) :
1480 IF Z 0 THEN PRINT "Error  ";Z : GOTO 1410
1490 RETURN
1500  '
1510  ' File operation submenu
1520  '
1530 CLS : LOCATE 8, 30 : PRINT "FILE OPERATIONS"
1540 PRINT
1550 P$ = ""
1560 PRINT "s to save the current data and setup"
1570 PRINT "r to recall stored data and setup"
1580 PRINT "p to plot current data"
1590 PRINT "d for directory listing"
1600 LOCATE 15,25 :PRINT " ** Your choice, please **  "
1610 P$ = INKEY$ : IF P$ = "" THEN 1610
1620 IF P$ = "s" OR P$ = "S" THEN 1770
1630 IF P$ = "r" OR P$ = "R" THEN 2010
1640 IF P$ = "p" OR P$ = "P" THEN GOSUB 2590 : GOTO 1370
1650 IF P$  "d" AND P$  "D" THEN 1530
1660 '
1670 ' If we got here, the file operation choice was "d" for directory
1680 '
1690 INPUT "Disk  ( a or b ) -- ",D$
1700 IF D$ = "a" THEN GOTO 1720
1710 GOTO 1730
1720 FILES"a:*.*"
1730 IF D$ = "b" THEN FILES"b:*.*"
1740 PRINT: PRINT " Hit any key to continue"
1750 IF INKEY$ = "" THEN 1750
1760 GOTO 1530
1770  '
1780  ' Save data to disk routine. The data is written to disk in
1790 ' ASCII form. The first thing stored is the number of data points
1800 ' in the file. The next four items are the rest of the user
1810 ' entered parameters. Finally all the data points are stored.
1820  '
1830 CLS : INPUT "Filename to write data to -- ",FILNAM$
1840 OPEN FILNAM$ FOR OUTPUT AS #1
1850 '
1860 ' Store the user entered parameters
1870 '
1880 PRINT #1,PASSES
1890 PRINT #1, FSPS
1900 PRINT #1, S$
1910 PRINT #1, FTL
1920 PRINT #1, AI.CHN(1)
1930 '
1940 ' Store the data
1950 '
1960 FOR I = 1 TO PASSES
1970 PRINT #1, Y(I)
1980 NEXT I
1990 CLOSE #1
2000 GOTO 1530
2010  '
2020 ' Recall data from disk routine. The data must be retrieved
2030 ' in the same order in which it was stored.2040 '
2040 '
```

```
2050 '
2060 CLS : INPUT "Filename to recall -- ",FILNAM$2080 '
2070 OPEN FILNAM$ FOR INPUT AS #1
2080 "
2090 ' Retrieve the user entered parameters
2100 '
2110 INPUT #1, PASSES
2120 INPUT #1, FSPS
2130 INPUT #1, S$
2140 INPUT #1, FTL
2150 INPUT #1, AI.CHN(1)
2160 '
2170 ' Retrieve the data
2180 '
2190 FOR I = 1 TO PASSES
2200 INPUT #1, Y(I)
2210 NEXT I
2220 CLOSE #1
2230 GOSUB 2590
2240 CLOSE #1
2250 GOTO 1530          ' Return to file menu
2260 '
2270 ' Subroutine to get acquisition parameters from the user
2280 '
2290 CLS : GOSUB 3380   '  Clear screen and print current params
2300 LOCATE 1,1
2310 '
2320 ' Get sample rate
2330 '
2340 INPUT "Samples per second (150 - 50000) ------- ",FSPS
2350 IF FSPS  150 OR FSPS  50000! THEN 2290
2360  '
2370  ' Get trigger level
2380  '
2390 INPUT "Trigger level (+/- %FS) ---------------- ", FTL
2400 IF FTL  100 OR FTL 100 THEN 2390
2410 '
2420 ' Get trigger slope
2430 '
2440 INPUT "Trigger slope ( + or -) ---------------- ",S$
2450 IF S$ = "+" THEN  S$ = "pos"
2460 IF S$ = "-" THEN  S$ = "neg"
2470 IF S$  "pos" AND S$ "neg" THEN 2440
2480  '
2490  ' Select the input channel. Must be in the range of 0 - 7
2500  '
2510 INPUT "Input channel (0 - 7) ------------------ ", AI.CHN(1)
2520 IF AI.CHN(1)  7 OR AI.CHN(1)  0 THEN 2510
2530 '
2540 ' Get number of passes
2550 '
2560 INPUT "Number of samples (10 - 5000) --------- ", PASSES
2570 IF PASSES 5000 OR PASSES  10 THEN GOTO 2560
2580 RETURN
2590  '
2600  ' Subroutine to set up system to selected parameters
2610  '
2620 ' Configure rate generator for correct scan rate
2630 ' Since not all scan rates can be hit exactly, we will get as
2640 ' close as possible, and then report the actual rate we got.
2650 ' The rate generator mode will be 2
2660 '670 FMEG4 = 4000000! : FMEG8 = 8000000! : COUNT1 = FMEG4 / FSPS
2670 FMEG4 = 4000000! :FMEG8 = 8000000! : COUNT1 = FMEG4 / FSPS
2680 COUNT2 = 2 : CHN = 0 : FCNT1 = COUNT1 : FCNT2 = COUNT2 : RGMODE = 2
2690 FSPS = FMEG8 / (FCNT1 * FCNT2) ' recompute the actual sample rate
2700 CALL CNF.RG(CHN, COUNT1, COUNT2, RGMODE)
2710 GOSUB 1470          ' Test for errors after every call
2720 '
2730 ' Set up the Trigger/Alarm module for the level and slope
2740 '
2750 LEVEL1 = ((FTL / 100)) * 128 + 127 : WINDW = 0
```

```
2760 IF S$ = "pos" THEN  LEVEL2 = &HFF
2770 IF S$ = "neg" THEN  LEVEL2 = 02800 '
2780 CALL CNF.TRIG(CHN, LEVEL1, LEVEL2, WINDW)
2790 GOSUB 1470
2800 '
2810 ' Set up the channel list for the high speed acquisition,
2820 ' and execute the configure instruction. We will use mode 4 -
2830 ' hardware controlled acquisition. Trigger will be the PCI-20020M,
2840 ' and acquisition will be paced by the PCI-20007M
2850 '
2860 AI.CHN(2) = -1 : PACER = RG : PCHN = 0 : HSMODE = 4
2870 TTYP = TRIG : TCHN = 0
2880 CALL CNF.HS(PACER, PCHN, HSMODE, TTYP, TCHN, AI.CHN(1))
2890 GOSUB 1470
2900 RETURN
2910  '
2920  ' Execute the high speed acquisition.
2930  ' This is the routine which actually takes the data. All
2940  ' parameters have been set elsewhere.
2950  '
2960 SEGMNT = 0
2970 PRINT "running";
2980 CALL HS.RUN(PASSES, Y(1), SEGMNT)
2990 '
3000 ' The DAS module's code is complimentary binary, so invert the data
3010 ' to get sensible numbers
3020 '
3030 FOR I = 1 TO PASSES : Y(I) = Y(I) XOR &HFFF : NEXT I
3040 GOSUB 1470
3050 RETURN
3060 '
3070 ' Subroutine to draw the plotting window
3080 '
3090 CLS : KEY OFF ' Clear the screen and keys
3100 SCREEN 2   ' Select high resolution graphics
3110 '
3120 ' Define the location and size of the graph.  The upper left hand
3130 '  is at topx,topy and the lower right at botx,boty.
3140 '
3150 TOPX = 600 : BOTX =56 : TOPY = 5 : BOTY = 145
3160 '
3170 ' Draw the box with a clear border of 2 pixels at top and bottom.
3180 '
3190 BORD = 2
3200 LINE (BOTX,BOTY+BORD) - (BOTX,TOPY-BORD)
3210 LINE (BOTX,BOTY+BORD) - (TOPX, BOTY+BORD)
3220 LINE (TOPX,TOPY-BORD) - (TOPX,BOTY+BORD)
3230 LINE (TOPX,TOPY-BORD) - (BOTX,TOPY-BORD)
3240 '
3250 ' Divide the x and y axes into 10 intervals, and draw tic marks
3260 '
3270 FXINT = (TOPX - BOTX) / 10 : FYINT = (TOPY - BOTY) / 10
3280 YTIC = 5 : XTIC = 10
3290 FOR I = 0 TO 10
3300 LINE (BOTX, BOTY + I * FYINT) - (BOTX - XTIC, BOTY + I * FYINT)
3310 NEXT I
3320 FOR I = 0 TO 10
3330 LINE (BOTX + I * FXINT, BOTY) - (BOTX + I * FXINT, BOTY + YTIC)
3340 NEXT I
3350 '
3360 ' Print out the acquisition parameters below the graph
3370 '
3380 TEXTLIN = 22
3390 LOCATE TEXTLIN, 5
3400 PRINT "Rate --";FSPS;" ";
3410 IF S$ = "-" THEN S$ = "neg"
3420 IF S$ = "+" THEN S$ = "pos"
3430 PRINT "Trig Level --";FTL;"%  Slope -- ";S$;"  Chan --";AI.CHN(1);
3440 PRINT " Samples --";PASSES
3450 RETURN
3460 '
```

```
3470 'Subroutine to find the min and max data values
3480 '  and calculate the span and x interval of the data points
3490 '
3500 YMIN = 4095 : YMAX = 03470 'Subroutine to find the min and max data values
3510 FOR I = 1 TO PASSES
3520 IF Y(I)  YMAX THEN YMAX = Y(I)
3530 IF Y(I)  YMIN THEN YMIN = Y(I)
3540 NEXT I
3550 YSPAN = YMAX - YMIN : FYFACT = (TOPY - BOTY) / YSPAN
3560 FXINC = (TOPX - BOTX) / (PASSES - 1)
3570 RETURN
3580
3590 ' Subroutine to label the axes and scale and plot the data
3600 '
3610 ' First, label the x and y axes, and the first data value
3620 '
3630 FLO = (YMIN/4096) * 20 -10 ' Label the y axis
3640 FHI = (YMAX/4096) * 20 -10
3650 FTRIG = (Y(1)/4096) * 20 - 10
3660 LOCATE 1,BOTX/8-6 : PRINT USING "###.##"; FHI
3670 LOCATE BOTY/8+1,BOTX/8-6 : PRINT USING "###.##"; FLO
3680 LOCATE BOTY/8 + 2, BOTX/8: PRINT"0"; ' Label the X axis
3690 LOCATE BOTY/8 + 2, TOPX/8-3 : PRINT USING "##.####"; PASSES/FSPS
3700 FOLDX = BOTX-FXINC
3710 OLDY = (Y(1) - YMIN) * FYFACT + BOTY
3720 LOCATE OLDY/8+1 ,BOTX/8-6 : PRINT USING "###.##"; FTRIG
3730  '
3740  'Scale and plot the data
3750  '
3760 FOR J = 1 TO PASSES
3770 NEWY = (Y(J) - YMIN) * FYFACT + BOTY
3780 FXNEW = FOLDX + FXINC
3790 '
3800 ' Special adjustment to put the first point on the graph
3810 '
3820 IF FOLDX  BOTX THEN FOLDX = BOTX @COMPTER 9-20 =
3830 LINE (FOLDX, OLDY) - (FXNEW, NEWY)
3840 FOLDX = FXNEW : OLDY = NEWY
3850 NEXT J
3860 RETURN
```

APPENDIX C

This appendix details the differences between the Compiled and Interpreted versions of the program. The compiler used was the IBM Personal Computer BASIC Compiler, Version 2.00.

program., and then the following lines changed as shown: (Note that call to AUTOGRPH on line 840 is in the header file, so the line number can vary depending on how you have initialized your software support package.)

```
840    CALL ABSOLUTE (VERS.L, VCHK(1), VCHK.L, AUTOGRPH)
1040   CALL ABSOLUTE (SYSINIT)
1060   CALL ABSOLUTE (SEGMT, INIT)
1120   DIM Y (25000) : EN = 1 : DIM AI,CHN(2)
1470   CALL ABSOLUTE (Z, ERR.SYS)
2560   INPUT "Number of samples (10 - 25000) ---------", PASSES
2570   IF PASSES > 25000 OR PASSES < 10 THEN GOTO 2560
2700   CALL ABSOLUTE (CHN, COUNT1, COUNT 2, RGMODE, CNF.RG)
2780   CALL ABSOLUTE (CHN, LEVEL1, LEVEL2, WINDW, CNF.TRIG)
2880   CALL ABSOLUTE (PACER, PCHN, HSMODE, TTYPE, TCHN, AI.CHN(1), CNF.HS)
2980   CALL ABSOLUTE (PASSES, Y(1), SEGMNT, HS.RUN)
```

As can be seen from the above, three essential changes have been made. First, the header file PCIHEAD has been merged into the program prior to compilation. Second, all CALL statements have been changed to CALL ABSOLUTE. First, PCIHEAD.BAS must be merged into the

Finally, the array Y(I) size has been changed from 5,000 elements to 25,000 elements since the greater processing speed of compiled BASIC allows us to effectively use more data.

PERSONAL COMPUTERS CHALLENGE MINI COMPUTERS

Almost as soon as the IBM PC was introduced, data acquisition boards to plug into them appeared on the market. These early boards were basic -- they handled analog to digital (A/D) conversion, digital to analog (D/A) conversion, and digital I/O. Nevertheless, these precursors to modern data acquisition and control boards gave scientists and engineers a way to apply the power of the personal computer to their real-world measurement and control problems. Most importantly, they did it at an unprecedented low system cost.

As time went on, the boards became increasingly sophisticated. Faster A/D converters with programmable gain instrumentation amplifier front ends were incorporated. Powerful features such as on-board memory and sophisticated DMA techniques began to appear. The number of competitors also increased, and products were quickly obsoleted by newer products with more powerful features. Today, there is a wide array of products covering the gamut from low end digital I/O boards to array processing systems costing several times as much as the personal computer itself.

Fixed Configurations - Most manufacturers offer fixed configuration, multi-function data acquisition boards. Typically, such a board contains 16 single ended or 8 differential analog inputs, two analog outputs, 16 digital I/O bits, some sort of pacer clock or timer for generating A/D conversions, and often one or more event counters. The main differentiating factor among these boards is generally either the speed or resolution of the A/D converter, or the mix of I/O offered.

One problem with the single multi-function board approach is the difficulty of expanding or upgrading a system. This is often necessary in R&D applications, where a system may be used for many different applications over a period of time. Even in fixed configuration production systems the number of channels provided by the board may be insufficient to handle the given problem. To expand the number of analog or digital I/O channels, one is faced with purchasing a complete second board. This can be a significant penalty if all you need is a few more digital I/O points, for example. To upgrade speed, you must buy an entirely different board with a higher performance A/D. Often, this also involves different software -- the program you have written based on the slower board may need re-writing to accommodate the different architecture of the faster board. For other applications, there may be functions provided by the multifunction boards which are not needed. For example, typically only 30% of data acquisition users require analog outputs. If they are provided, you pay for them whether or not they are used.

Modularity = Flexibility - Several manufacturers, such as QuaTech, Di-An, and Burr-Brown, solved this problem by offering modular systems. Burr-Brown's PCI-20000 product family began with a simple motherboard, called a Carrier, and function Modules which plugged into the carrier. The carrier plugs into the PC's backplane, and handles all the bus interfacing tasks. The function Modules plug into the carrier, with each module handling one specific data acquisition task, such as A/D conversion, for example. The interface between the Modules and the carrier is the patented I^3 (Intelligent Instrumentation Interface) Bus.

The current list of Modules includes several different multi- channel A/D input modules, 12- and 16-bit D/A modules, a Digital I/O module, a Counter/Timer module, a Trigger Alarm Module, an Analog Input Expander, and an Analog Input Expander with automatic Scan list. The list of modules grows continuously in response to advances in technology, and requirements of customers. As new carriers and modules are introduced, compatibility with existing products is insured by maintaining conformance to the I^3 bus specification.

Solving the Real-Time Crunch - A major limitation of the IBM PC/XT/AT family of computers in data acquisition applications is the fact that they were designed with office automation in mind. They were intended to be single user, single tasking, simple, low cost machines. They excel at word processing and spread sheet applications, but often are not up to the real-time requirements of high performance data acquisition and control. Indeed, many of the technical advances found in the data acquisition and control boards on the market today have been directed at overcoming this sort of limitation.

One excellent solution to this problem is to put a high performance processor right on the data acquisition board itself. This processor can assume control of the data acquisition functions, allowing the personal computer to act in a supervisory role. The PC can download programs to the data acquisition system, and leave all the time critical operations where they are most effectively dealt with.

The architecture of the PCI-20000 system lends itself particularly well to this approach since the data acquisition functions are already on modules. This allows the limited available carrier board space to be dedicated to the on-board processor's functions.

A recent offering in the PCI-20000 family, the PCI-20202C-1 *Smart* carrier, is such a board. This carrier includes positions for two standard PCI-20000 I/O Modules. The high performance processor used is the industry standard TMS320C25 Digital Signal Processor from Texas Instruments. The board also includes high speed program and data memory, and provisions for synchronizing the system to external events. This carrier begins to transcend traditional notions of what a PC can accomplish in a data acquisition and control system.

Introduced in May of 1988, it was originally thought of as a DSP oriented product. It has actually proven to be most useful in many sophisticated data acquisition and control applications. While there are other DSP processor boards readily available, none have the I/O versatility required for serious data acquisition and control. Often, in this sort of application, traditional DSP algorithms, such as FFT's and digital filtering, never come into play.

PC Controlled Ultrasonic Welder - One such data acquisition and control application was developed by DISTEC Hard- und Software Gmbh, a small company in West Germany. They used this carrier in a system to monitor and control 16 ultrasonic welders in real- time. The hardware used to accomplish this task was the PCI-20202C-1 Smart Carrier, a PCI-20002M-1 16 channel Analog Input Module, and a PCI-20004M-1 32 Channel Digital I/O Module. See Figure 1.

Upon system initialization, the personal computer downloads the control program into the carrier from disk. It also downloads standard maxima for various parameters as explained below, and then starts the carrier's processor running. After this point, the PC has no further interaction with the welding system other than to act as a power supply. The PC is now available to run an inventory control program.

16 of the Digital I/O channels are connected to relays used to turn the individual welders on and off. Additional channels are connected to an external machine controller which provides supervisory control. For example, it determines when a part is available for welding, and informs the carrier. It also monitors various system level alarm conditions, such as open welder doors, and communicates these to the carrier as well.

Each of the 16 analog input channels is connected to one of the 16 welders. These are used to monitor the power output of the individual welders whenever a part is being welded. The bandwidth of interest is 50Hz for each channel. To attain a clean 50Hz bandwidth, the power for each channel is sampled at 1000 samples per second. These samples are passed through a finite impulse response (FIR) digital filtering algorithm to remove 50 Hz hum. A 20 to 1 downsampling algorithm is then used to develop 50 clean samples per second per channel. Please refer to Figure 2.

Note that since there are 16 channels, and each must be sampled at 1000 samples per second, the maximum aggregate system throughput is 16,000 samples per second if all 16 welders are operating concurrently. Since all required processing must be performed in real-time, each channel's processing must be completed in between two successive samples -- 1/16,000 sec. or 62.5 microseconds! This would be an impossible task for the PC alone.

The power vs time data developed above is compared with a stored optimum which was downloaded from the PC at system initialization. Additionally, alarm signals from the system supervisory controller are monitored, the on-time of each individual welder is monitored, and total power for each welder is summed to give energy. Any anomalies in any of the monitored inputs are used to shut down the offending welder. This provides early detection of error conditions, prevents serious damage to the machine, and prevents the production of large amounts of scrap material.

Pneumatic Actuator Controller - Another challenging data acquisition and control application was in a high speed pneumatic actuator system. Such systems can be found in a variety of industries including aircraft simulators, automotive frame testing, and high speed manipulators. This application used only digital I/O (unavailable on other processor boards) along with the serial I/O of the TMS320C25 to monitor and control the position of a piston in a pneumatic tube.

The position of the piston in the tube is controlled by four solenoid valves connected to a high pressure compressed air system. Two of the valves pressurize the cylinder to move the position up, while the other two pressurize the cylinder to move it down. See Figure 3.

The position of the piston is monitored by a sophisticated linear magnetic detection system. A small magnet is attached to the piston inside the tube. Hundreds of sensors are positioned on the outside of the tube to detect the position of the piston. An accuracy of better than .1mm over a length of 1m is maintained.

The detector system communicates with the *Smart* Carrier with a serial data stream at 1.5 Mbaud on the processor's serial input. The *Smart* Carrier uses a PCI-20004M-1 32 Channel Digital I/O Module to drive the four solenoid valves in response to setpoint commands from the host PC. The PC's role is only supervisory -- all the complex feedback control algorithms are performed locally in the program running on the carrier. With the actuator attaining speeds of several meters per second, this is a demanding real-time data acquisition and control application which would be very difficult for a PC on its own.

Airframe Stress Testing - Another demanding application having appeal in a variety of industries was demonstrated to a major U.S. aircraft manufacturer. Their specific interest was in airframe structural testing, but the principles involved would apply equally in virtually any high speed, multi channel control application.

The manufacturer wanted to construct a stress test control system. Hydraulic jacks, controlled by analog proportional valves, are used to stress an aircraft's wings. Strain gages monitor the resulting forces. Each hydraulic jack would have one or two strain gages associated with it. On computer command, a given stress level would be called for, and the system would then drive the jacks and monitor the strain gages to achieve that level in a feedback control arrangement. Figure 4 suggests the system configuration.

As many as 32 jacks, with up to 64 strain gages as feedback elements, needed to be controlled. An update rate of 200 points per second for each hydraulic jack was calculated to be optimum. Considering that there would be a maximum possible of 64 analog inputs to monitor,

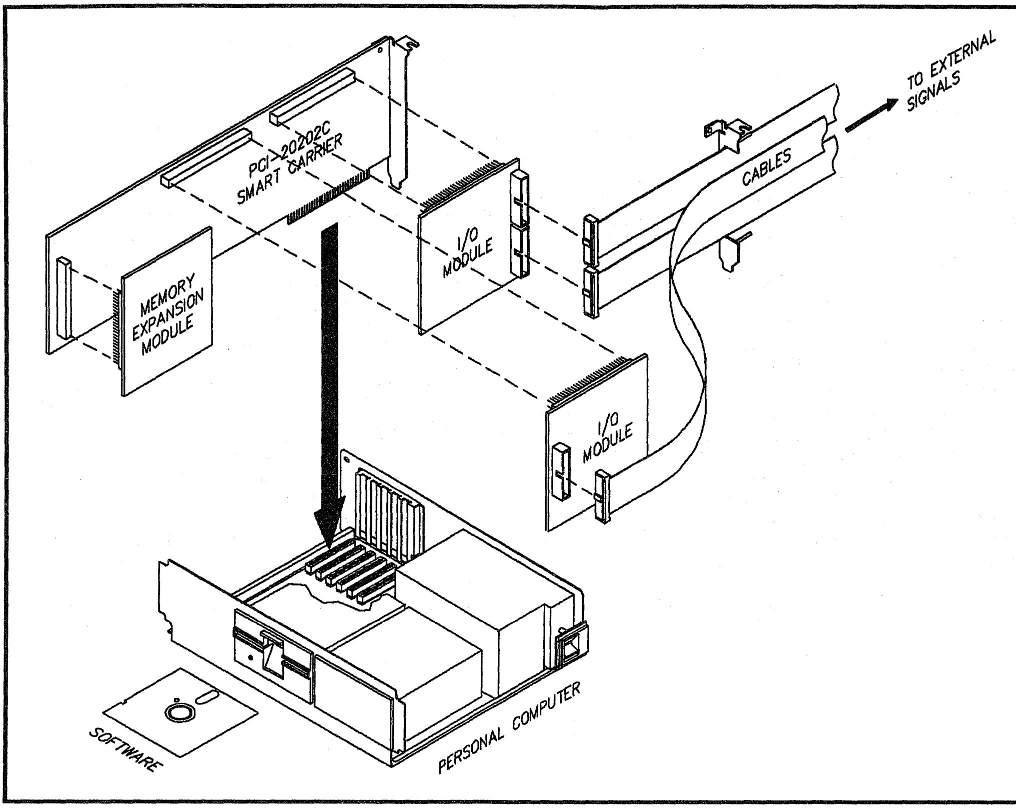


FIGURE 1. PCI-20000 Hardware Configuration.

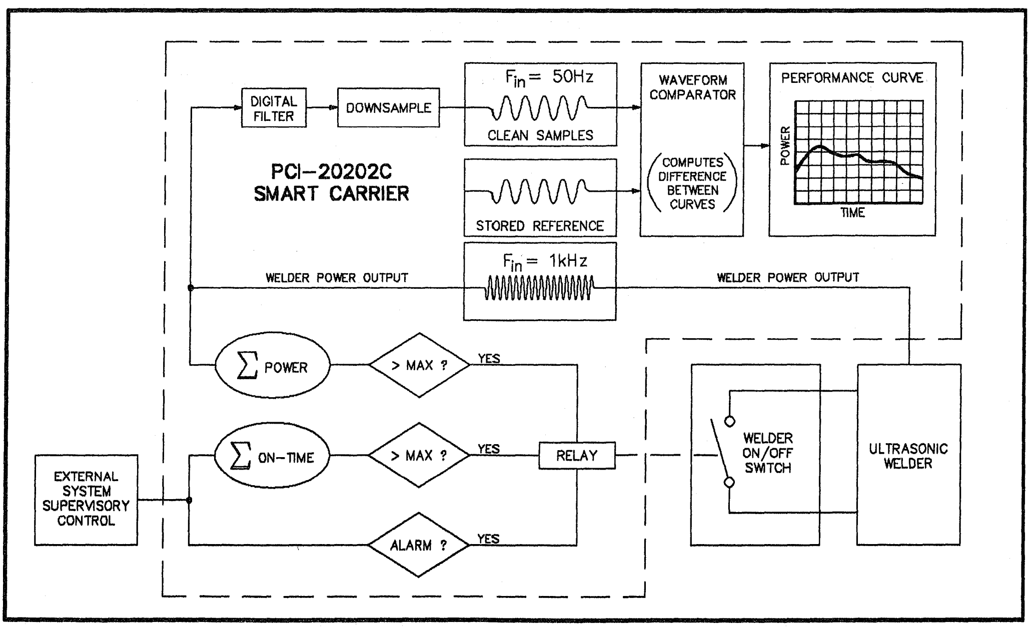


FIGURE 2. Ultrasonic Welder Flow Diagram.

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this would be an aggregate system throughput of 12,800 points per second.

64 analog inputs and 32 analog outputs are required. Because of the large channel count the system will involve a number of carriers and modules. The *Smart* Carrier can accept two modules. One will be used for a PCI-20019M-1 high speed analog input module. A PCI-20041C-2 (standard type) carrier with two PCI-20031M-1 32 channel expander/sequencer modules will provide the required 64 inputs. The inter-carrier connector on this PCI- 20041C is cabled to the second module position on the *Smart* Carrier. The expander/sequencer modules are preprogrammed with a scan sequence at system initialization, and run automatically thereafter, synchronized by the *Smart* Carrier's pacer clock.

The analog outputs are handled by two PCI-20041C-3 DMA Carriers (itself a unique product), with two PCI-20021M-1 8 Channel analog output modules each, giving a total of 32 analog outputs. Note that both the PCI-20041C-1 and PCI-20041C-3 can accept up to three modules each. Therefore, additional channels could easily be added to this application.

The *Smart* Carrier would acquire the analog inputs, perform all necessary calculations, and send the analog control outputs to a small block of the PC's memory via DMA control. Through a second DMA process, again synchronized by the *Smart* Carrier's pacer clock, these outputs are removed from the PC's memory and sent to the analog output modules.

All data transfer through the PC is via DMA, so none of the PC's computing time is required after system startup. The total data transfer rate to the PC is 32 outputs, times 2 bytes per output, times 200 updates per second. This is equivalent to a total of 12800 bytes per second. The DMA transfer rate from the PC's memory to the analog outputs is the same, resulting in a total rate of 25,600 bytes per second. Since a PC is capable of bursts of up to 400 Kbytes per second, clearly this system uses very little of the PC's capacity.

The software overhead required to acquire each sample, put it into 2's complement binary format, re-format the result of the algorithms for the analog output modules, and output the samples to the PC is approximately 5 microseconds. Since the control algorithm for each channel must run in the time between

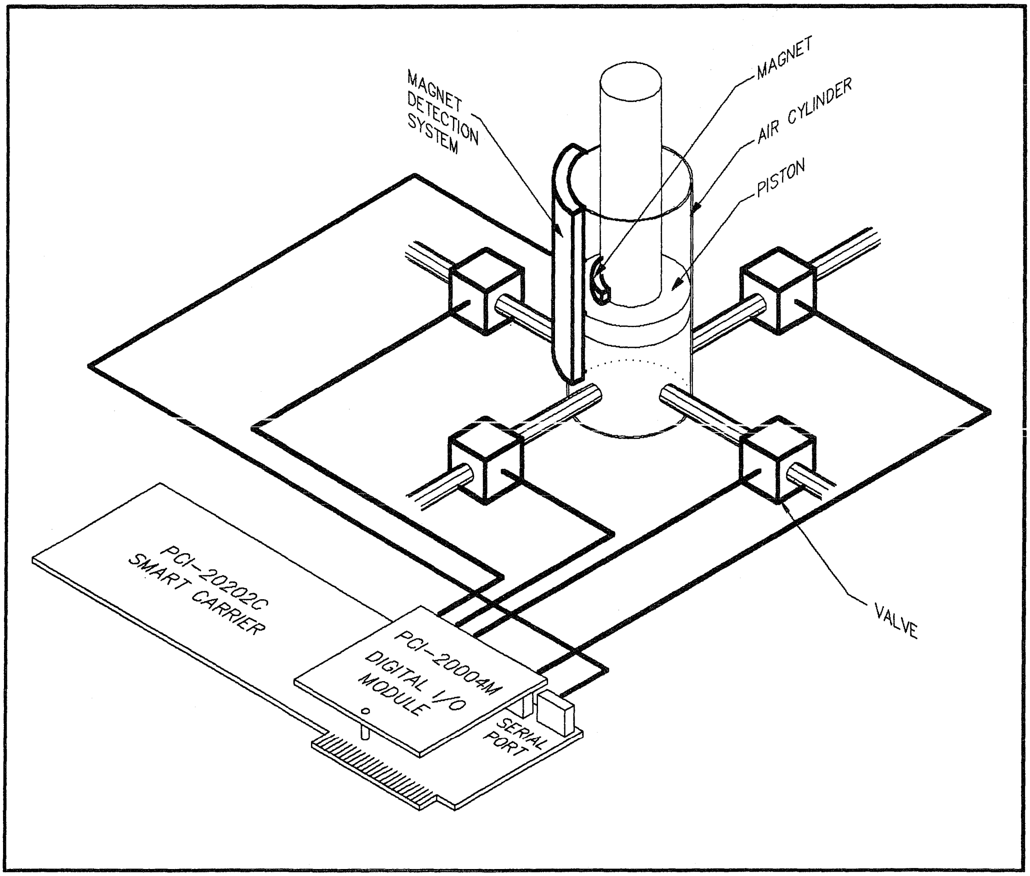


FIGURE 3. Pneumatic Actuator Block Diagram.

analog samples (within 78 microseconds), this leaves 73 microseconds available to process each channel.

A PCI-20202C-1 (TMS320C25 at 28MHz) machine cycle requires 140nsec (a 100nsec model is available), and a typical instruction requires two cycles (280nsec). In this system, roughly 250 instructions are allowed for each of the 32 algorithms. The Texas Instruments TMS320 User's Guide gives an example of a simple PID loop, roughly equivalent to the task at hand, which requires 11 instructions running in approximately 5.3 microseconds. From these thumbnail calculations, it is clear that there is plenty of time to execute a fairly complex control algorithm in real-time for each channel.

Applications such as those described above are usually being satisfied today with high powered VME and Multibus systems, with their attendant high cost and long development times. With sophisticated PC-based data acquisition and control processors, such as the PCI-20202C-1 *Smart* Carrier, many of these tasks can now be accomplished with a much lower hardware cost. In addition, system integration and software development are greatly simplified, resulting in a total system cost that is a fraction of previous levels.

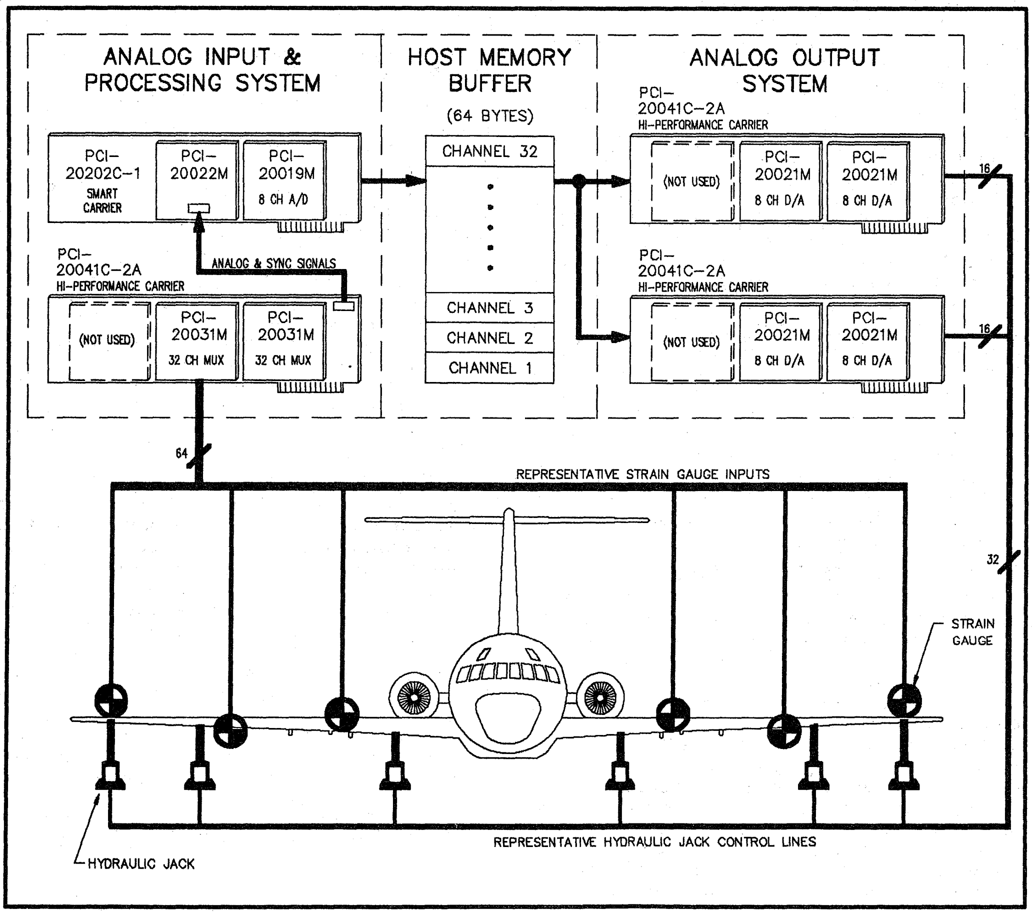


FIGURE 4. Airframe Stress Testing System.

9

ADVANCED APPLICATIONS FOR THE PCI-20007M-1 COUNTER/TIMER MODULE

FEATURING

- Terminal characteristics of the Intel 8254
- Alternate methods for frequency measurement
- Gate generation and speed measurement
- Enhanced, programmable, pulse generation
- Measuring the time between pulses

INTRODUCTION

The PCI-20007M-1 Counter/Timer Module finds wide application in fields such as interval timing, event counting, frequency measurement, speed monitoring and time-base or pulse (frequency) generation.

This module is based upon the Intel 8254 integrated circuit, which provides a spectrum of useful functions. To exploit many of the features of this module, however, can require a detailed knowledge and understanding of the "chip" itself. To assist users of the PCI-20000 system, an array of software tools has been created. This software provides a broad range of capabilities while eliminating the need for the user to program the 8254 directly.

Some of the characteristics of the 8254 merit clarification in order to avoid possible difficulties. For example: how does a counter load an initial value and record input pulses? This segment will offer useful background information and solutions to what some might call shortcomings of the 8254. Also included are alternate techniques for frequency measurement and external hardware approaches to speed monitoring, time measurements and programmable pulse generation.

TALKING TO THE COUNTERS

The PCI-20007M-1 consists of four independent counter channels and one "rate generator". Each counter has three input/output terminals: clock input (CLK), gate input (gate) and output (out). Six different operating modes can be selected, each with unique characteristics. A complete description of the various modes can be found in the PCI-20007M-1 user manual. Of importance here is that the initial output level and its response to both clk and gate inputs are strongly dependent upon the mode chosen. Assumptions are often wrong. Please read the manual. In addition to the above I/O points, there are a number of on-board registers that permit software to set up the control parameters and to read the status of the counters. Each register function is explained in the user manual. The rate-generator consists of an 8MHz crystal oscillator driving two divide-by-"N" counters (separate from above), connected in series. The resulting output is a software-programmable pulse generator. By selecting the N values for the two counters, a wide range of pulse frequencies and duty-cycles can be obtained. All counters are 16-bit devices capable of representing numbers between 0 and 65, 535 (2^{16}).

In the context of the PCI-20007M, a pulse is defined as a digital signal which changes from a low-to-high-to-low state. An example of this is shown in Figure 1.

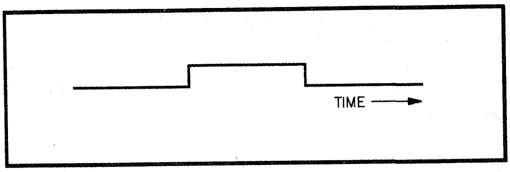


FIGURE 1. A Single Pulse.

Any of the counters on the PCI-20007M-1 module can be configured to accumulate input pulses (input to clk). The Rate Generator can be used to produce an accurate time-base (input to gate). The number of input impulses counted will be directly related to the length of time that the gate input is held high.

The counter gates can be jumper programmed to respond to either signal or software inputs. In the signal mode, each independent counter can be inhibited from counting by holding its gate low (TTL 0). Internal pull-up resistors are not provided, so it is very important to drive the gates to the desired level. In the absence of an input, operation is not predictable. Remember, for the rate generator to be active, both associated counters must be gated "on".

COUNTING

Often it is desired to initialize a counter with a given number ("NUM") for example) and to either count inputs with reference to NUM or to generate a hardware output upon NUM inputs. The count value contained in the output register, decrements (reduces) with each clock pulse. However, the defined value, NUM, is not actually loaded into the counter until the first clock pulse occurs. The result is that the contents of the output register contains one less count than was actually applied. It is normally very easy to account for this condition, by adding 1 to reading. But, what if fewer than two pulses are received? Under these conditions, the value contained in the register is unpredictable. Fortunately, there are solutions to this problem. One method using the PCI-20046S is outlined below.

Method 1:

a) Disable the counter............(WRITE.CH with 0)
b) Set the Initial Count to 65, 535 .... (CNF.CNTR)
c) Start counting.......................(WRITE.CH with 1)
d) Read the counter's STATUS & COUNT............................ (STAT.CNT)

If STATUS=0, zero pulses have arrived
If STATUS=1, read the counter (COUNT)

The number of input pulses=65,536-COUNT

Sometimes it is required to count events in excess of 65,535. It may seem logical to cascade two counters to produce a 32-bit device, but this is not quite as simple as might be expected. In the divide-by-N mode, the counter output is initially HIGH and it goes LOW when decremented to 1. The next input pulse causes the output to return to a HIGH state. Unfortunately, this is NOT the correct waveform to decrement the second counter. Intel defines an input pulse as a LOW to HIGH to LOW transition. As a result, 65K pulses will be missed before this condition is met. There is, however, an external way (Method 2, below) of correcting the hardware levels. In addition, a software solution is also available. This technique uses the fact that when a counter decrements to zero it automatically rolls over to full scale (65,535) and continues counting (Method 3, below).

Method 2:

a) Use two counters.

b) Add a hardware inverter between the output of the first counter and the input of the second. This corrects the "sense" of the pulse.

c) Set up and read both counters following the general procedure suggested in Method 1. However, compute the total input pulses by applying the proper "weighting" factor to the second counter.

Method 3:

a) Use only one counter.

b) Follow the procedure in Method 1.

c) Read the counter often enough to detect a "zero crossing".

d) For each zero crossing add 65,535 to the count computed in Method 1. That is: Total = (65,536 - COUNT) + (65,535 · number of zero crossings).

FREQUENCY MEASUREMENT

The structure of the PCI-20007M is well suited to frequency measurement. Depending upon the application, several configurations are possible. The PCI-20046S Software Drivers support the most popular arrangement. This technique is suggested in Figure 2.

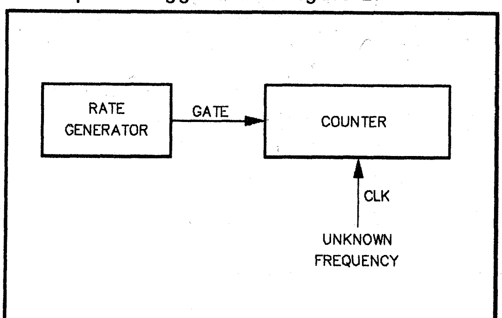


FIGURE 2. High Frequency Measurement Circuit.

This circuit counts input pulses for a known time interval (Gate time), as defined by the rate Generator. Gate times of 1ms to one second are very common. Clearly, the longer the measurement interval, the larger will be the accumulated count (for a given input frequency). Resolution and accuracy are proportionally enhanced. Maximum resolution is limited by the requirement that no more than 65K pulses be accumulated in any one measurement interval. The practical (useful) frequency range for this circuit extends from about 100Hz to beyond 8MHz.

An alternate approach is suggested in Figure 3. This circuit differs in that it counts high-frequency clock pulses for the duration of the unknown input signal. The result is enhanced resolution at low frequencies. In the simple form shown here, the count value is a function of the input signal's duty-cycle (counting takes place while the input is high). Therefore, the exact value of the duty-cycle must be known to accurately compute the true input frequency. Given this information, practical measurements are possible from a small fraction of a Hertz to beyond 1kHz. In fact the lower limit is only restricted by the time available to make the measurement (i.e., measuring 0.01Hz requires 100 seconds). Both of these circuits have an ultimate (maximum) resolution of one part in 65K. Note, however, that this resolution is not available at all frequencies within the measurement range. Programmers can implement this technique using the PCI-20046S, but it is not directly supported by the READ.FRQ command.

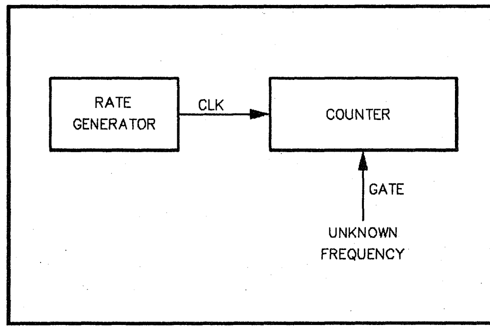


FIGURE 3. Low Frequency Measurement Circuit.

GATE GENERATION AND SPEED MEASUREMENT

As was stated above, Figure 3 requires a known duty-cycle. Very often this information is not available. For example, when measuring speed (i.e., motor rotation, conveyor travel, linear motion) with an optical or magnetic pickup, duty-cycle is variable. One solution is to use the circuit shown in Figure 4. This circuit uses flip-flops to convert the input signal into a positive pulse that is the width of a complete input cycle. Thus, measurements are now duty-cycle independent. An external logic input is applied to control the arming of the "gate generator". One of the PCI digital output lines can be used to produce this level internally. The selection of the Rate Generator frequency requires a balancing of two competing factors. The higher the frequency, the greater is the resolution of the final reading. However,remember that the counter is limited to 65,535. "Speed" or "inputs per second" are proportional to:

$$\frac{\text{Frequency (Rate Generator)}}{\text{Number of Pulses Counted}}$$

WIDE RANGE, PROGRAMMABLE DUTY-CYCLE, PULSE GENERATOR

The Rate Generator within the PCI-20007M-1 can be programmed in both frequency and duty-cycle by selecting the "N" values for each of the two related counters. N_1 and N_2 designate the division factor for each counter. Because the crystal oscillator is 8MHz, the rate generator's output frequency is $8MHz/(N_1 \cdot N_2)$. Consider that the output waveform consists of a "low" and "high" level portion, represented by t_1 and t_2. Thus:

$t_1 = N_1 \cdot 125ns$, while $t_2 = N_1 \cdot 125ns\ (N_2 - 1)$.

Combinations of N_1 and N_2 allow a wide range of frequencies and duty-cycles to be selected. However, both parameters are interdependent.

Figure 5 shows a circuit configuration, using two counters in addition to the rate generator, that allows duty-cycle variation without interfering with the separately programmed frequency. Define the four "N" values:

N_1=Rate Generator, counter 1
N_2=Rate Generator, counter 2
N_3= Independent counter 1 (operate in Mode 2)
N_4=Independent counter 2 (operate in Mode 1)

The frequency and duty-cycle for this circuit are:

Frequency = $8\ MHz/(N_1 \cdot N_2 \cdot N_3)$,
Duty-Cycle = $[(N_3 - N_4)/N_3] \cdot 100$, in percent.

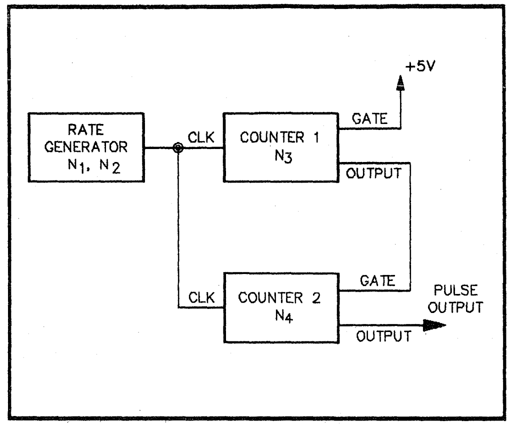


FIGURE 5. High Resolution, Variable Duty-Cycle Pulse Generator.

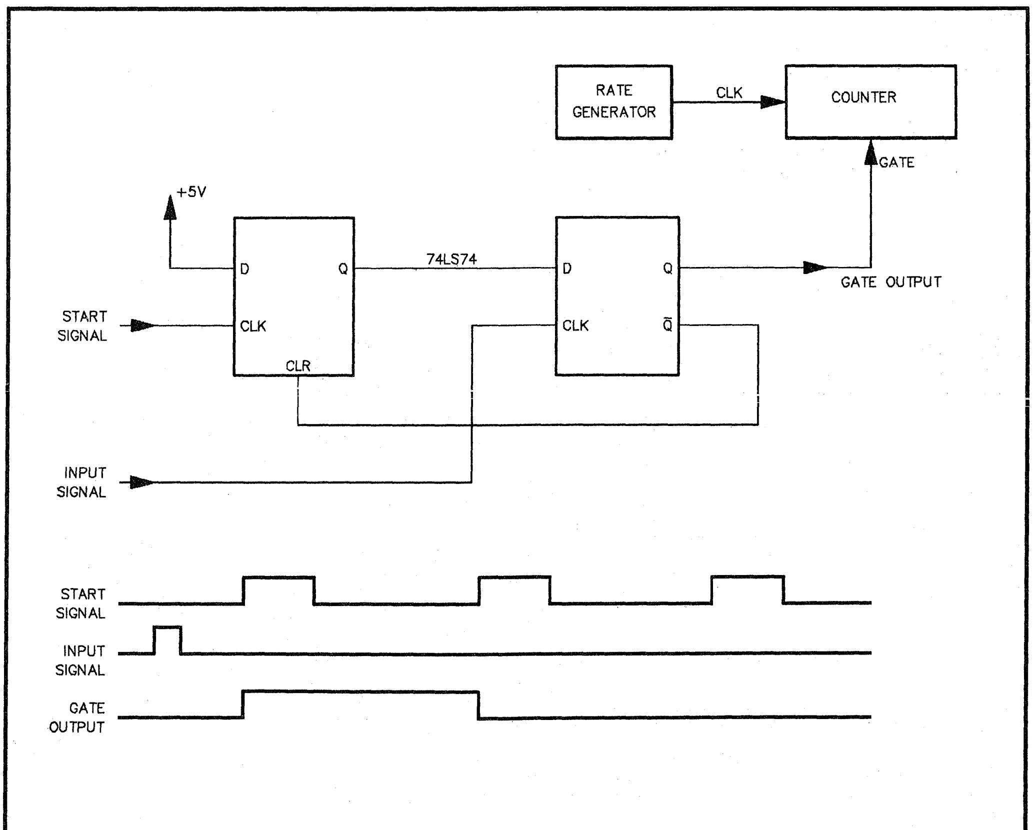


FIGURE 4. Gate Generator Circuit.

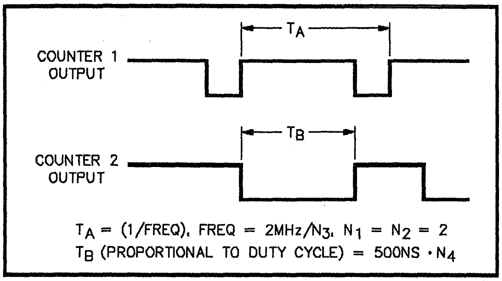


FIGURE 6. Waveforms for Variable Duty-Cycley Generator.

MEASURING THE TIME BETWEEN PULSES

The following applications are related to the measurement of time *between* pulses. Three different circuits are shown:

- Low speed, time between two pulses on the same line.
- High speed, time between two pulses on the same line.
- Time between two pulses on different lines.

The trick is to generate an appropriate gate signal corresponding to the time between two input pulses. This is suggested in Figure 7.

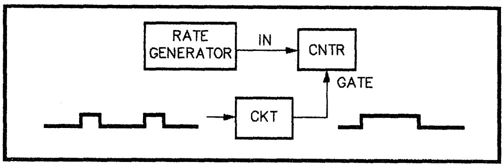


FIGURE 7. Basic Counting Circuit.

Before choosing the frequency of the rate generator, the user must first know the maximum duration of time that the pulse at the gate will exist. The product of the maximum gate time

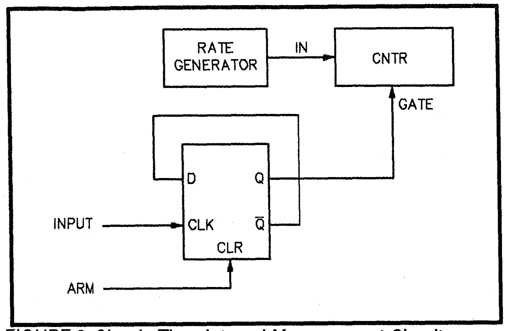


FIGURE 8. Simple Time Interval Measurement Circuit.

and the frequency must not exceed the 16-bit counters' limit of 65,535. However, the higher the rate generator frequency, the greater the resolution of the interval measurement will be.

Figure 8 shows a simple circuit for converting successive input pulses, on a single line, to a gate signal. This circuit is slow because once armed, the counter must be read before a third input pulse occurs. If this condition is not satisfied, the counter will be restarted and an incorrect count will result. Another alternative is to bring the Arm signal low after the second input pulse. This condition can be detected by reading the counter output until a stable count is observed.

Figure 9 shows a variation on the above circuit. Here, the acquisition of the desired time interval is latched with hardware. Thus, the measurement of the desired data is assured without intervention from the host computer.

This circuit will capture one full cycle of an input pulse train and wait for the Arm line to go high-to-low and then low-to-high. The timing characteristics for Figure 9 are shown in Figure 10.

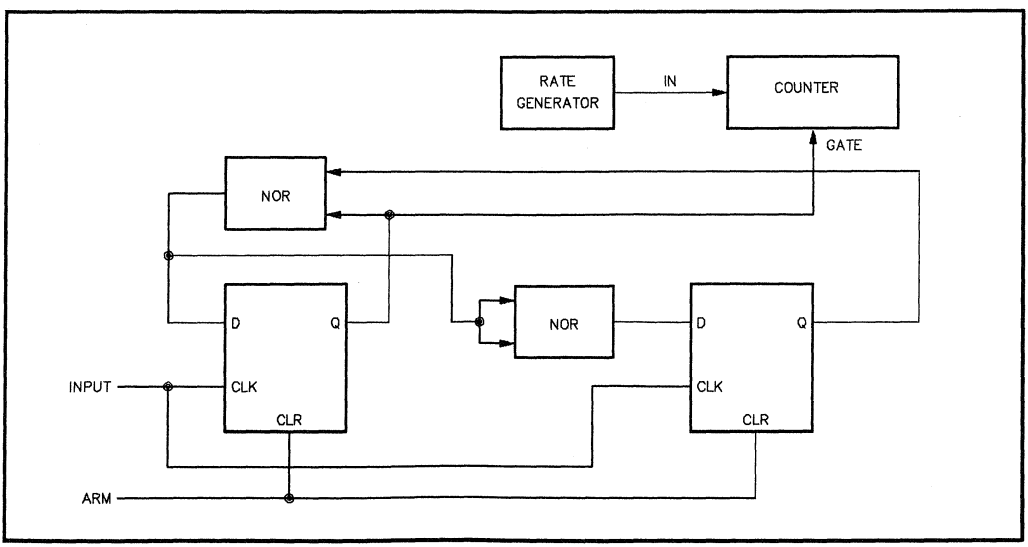


FIGURE 9. Fast Time Interval Measurement Circuit.

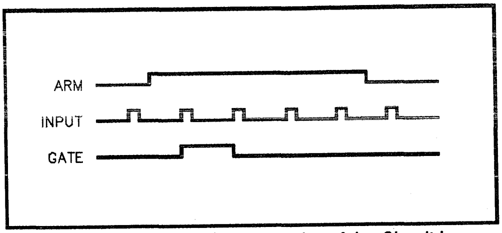


FIGURE 10. Timing Characteristics of the Circuit in Figure 9.

In both of the above circuits, the time interval was measured between two pulses occurring on the same input line. Figure 11 shows a circuit that performs the same function with separate START and STOP inputs.

Input A gives the START pulse, and Input B gives the STOP pulse. The time between the START/STOP signals is what this circuit is measuring. As in Figure 3, this circuit is most useful for low-speed pulses. It is again required that the counter be read before a second start pulse occurs.

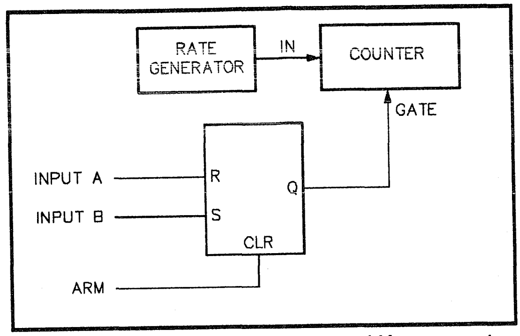
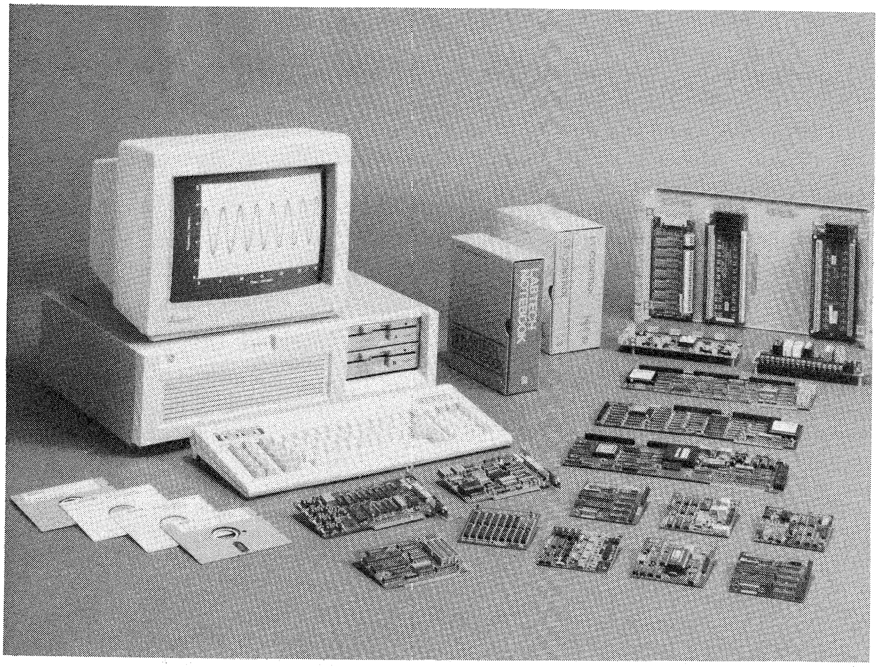


FIGURE 11. Double-Input Time Interval Measurement Circuit.

Section 10

PCI-20000 HARDWARE

BOARDS, CARRIERS, MODULES, and ACCESSORIES



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Free Burr-Brown Demonstration Diskettes showing product capabilities, specifications, and applications for the PCI-20000 system are available through Burr-Brown sales offices. These diskettes run on the IBM PC and compatible computers containing a graphics card. Please contact your local sales office for free diskettes. See office listings at the back of this handbook.

TABLE OF CONTENTS

PCI-20000 SYSTEM

A New Concept in Flexibility and Cost Efficiency

PCI-20000 is an all-new, high technology, computer-based instrumentation system which allows a user to specify exactly the system needed for his particular application, and to buy only that system—no more, no less—without giving up extensive expansion capabilities for the future.

Modularity—The Key Concept for Optimum System Design

A key feature of the PCI-20000 is modularity. In addition to dedicated fixed-function **Boards**, the PCI-20000 includes user-configurable components consisting of **Carriers** and **Modules**.

The carrier, or "mother-board", provides the interface between the desired input/output functions and the host computer. In addition, the carrier provides the physical mounting mechanism, power, and internal communications for the modules. Many of the carriers also include on-board, fully buffered, TTL-compatible, digital I/O as well as other important features. Carriers can accommodate two or three modules depending upon the specific model.

Modules add input/output functionality when physically plugged into a carrier. In most cases it is the modules that provide the majority of the input/output capacity for a given data acquisition, test, measurement and control system. Each module provides one function, such as analog input, channel expansion, simultaneous sample/hold, hardware trigger/alarm, digital I/O, analog output, or counter/timer/pulse generator. Any combination of modules can be mixed to meet a specific application requirement. This is a powerful approach that allows standard modules to be

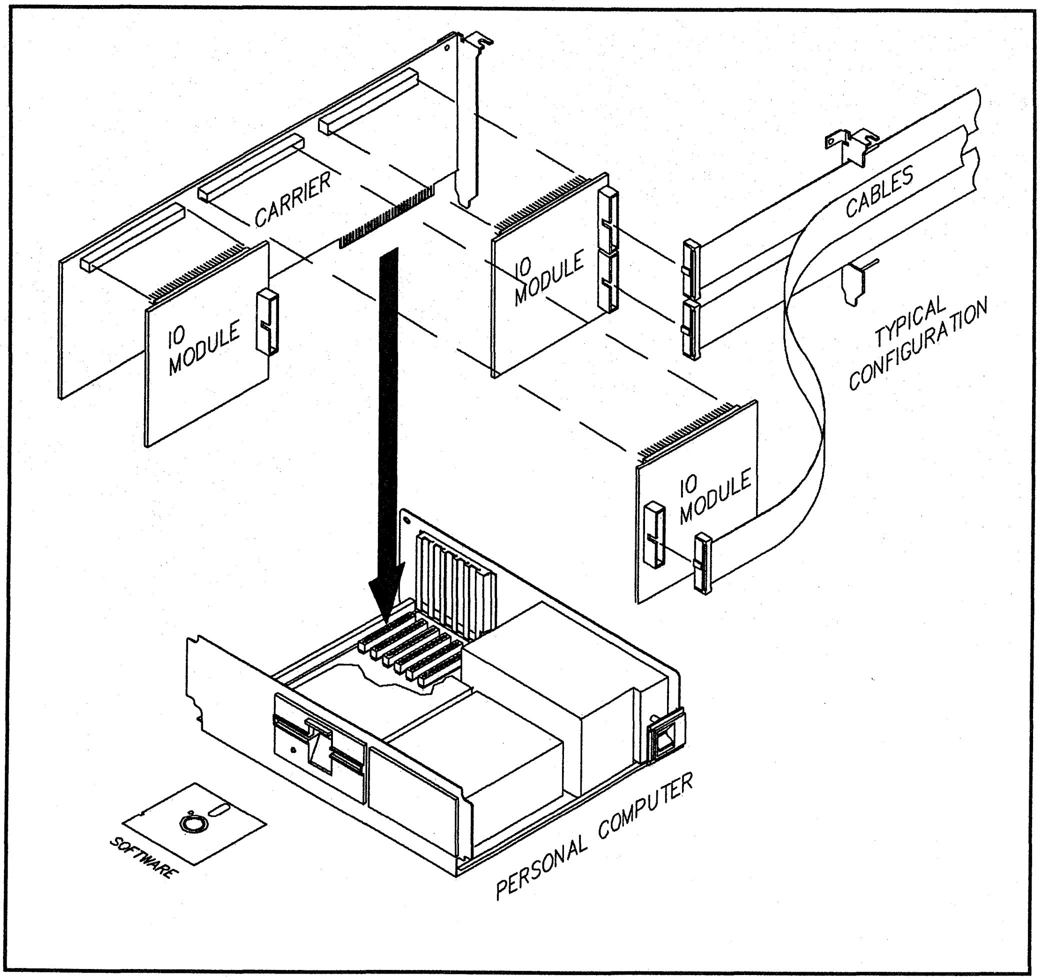

Figure 10.1. Illustration of the Modular Approach to Personal Computer Instrumentation.

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specified and configured by the user into a system optimized for an individual requirement. This maximizes performance since the user has complete control over the final system configuration. Cost is minimized because only necessary hardware need be purchased.

As requirements change, different modules can be substituted to solve the new problem. More modules can be added if requirements expand. As new, improved modules are added to the product line, performance can be upgraded easily.

PCI modules can also be used in special applications where it is not desirable or appropriate to use the personal computer as an instrumentation platform. All PCI-20000 modules are designed to be used as stand-alone "components" in custom designs. Complete documentation is provided with each module stating both the electrical and mechanical interface requirements. OEM customers are encouraged to contact the factory for additional information.

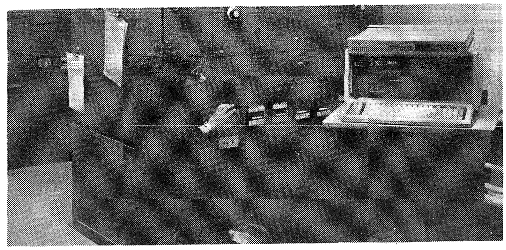
OUTSTANDING SOFTWARE SUPPORT

A wide range of software products is available for use with the PCI-20000. There are "general-purpose" packages that support all hardware configurations from a choice of popular programming languages. Thermocouple support is included at no extra cost. "High-performance" packages perform specialized functions such as high-speed read, DMA, and direct to/from disk operations. Of special significance is SYSCHECK, the system assurance utilities and diagnostics software package. This menu-driven product, shipped at no extra charge with each system, easily verifies proper installation and utilization of all PCI system components. Not only does SYSCHECK greatly reduce the time required to confirm appropriate operation but it provides a permanent resource for test and calibration. In addition, SYSCHECK provides non-programmers with a fundamental way of exercising the input/output capabilities of the system. This can be useful as both a product tutorial and in performing modest test and simulation functions. The range of software products is summarized in Table 10.4. For more complete information, please refer to the Software Section of this handbook. Also, the Applications Section describes a number of practical programs and techniques.

HIGH-TECH BUS

Modules communicate with each other through the patented Intelligent Instrumentation Interface (I^3) bus on the carrier. This bus is optimized for data acquisition and measurement functions.

The I^3 bus is an extension to the PC bus. It allows for standard memory and I/O access to the PC. In addition, the I^3 bus also provides for the "chaining" of analog signals between the plug-in modules. The unique "daisy-chaining" of analog lines allows one module to process (amplify, multiplex, etc.) a signal and then pass it on to another module. The bus provides a path for both sync and trigger signals to pass among the modules. Sync and trigger signals provide coordination of the various modules to insure proper system performance.

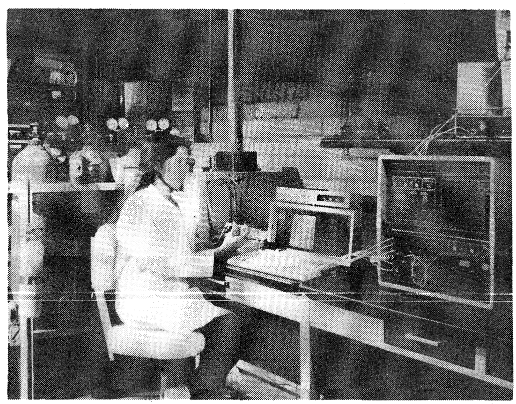


Environmental Test Application.

PCI-20000 MAKES OBSOLESCENCE OBSOLETE

The thought put into the I^3 bus permits new modules with innovative features or higher performance to be added to a system without displacing other features. Compatibility is insured. This prevents system obsolescence. As technology improves, modules in critical functions can be upgraded to achieve higher performance without the necessity of replacing the whole system.

Also, a system can be expanded if the number of channels, types of measurements, or number of control loops need to be increased. This is easily done by adding modules to vacant carrier positions or by adding additional carriers, as required.



Laboratory Application.

The classic deficiencies found in other fixed configuration data-acquisition systems are largely eliminated in this design.

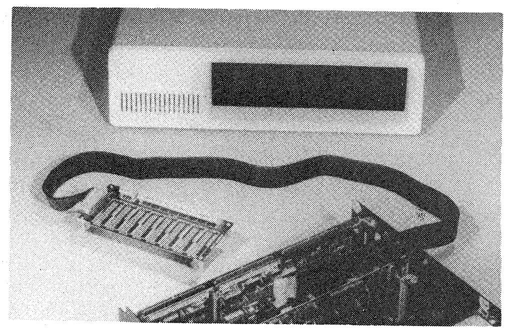
1. A wide variety of I/O types is supported: analog input (voltage, current, thermocouple, etc.), simultaneous multiple channel readings, analog output, digital input, digital output, counter input, frequency measurement, pulse generation along with high-speed triggering and alarm monitoring.
2. Large numbers of channels can be accommodated. Up to 128 digital I/O points or 80 analog inputs or 24 analog outputs or 12 counter/timer ports can be configured on a single carrier, using the modules available.

In addition, multiple carriers can be used to build systems of 200-600 channels.

3. By selecting the appropriate mix of modules, the capability of the system can be tailored to a particular application. Thus, function and cost can be optimized. Modules can be added, changed or rearranged at any time to satisfy new measurement or control requirements.
4. In addition to the digital connections provided by a standard computer bus, the internal Intelligent Instrumentation Interface (I^3) bus also provides for analog, synchronization and trigger signal routing. This facility allows the chaining of analog signals from one module to another as well as the triggering or synchronizing of events on a particular module by another module.

Some of the data acquisition systems on the market today do not clearly state how fast they can acquire data. Performance can be measured in many ways, some more meaningful than others. For example, on the subject of data acquisition speed, "conversion time" is often quoted. However, as was described in an earlier portions of this handbook, the A/D's conversion time is but one of many important components of speed. When selecting a DA&C system it is necessary to know not only the "real" specifications but under what conditions they apply.

The SPEED SUMMARY TABLE and the individual PRODUCT DATA SHEETS found later in this handbook, clearly define the detailed performance characteristics of the PCI-20000 system. An overview of the capabilities is presented here, in the SPECIFICATION SUMMARY TABLE. Please note that under most conditions the PCI-20000 is faster, without DMA, than most other systems are using DMA. The unique features of PCI DMA not only include very high speed (360K bytes/sec to RAM) but it is also the only system that can transfer Analog I/O, Digital I/O and Counter/Frequency data.



Shielded Cable Connects Module Inside the PC to an Outside Termination Panel.

Hundreds of different system configurations can be arranged by intermixing the wide variety of components within the PCI-20000 family. This permits each unique application to be satisfied without cost and performance compromises.

TABLE 10.1. PCI-20000 HARDWARE SPECIFICATION SUMMARY

SUPER BOARDS

PCI-20087W-1 **Digital I/O Board** -- 32 buffered channels plus 8 handshake control lines (40 total channels). TTL levels. BASIC S/W drivers are included.

PCI-20089W-1 **Analog Input Board** -- 16 single-ended or 8 differential channels. 12-bit resolution. Programmable gains of 1, 10, 100. 32 kHz sample rate. Internal rate-generator plus independent counter/timer. BASIC S/W drivers are included.

PCI-20091W-1 **High Speed Analog Input Board** -- Eight channels. Single-ended. 12-bit resolution. 89kHz sample rate. Internal/external trigger. Automatic input channel advance. Rate-generator. BASIC S/W drivers are included.

PCI-20093W-1 **Analog Output Board** -- Eight voltage or current outputs. 12-bit resolution. 0.5LSB linearity. Ranges: 0-5V, ±2.5V, ±5V, and 4-20mA FS. 32kHz total throughput rate. BASIC S/W drivers are included.

CARRIERS

PCI-20001C-1 **Carrier Board** -- Plugs into an expansion slot of any IBM PC, XT, AT or other compatible computers. Holds up to three modules.

PCI-20001C-2 **Carrier Board** -- Same as PCI-20001C-1 with the addition of 32 points of digital I/O.

PCI-20041C-2 **High Performance Carrier Board** -- Same as PCI- 20001C-2 with the addition of an inter-carrier bus, a programmable Pacer/Timer and external Interrupt/Acquisition control.

PCI-20041C-3 **High Performance Carrier Board** -- Same as PCI- 20041C-2 with the addition of full featured DMA supporting Analog I/O, Digital I/O and Counter data.

PCI-20098C-1 **Multifunction Carrier Board** -- Totally programmable. No jumpers. On-board analog input (8/16 channels), with programmable gain amplifier, and DMA. 32kHz sample rate. 16 digital I/O and Rate/burst-generator. 2 counters read frequency, period, pulsewidth, count, divide, etc. Holds two modules.

PCI-20202C-1 **_Smart_ Carrier Board** -- High speed with on-board TMS320C25 DSP processor running at 28MHz. Holds two I/O modules plus memory expansion.

PCI-20202C-2 **_Smart_ Carrier Board** -- Very high speed with on- board TMS320C25 DSP processor running at 40MHz. Hold two I/O modules plus memory expansion.

MODULES

PCI-20002M-1 **Analog Input Module** -- 16 single-ended or eight differential channels. 12-bit resolution. Programmable gains of 1, 10, 100, 1K. Up to 32kHz sample rate. Compatible with PCI-20005M-1 and PCI- 20031M-1 expanders.

PCI-20003M-2 **Analog Output Module** -- High Speed. Two voltage outputs. Ranges: 0-10V, ±5V and ±10V FS. 12-bit resolution. ±0.5LSB linearity. 3us settling time.

PCI-20003M-4 **Analog Output Module** -- High Speed. Two voltage/current outputs. Ranges: 0-10V, ±5V, ±10V and 4-20mA FS. 12-bit resolution.

PCI-20004M-1 **Digital I/O Module** -- 32 channels. TTL levels. Programmable I/O in groups of eight channels. Buffered outputs provide up to 24mA sink and 15mA source current. Input current is 200uA, max.

PCI-20005M-1 **Analog Input Expansion Module** -- Adds 32 single- ended or 16 differential channels to the PCI-20002M-1.

PCI-20006M-1 **Analog Output Module** -- High Speed. One voltage output. 16-bit resolution. Ranges: 0-10V, ±5V, and ±10V FS. ±.002% FS linearity. 10us settling time.

PCI-20006M-2 **Analog Output Module** -- High Speed. Two voltage outputs. 16-bit resolution. Ranges: 0-10V, ±5V, and ±10V FS. ±.002% FS linearity. 10us settling time.

PCI-20007M-1 **Counter/Timer/Pulse Generator Module** -- Four Counter/Timer input channels, count and measure frequency. One programmable output pulse generator. ±.008% accuracy. 8MHz clock rate.

PCI-20017M-1 **Simultaneous Sample/Hold Module** -- Four differential input channels. 20ns channel to channel scatter. Programmable gains: 1, 10, 100, 1000. 90dB Common Mode rejection. Up to 30kHz bandwidth. 100us settling time.

PCI-20019M-1 **High Speed Analog Input Module** -- Eight channels. Single-ended. 12-bit resolution and accuracy. Up to 89kHz sample rate. Internal/external trigger. Automatic input channel advance. Compatible with PCI-20031M-1 Expander.

PCI-20020M-1 **Trigger/Alarm Module** -- 3.5us response time. Dual channel. High, Low or Window comparisons. Reference programmable from -10V to +9.92V with 78mV resolution. Both analog and digital outputs available.

PCI-20021M-1 **Analog Output Module** -- Eight voltage outputs. 12-bit resolution and accuracy. 0.5LSB linearity. Ranges: 0-10V, ±5V, and ±10V FS. 16kHz total throughput.

PCI-20023M-1 **High Speed Analog Input Module** -- Eight channels. Single-ended. 12-bit resolution. 180kHz sample rate. Internal/external trigger. Automatic input channel advance. Compatible with PCI-20031M-1 Expander.

PCI-20031M-1 **High-Speed Analog Expansion Module** -- Adds up to 32 channels to the PCI-20002M-1, PCI-20019M-1, or PCI- 20023M-1. On-board channel list memory.

PCI-20201M-1 **Memory Expansion Module** -- Adds 64KWords of 55nS RAM to PCI-20202C-1 *Smart* carrier.

PCI-20201M-2 **Memory Expansion Module** -- Adds 64KWords of 25nS RAM to PCI-20202C-2 *Smart* carrier.

TERMINATION PANELS

PCI-20010T-1 **Analog Signal Termination Panel** -- 16-channel, screw-terminal connections. Can be used for inputs or outputs. Passive signal conditioning capability. Provisions for external current loop connections.

PCI-20010T-2 **Analog Signal Termination Panel** -- Optimized for thermocouple applications, but can be used for any analog input. Seven channels plus cold-junction compensation. Passive signal conditioning capability. Provisions for external current loop connections.

PCI-20011T-1 **Digital Signal Termination Panel** -- 16-channel, screw-terminal connections. Provisions for LEDs, pullups, pulldowns, debounce filters, etc. Can be used for inputs or outputs.

PCI-20018T-1 **Isolated, Digital Termination Panel** -- Eight-channel, screw terminal connections. Compatible with the PCI-1100 series and other industry standard opto-isolators. LED indicators show activated channels. For inputs or outputs.

PCI-20024T-1 **Analog Customizer Panel** -- 32-channel, screw-terminal connections. For use with PCI-20098C-1. Large Breadboard area. Thermocouple support. Passive and active signal conditioning capability.

PCI-20024T-2 **Analog Customizer Panel** -- 32-channel, screw-terminal connections. For use with PCI modules. Large Breadboard area. Thermocouple support. Passive and active signal conditioning capability.

PCI-20025T-1 **Digital Customizer Panel** -- 32-channel, screw-terminal connections. For use with PCI-20098C-1. Large Breadboard area. Passive and active signal conditioning capability. For both inputs and outputs. Passive and active signal conditioning capability.

PCI-20025T-2 **Digital Customizer Panel** -- 32-channel, screw- terminal connections. Use with other than PCI-20098C-1. Large Breadboard area. Passive and active signal conditioning capability. For both inputs and outputs. Passive and active signal conditioning capability.

PCI-20042-T1 **Isolated, Analog Input Signal Conditioning Termination Panel** -- Four channels (can be expanded with PCI-20042T-1). 750V channel-to-channel and input-to-output isolation. Differential inputs. Programmable gains: 1, 10, 100, 1000. Provisions for bridges and thermocouples. Bridge excitation.

PCI-20043T-1 **Isolated, Analog Input Expansion Termination Panel** -- Adds four channels to PCI-20042T-1. Other features are the same. Units stack together and take only one physical space.

PCI-20044T-1 **Active, Analog Input, Signal Conditioning Termination Panel** -- Four channels (can be expanded with PCI-20045T-1). Differential inputs. Programmable gains: 1, 10, 100, 1000. Provisions for bridges and thermocouples. Bridge excitation.

PCI-20045T-1 **Active, Analog Input Expansion Termination Panel** -- Adds four channels to PCI-20044T-1. Other features are the same. Units stack together and take only one physical space.

PCI-20048T-1 **Isolated, Digital Termination Panel** -- Same as PCI-20018T-1 except 16 channels. Compatible with PCI- 20051A-1 enclosure and 52A-1 cover.

PCI-20057T-1 **High Density, Analog Signal Termination Panel** -- 48-channel, screw-terminal connections. Passive signal conditioning capability. Thermocouple support. Can be used for inputs or outputs.

PCI-20058T-1 **High Density, Digital Signal Termination Panel** -- 48-channel, screw-terminal connections. Provisions for pullups, pulldowns, debounce filters, etc. Can be used for inputs or outputs.

CABLES

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PCI-20008A-1 **Analog Input Signal Cable** -- Flat, fully shielded, ribbon cable. Four feet (1.2 meters) long. For use with PCI-20098C-1 and PCI-20024T-1.

PCI-20009A-1 **Digital I/O Signal Cable** -- Flat, ground-plane, ribbon cable. Four feet (1.2 meters) long. For use with PCI-20098C-1 and PCI-20025T-1.

PCI-20012A-1 **Analog Signal Cable** -- Flat ribbon cable, six feet (2 meters) long. Fully shielded. Can be used with input or output devices.

PCI-20012A-2 **Analog Signal Cable** -- Same as PCI-20012A-1 except 12 feet (4 meters) long.

PCI-20013A-1 **Digital Signal Cable** -- Flat ribbon cable, six feet (2 meters) long. Ground-plane type shield. Can be used for input and output. For all digital termination panels except PCI-20058T-1 and PCI-20025T-1.

PCI-20013A-2 **Digital Signal Cable** -- Same as PCI-20013A-1 except 12 feet (4 meters) long. For all digital panels except PCI-20058T-1 and PCI-20025T-1.

PCI-20015A-1 **Analog Signal Cable** -- Flat ribbon cable, four feet (1.2 meters) long. Fully shielded. For input or output devices. For use with PCI-20024T series.

PCI-20032A-1 **Analog Output Cable** -- Special-purpose, three-connector cable intended to connect up to three 1- or 2-channel analog output modules to one termination panel. Not shielded. Six feet (2 meters) long.

PCI-20036A-1 **Digital Signal Cable** -- Flat ribbon cable, four feet (1.2 meters) long. Not shielded. For use with PCI-20058T-1 and PCI-20025T-2. Can be used for inputs and outputs.

PCI-20061A-1 **Digital Signal Cable** -- Flat ribbon cable, six feet (2 meters) long. Ground-plane type shield. For use with PCI-20058T-1 and PCI-20025T-1 termination panels. Can be used for input and output.

PCI-20062A-1 **Inter-Carrier Cable** -- Flat ribbon cable, five inches (13cm) long. Ground-plane type shield. For use in inter-connecting (extending) the I^3 Bus between adjacent PCI-20041C carriers.

PCI-20062A-2 **Inter-Carrier Cable** -- Flat ribbon cable, ten inches (25cm) long. Ground-plane type shield. For use in inter-connecting (extending) the I^3 Bus between non-adjacent PCI-20041C carriers.

OPTO-ISOLATORS

PCI-1101 **Digital Opto-Isolation Module** -- 10-32V AC/DC input. Isolation rating is 4000V. Compatible with PCI-20018T-1 and PCI-20048T-1 panels. One channel per module.

PCI-1102 **Digital Opto-Isolation Module** -- 90-140V AC/DC input. Isolation rating is 4000V. Compatible with PCI-20018T-1 and PCI-20048T-1 panels. One channel per module.

PCI-1103 **Digital Opto-Isolation Module** -- 5-60V DC output at 3A. Isolation rating is 4000V. Compatible with PCI-20018T-1 and PCI-20048T-1 panels. One channel per module.

PCI-1104 **Digital Opto-Isolation Module** -- 12-140V AC output at 3A. Isolation rating is 4000V. Compatible with PCI-20018T-1 and PCI-20048T-1 panels. One channel per module.

PCI-1105 **Digital Opto-Isolation Module** -- 180-280V AC/DC input. Isolation rating is 4000V. Compatible with PCI-20018T-1 and PCI-20048T-1 panels. One channel per module.

PCI-1106 **Digital Opto-Isolation Module** -- 24-280V AC output at 3A. Isolation rating is 4000V. Compatible with PCI-20018T-1 and PCI-20048T-1 panels. One channel per module.

ENCLOSURES

PCI-20029A-1 **Quad Termination Panel Enclosure** -- Rack or table- top use. Holds up to four standard-size termination panels.

PCI-20051A-1 **Termination Panel Enclosure** -- Rack mount enclosure for PCI-20048T-1 panel.

PCI-20052A-1 **Enclosure Cover** -- Cover for PCI-20051A-1 enclosure.

ACCESSORIES

PCI-20028A-3 **Strain-Relief Bracket** -- Supports ribbon cables at the rear of the PC. In most applications, one is recommended for each carrier used.

PCI-20033A-1 **Module Extender** -- Facilitates calibration and test of PCI modules.

PCI-20038A-1 **DC Power Supply** -- ±15V at 0.8A. ±0.05% regulation. Short-circuit protected. 120V AC input (nominal).

PCI-20038A-3 **DC Power Supply** -- ±15V at 0.8A. ±0.05% regulation. Short-circuit protected. 240V AC input (nominal).

TABLE 10.2A. BASIC (INTERPRETED) LANGUAGE

These tables are NOT specification sheets. Execution speed is a function of many factors, some of which are beyond the scope of a simple table. The speeds indicated here are offered as guidelines to assist the user in estimating the appropriateness of the PCI-20000 in a given application. All data is expressed in **Readings/Second**, unless otherwise noted, and includes the time to read or write to the PC's RAM using PCI software drivers.

SPEED SUMMARY TABLE

PARAMETER	CONDITIONS		80286 @ 12MHz	80386 @ 16MHz
Analog Input	PCI-20026S-1			
	PCI-20002M-1	(READ.CH)		
	G = 1,10		720	1000
	G = 100		530	740
	G = 1K		120	160
	with PCI-20017M-1 (1)	(READ.SSH)	960	1300
	Read Thermocouple	(READ.CH)	110	150
	Read RTD	(READ.CH)	210	290
	PCI-20019M-1	(READ.CH)	990	1400
	with PCI-20017M-1 (1)	(READ.SSH)	1500	2100
	PCI-20023M-1	(READ.CH)	990	1400
	PCI-20089W-1	(READ.CH)	720	1000
	PCI-20091W-1	(READ.CH)	990	1400
	PCI-20098C-1	(READ.CH)	800	1100
Analog Output	PCI-20026S-1	(WRITE.CH)		
	PCI-20003M, 6M, 21M series		1000	1400
	PCI-20093W-1		1000	1400
Digital I/O	PCI-20026S-1	(READ/WRITE.CH)		
	PCI-20004M-1 or On-Carrier	(Bytes/Sec)	1100	1600
	PCI-20087W-1		1100	1600
Counter/Timer	PCI-20026S-1			
	PCI-20007M-1 Read Counter	(READ.CH)	660	790
	Read Group (2)	(READ.CTS)	1100	1400
	PCI-20098C-1 Read Counter	(READ.CH)	880	1100

NOTES: (1) Data for the PCI-20017M-1 takes into account that each READ.SSH command reads four channels. (2) Read Group data takes into account that each READ.CTS command reads three channels.

TABLE 10.2B. BASIC (COMPILED) LANGUAGE SPEED SUMMARY TABLE

For information about the Data Professional products please refer to the PCI-20202C Data Sheet.

PARAMETER	CONDITIONS		80286 @ 12MHz	80386 @ 16MHz
Analog Input	PCI-20026S-1			
	PCI-20002M-1	(READ.CH)		
	G = 1,10		3300	4100
	G = 100		2100	2500
	G = 1K		380	440
	with PCI-20017M-1 (1)	(READ.SSH)	4000	4900
	Read Thermocouple	(READ.CH)	390	450
	Read RTD	(READ.CH)	810	970
	PCI-20019M-1	(READ.CH)	5700	7700
	with PCI-20017M-1 (1)	(READ.SSH)	8400	11,000
	PCI-20023M-1	(READ.CH)	5900	8200
	PCI-20089W-1	(READ.CH)	3300	4100
	PCI-20091W-1	(READ.CH)	5700	7700
	PCI-20098C-1	(READ.CH)	4000	5000
Analog Output	PCI-20026S-1	(WRITE.CH)		
	PCI-20003M, 6M series		6800	9800
	PCI-20021M-1		2000	2000
	PCI-20093W-1		3900	3900
Digital I/O	PCI-20026S-1	(READ/WRITE.CH)		
	PCI-20004M-1 or On-Carrier	(Bytes/Sec)	7200	10,000
	PCI-20087W-1		7200	10,000
Counter/Timer	PCI-20026S-1			
	PCI-20007M-1 Read Counter	(READ.CH)	4500	5300
	Read Group (2)	(READ.CTS)	7600	9100
	PCI-20098C-1 Read Counter	(READ.CH)	6000	7200

NOTES: (1) Data for the PCI-20017M-1 takes into account that each READ.SSH command reads four channels. (2) Read Group data takes into account that each READ.CTS command reads three channels.

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TABLE 10.2C. C LANGUAGE SPEED SUMMARY TABLE

For information about the Data Professional products please refer to the PCI-20202C Data Sheet.

PARAMETER	CONDITIONS		80286 @ 12MHz	80386 @ 16MHz
Analog Input	PCI-20026S-1			
	PCI-20002M-1	(READ.CH)		
	G = 1,10		3400	4200
	G = 100		2200	2600
	G = 1K		390	440
	with PCI-20017M-1 (1)	(READ.SSH)	4200	4800
	Read Thermocouple	(READ.CH)	400	460
	Read RTD	(READ.CH)	840	990
	PCI-20019M-1	(READ.CH)	6000	8100
	with PCI-20017M-1 (1)	(READ.SSH)	8800	11,000
	PCI-20023M-1	(READ.CH)	6200	8600
	PCI-20089W-1	(READ.CH)	3400	4200
	PCI-20091W-1	(READ.CH)	6000	8100
	PCI-20098C-1	(READ.CH)	4100	5200
Analog Output	PCI-20026S-1	(WRITE.CH)		
	PCI-20003M, 6M series		7300	10,000
	PCI-20021M-1		2000	2000
	PCI-20093W-1		3900	3900
Digital I/O	PCI-20026S-1	(READ/WRITE.CH)		
	PCI-20004M-1 or On-Carrier	(Bytes/Sec)	7700	11,000
	PCI-20087W-1		7700	11,000
Counter/Timer	PCI-20026S-1			
	PCI-20007M-1 Read Counter	(READ.CH)	4800	5700
	Read Group (2)	(READ.CTS)	8200	9800
	PCI-20098C-1		6400	7700

NOTES: (1) Data for the PCI-20017M-1 takes into account that each READ.SSH command reads four channels. (2) Read Group data takes into account that each READ.CTS command reads three channels.

TABLE 10.2D. TURBO PASCAL LANGUAGE SPEED SUMMARY TABLE

For information about the Data Professional products please refer to the PCI-20202C Data Sheet.

PARAMETER	CONDITIONS		80286 @ 12MHz	80386 @ 16MHz
Analog Input	PCI-20026S-1			
	PCI-20002M-1	(READ.CH)		
	G = 1,10		2900	3700
	G = 100		1900	2300
	G = 1K		390	470
	with PCI-20017M-1(1)	(READ.SSH)	4000	4800
	Read Thermocouple	(READ.CH)	360	420
	Read RTD	(READ.CH)	730	890
	PCI-20019M-1	(READ.CH)	4800	6600
	with PCI-20017M-1(1)	(READ.SSH)	7100	9900
	PCI-20023M-1	(READ.CH)	4900	6800
	PCI-20089W-1	(READ.CH)	2900	3700
	PCI-20091W-1	(READ.CH)	4800	6600
	PCI-20098C-1	(READ.CH)	3400	4400
Analog Output	PCI-20026S-1	(WRITE.CH)		
	PCI-20003M, 6M series		5500	8000
	PCI-20021M-1		2000	2000
	PCI-20093W-1		3900	3900
Digital I/O	PCI-20026S-1	(READ/WRITE.CH)		
	PCI-20004M-1 or On-Carrier	(Bytes/Sec)	5800	8800
	PCI-20087W-1		5800	8800
Counter/Timer	PCI-20026S-1			
	PCI-20007M-1 Read Counter	(READ.CH)	3600	4300
	Read Group(4)	(READ.CTS)	6200	7400
	PCI-20098C-1 Read Counter	(READ.CH)	4900	5800

NOTES: (1) Data for the PCI-20017M-1 takes into account that each READ.SSH command reads four channels. (2) Read Group data takes into account that each READ.CTS command reads three channels.

TABLE 10.2E. ASYST LANGUAGE SPEED SUMMARY TABLE

The ASYST Language is a separate product, PCI-20301S Series. The complete Data Sheet is in section 12.

PARAMETER	CONDITIONS		80286 @ 12MHz	80386 @ 16MHz
Analog Input	PCI-20301S-3			
	PCI-20098C-1			
	G = 1,10, 100		38kHz	38kHz
Analog Output	PCI-20301S-3			
	PCI-20003M, 6M Series	(Chs/Sec)	5500	8000
	PCI-200021M-1	(Chs/Sec)	2000	2000
Digital I/O	PCI-20301S-3			
	On-Carrier	(Bytes/Sec)	5800	8800
Counter/Timer	PCI-20301S-3			
	On-Carrier Read Counter	(Reading/Sec)	4900	5800

TABLE 10.2F. ASSEMBLY LANGUAGE SPEED SUMMARY TABLE

For information about the Data Professional products please refer to the PCI-20202C Data Sheet.

PARAMETER	CONDITIONS	80286 @ 12MHz	80386 @ 16MHz
Analog Input	PCI-20002M-1 Single Channel Read		
	G = 1, 10, 100, 1K	32,000	32,000
	Multi Channel		
	G = 1, 10 11,000	12,000	
	G = 100	5500	5500
	G = 1K	800	800
	with PCI-20017M-1	5200	5200
	PCI-20019M-1	89,000	89,000
	with PCI-20017M-1	41,000	41,000
	PCI-20023M-1	150,000	180,000
	PCI-20089W-1	32,000	32,000
	PCI-20091W-1	89,000	89,000
	PCI-20098C-1	38,000	38,000
Analog Output	PCI-20003M-2	80,000	80,000
	PCI-20003M-4 (Current Output)	40,000	40,000
	PCI-20006M-1,-2	80,000	80,000
	PCI-20021M-1	2000	2000
	PCI-20093W-1	3900	3900
Digital I/O	PCI-20004M-1 or		
	On-Carrier (Bytes/Sec)	160,000	280,000
	PCI-20087W-1	160,000	280,000
Counter/Timer	PCI-20007M-1 Read Counter	130,000	230,000
	Read and Reset	100,000	170,000
	PCI-20098C-1 Read Counter	130,000	230,000
	Read and Reset	100,000	170,000

TABLE 10.2G. LANGUAGE INDEPENDENT SPEED SUMMARY TABLE

HIGH SPEED COMMANDS, APPLIES TO ALL LANGUAGES

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For information about the Data Professional products please refer to the PCI-20202C Data Sheet.

PARAMETER	CONDITIONS	80286 @ 12MHz	80386 @ 16MHz
Analog Input	PCI-20027S, Block Mode(1) (HS.RUN)		
	PCI-20002M-1 (mode 1)		
	G = 1,10	11,000	12,000
	G = 100	5500	5500
	G = 1K	800	800
	with PCI-20005M-1 or		
	PCI-20031M-1 (mode 1)		
	G = 1,10	10,000	11,000
	G = 100	5500	5500
	G = 1K	970	970
	PCI-20019M-1 (mode 4)	89,000	89,000
	with one PCI-20017M-1(3) (mode 2)	38,000	41,000
	with two PCI-20017M-1's(3) (mode 2)	36,000	40,000
	PCI-20023M-1 (mode 4)	130,000	180,000
	PCI-20089W-1	11,000	12,000
	PCI-20091W-1	89,000	89,000
	PCI-20098C-1	38,000	38,000
	PCI-20027S Series (DMA.RUN)		
	PCI-20002M-1 (1 Channel only)	32,000	32,000
	with PCI-20031M-1 (multi Chs)(2)		
	G = 1,10	12,350	12,350
	G = 100	7,600	7,600
	G = 1K	970	970
	PCI-20019M-1		
	Transfer Conditions:(4)		
	1K frames at 2 bytes/frame	89,000	89,000
	Continuous at 2 bytes/frame	89,000	89,000

Continued...

PARAMETERS	CONDITIONS		80286 @ 12MHz	80386 @ 16MHz
	PCI-20023M-1	(DMA.RUN)		
	Transfer Conditions:(4)			
	1K frames at 2 bytes/frame		91,000	110,000
	Continuous at 2 bytes/frame		91,000	110,000
	PCI-20091W-1			
	Transfer Conditions:(4)			
	1K frames at 2 bytes/frame		89,000	89,000
	Continuous at 2 bytes/frame		89,000	89,000
	PCI-20098C-1			
	Transfer Conditions:(4)			
	1K frames at 2 bytes/frame		38,000	38,000
	Continuous at 2 bytes/frame		38,000	38,000
Analog Output	PCI-20027S Series (DMA.RUN)			
	PCI-20003M-2, 6M-1/-2			
	Transfer Conditions:(4)			
	1K frames at 3 bytes/frame		61,000	74,000
	Continuous at 3 bytes/frame		61,000	74,000
	PCI-20021M-1		2,000	2,000
Digital I/O	PCI-20027S Series	(DMA.RUN)		
	Transfer Conditions:(4)			
	1K frames at 2 bytes/frame		182Kbyte	220Kbyte
	1K frames at 8 bytes/frame		182Kbyte	220Kbyte
	Continuous at 2 bytes/frame		182Kbyte	220Kbyte
	Continuous at 8 bytes/frame		182Kbyte	220Kbyte
Counter/Timer	PCI-20027S Series (DMA.RUN)			
	PCI-20007M-1	Read Counter		
	Transfer Conditions:(4)			
	1K frames at 2 bytes/frame		91,000	110,000
	Continuous at 2 bytes/frame		91,000	110,000

NOTES:

(1) Block Mode. This corresponds to reading one or more channels, one or more times.

(2) When the 31M-1 Expander Module is used with either HS.RUN, Mode 4 (i.e., with PCI-20019M) or DMA, analog input (i.e., with PCI-20002M or PCI-20019M), the total available channels are determined by the PCI-20031Ms. That is, the channels on the PCI-20002M or PCI-20019M are not available for use.

(3) Data for the PCI-20017M-1 takes into account that each READ.SSH command reads four channels.

(4) A "frame" is defined as the list containing the channels to be read (or written to). "1K frames" refers to reading the list 1024 times. "Bytes/frame" refers to the amount of data in each frame (reading one PCI-20019M-1 requires two bytes).

THE PCI-20000 CONFIGURATION GUIDE

INTRODUCTION

In addition to components, the PCI family now encompasses complete systems to satisfy test, measurement, control, and instrumentation demands. The term "system" is normally used to describe a complete, high-level product. Components are sub-systems. However, we often refer to PCI components, in a computer, as a system. Systems bring together the various hardware items needed to fulfill a general applications category. All systems include easy-to-use, menu-driven software. The PCI WORK STATION is an industrial quality system built on a PC/AT compatible platform. Components consist of board-level products. When used with a personal computer (PC), you can easily configure a specialized test, measurement or control facility.

PCI-20000 components are built on printed circuit boards that plug into an expansion slot within the host computer. Direct connection is made to the PC's internal bus, allowing high-speed data acquisition and control. The internal PCI-20000 architecture is designed to interface with most microcomputers. Compatibility with a specific PC is achieved with bus translation circuitry located on the plug-in board. At this time all PCI boards and carriers are designed for the traditional IBM PC/XT/AT architecture. Burr-Brown expects to introduce data acquisition products for other PC bus architectures in the future.

Mechanically, the PCI-20000 component family consists of several types of printed circuit boards: "Boards", "Carriers", "Modules" and "Termination Panels". A carrier is the system's "main board". Carriers plug into one of the PC's expansion slots. The modules connect, "piggyback" style, to the carrier. Figure 10.2 is a block diagram showing a typical carrier's basic configuration. The unique

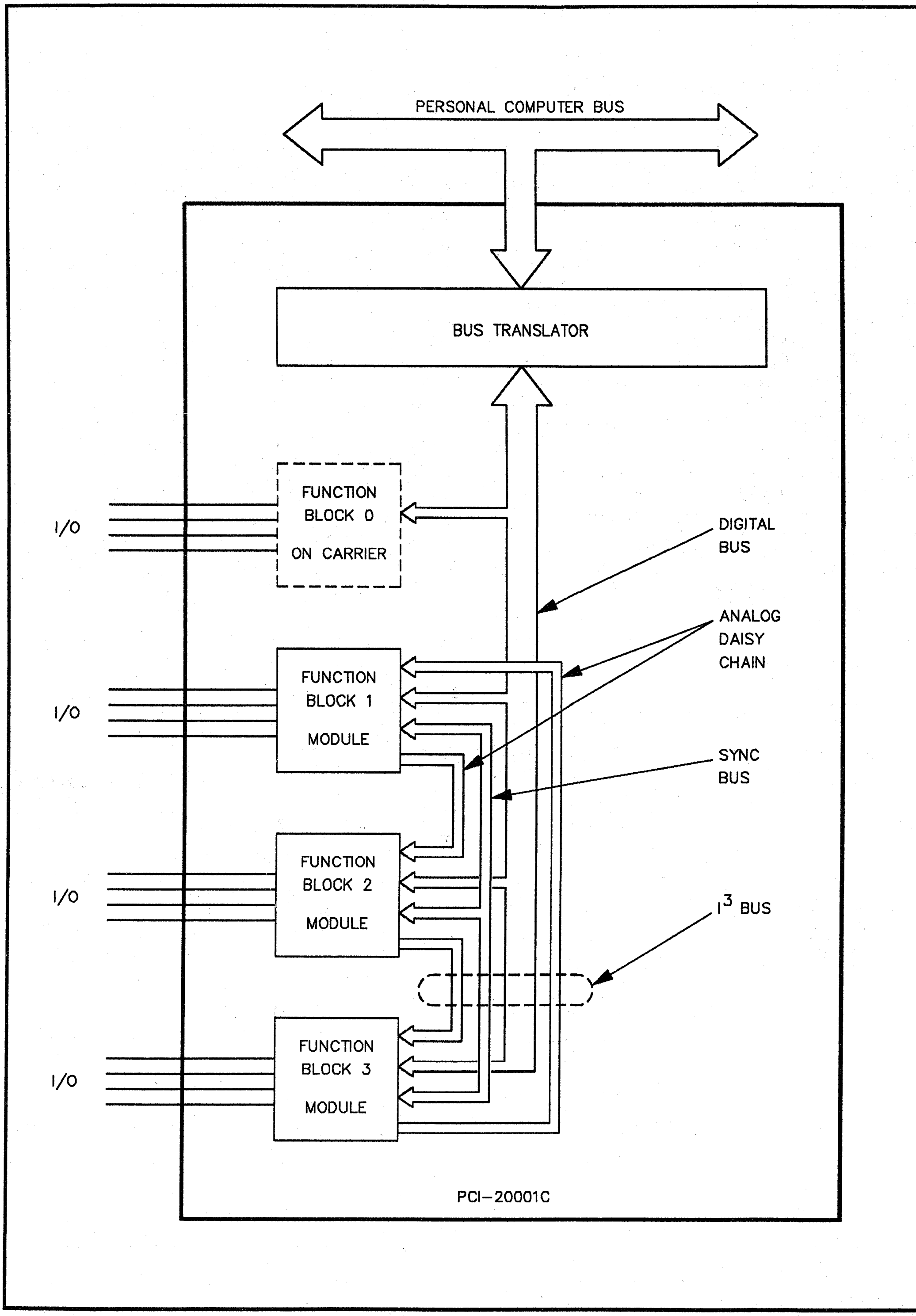

Figure 10.2. Personal Computer-Based Data Acquisition and Control System--Block Diagram.

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design allows the input/output configuration to be optimized for a particular need. Key concepts include its modular construction, its proprietary "Intelligent Instrumentation Interface" (I^3) bus and its memory-mapped address structure.

In general, each different module supports a unique I/O function. Many of the carriers have built-in I/O capabilities. That is, they have a useful role without any modules installed. The carriers and modules usually reside inside the PC or in an adjacent expansion enclosure. Burr-Brown's PC Expander adds seven slots to an existing PC. The term "Board" is reserved for non-modular, fixed-configuration products. Both boards and carriers can plug directly inside the PC. Termination panels, on the other hand, are installed in external cabinets or on available mounting surfaces.

The PCI family now contains four boards and six carriers. These ten types are designed for the IBM series of PCs as well as the COMPAQ, AT&T, Zenith, Siemens and other IBM-compatible personal computers. Boards are intended for small or well defined applications. They represent the lowest cost per channel available. While carrier-based products do cost more than fixed boards, they also provide the greatest range of functions, capabilities and channels. Each carrier provides space for two or three (depending upon the model) modules. Carriers include the Intelligent Instrumentation Interface (I^3) bus, which facilitates inter-module communications. Most carriers provide numerous digital I/O points as well as other useful features.

A wide variety of modules for analog and digital applications exist. Because of the versatility and ease of expansion of a modular system, the family of modules will continue to grow. In addition, modules can be treated as building-block components in a wide range of OEM applications not associated with standard PCs.

Signal termination panels complement the system by providing convenient screw-terminal connections between the internal electronics and the external field signals. Appropriate cables are available to link the termination panels to the modules. The product line also includes rack and table-top enclosures for the termination panels.

There are many software support packages that make using or interfacing to the PCI-20000 easy. Some of the packages contain libraries of routines that can be called from high-level languages. Versions to work with BASIC, C, Turbo Pascal, and Assembly languages are now available. Menu-driven packages provide complete solutions without writing a single line of code. The wide range of software products gives the user easy and uncomplicated access to the extensive features of the PCI family.

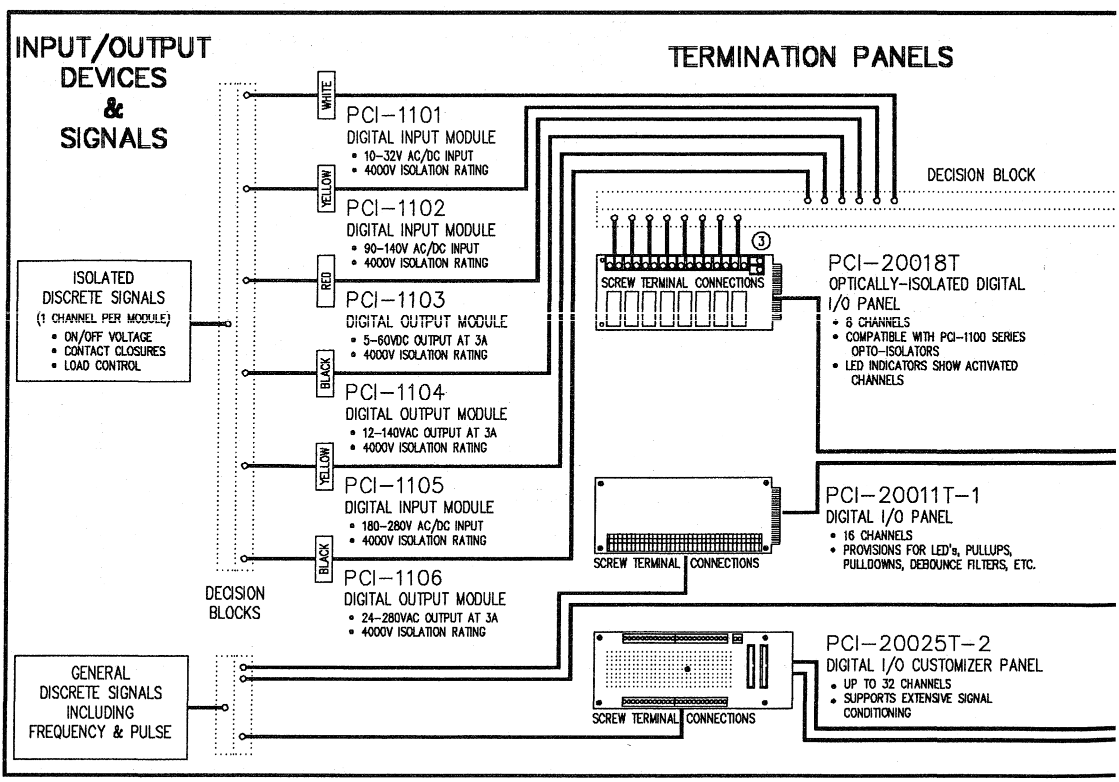


FIGURE 10.2a. PCI-20000 System Component Configuration Chart--Digital I/O Boards.

Please refer to Table 10.1, PCI-20000 Specification Summary, and to Figure 10.2, PCI-20000 System Component Configuration Charts, for an overview of, and the relationship between, the many components within the PCI-20000 family. Complete details appear in the individual Product Data Sheets shown later in this section

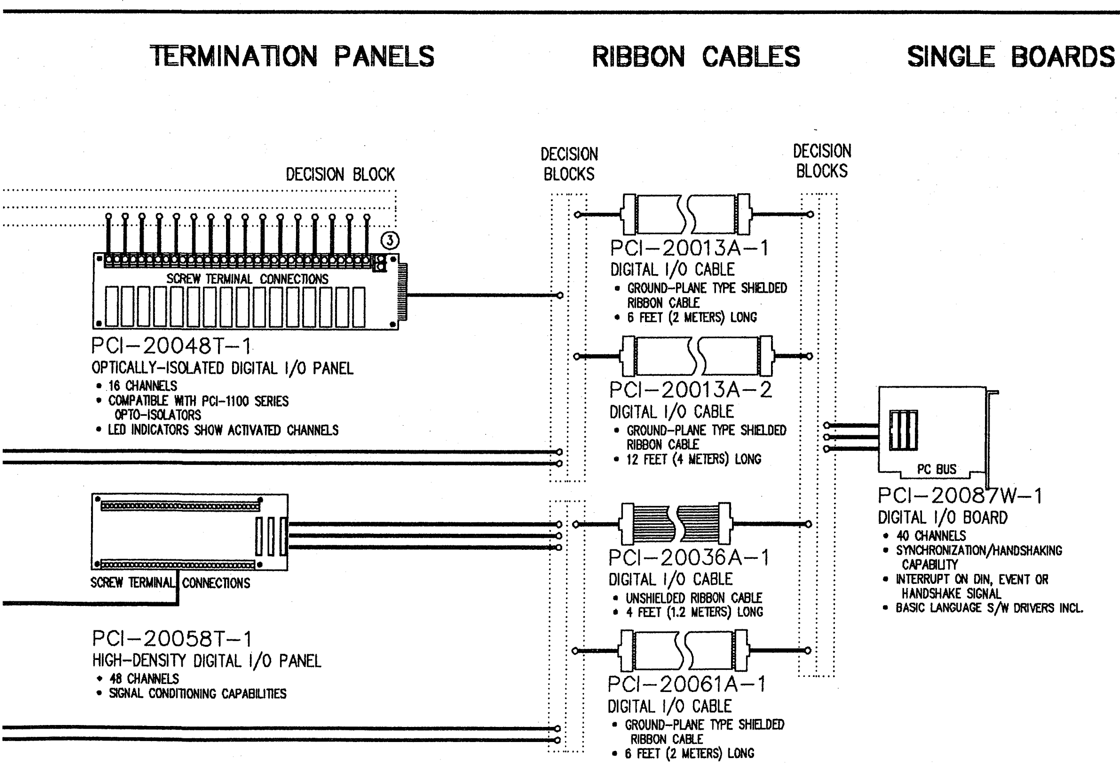
CONFIGURING A PCI-20000 SYSTEM

This material is intended as an aid in configuring a system for a given application. All that is needed is a working knowledge of the desired task, this handbook, and a little attention to details. Here are some suggestions:

SOFTWARE CONFIGURATION TABLE

A summary of the major software products available to operate the PCI-20000 is shown in Table 10.4. (Table 10-4 is located on page 10-24.) Software package ratings are in some cases based upon cursory data, but they are still included in hopes of giving a new potential user a place to start in his evaluation. A "***" symbol implies "major strength" in the indicated area. A "**" symbol means "many useful features", while a single "*" suggests "some capabilities" in the area noted.

Note that some of these product are listed with PCI numbers while others are not. "Order Direct" means that the material is not available directly through PCI channels and should be ordered directly from the software manufacturer. Detailed information about all of these products, including information about where "Order Direct" materials can be obtained, is found in the Section 12 of this handbook.



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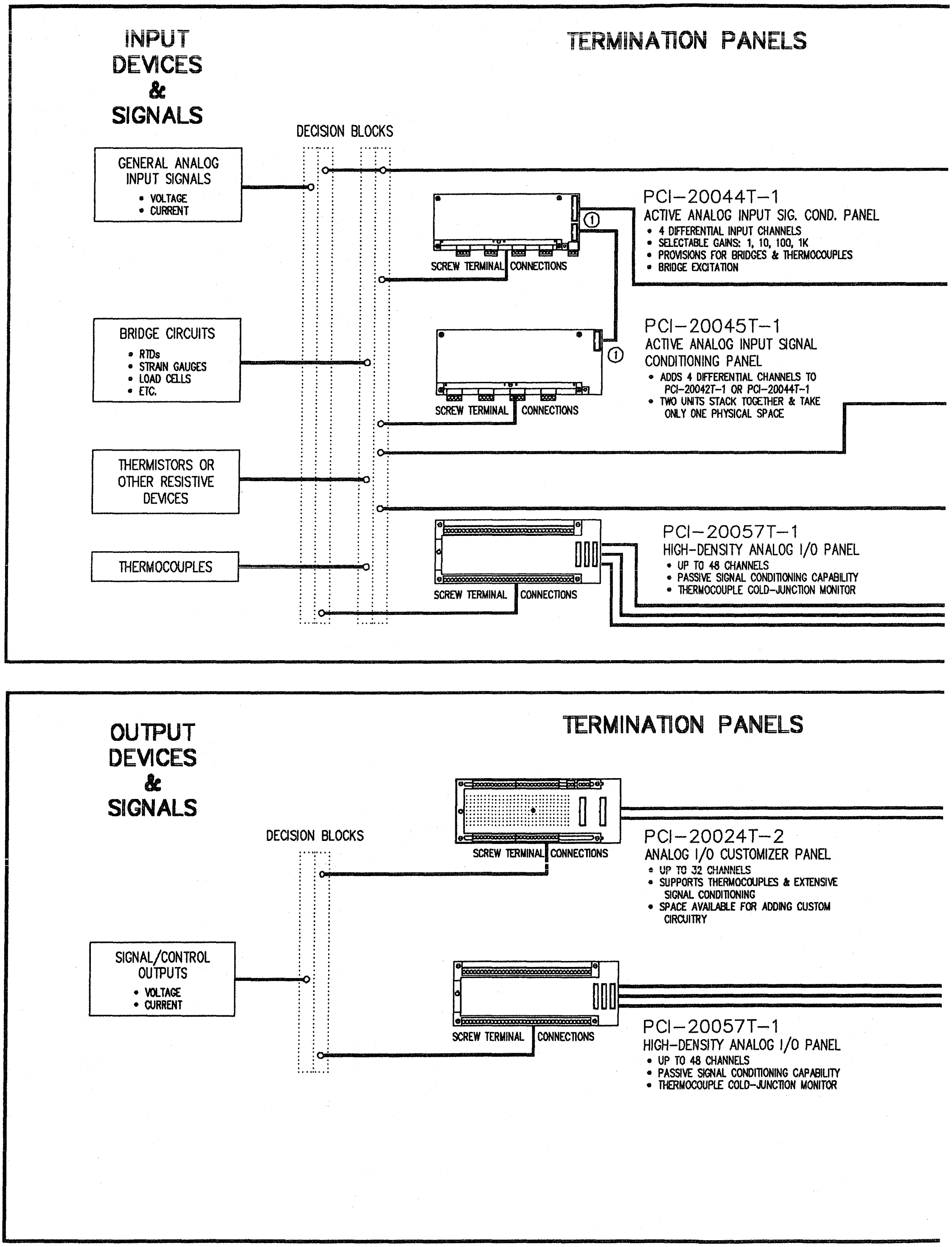
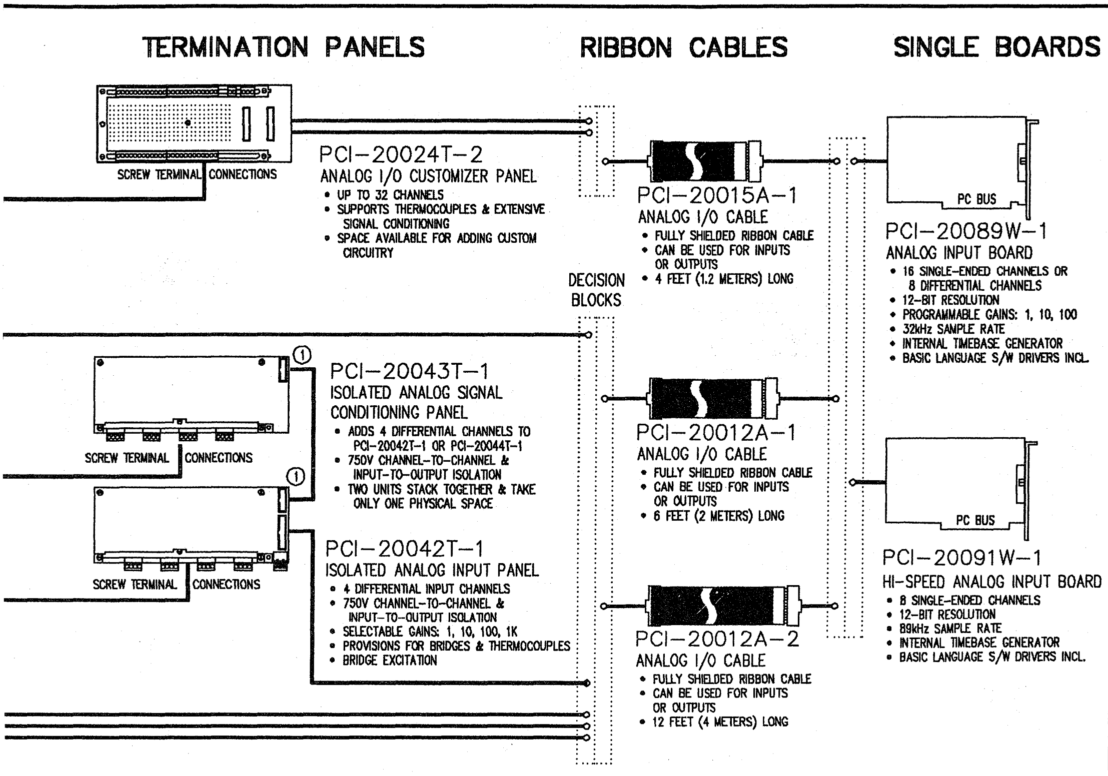


FIGURE 10.2b. PCI-20000 System Component Configuration Chart--Analog I/O Boards.


TERMINATION PANELS
RIBBON CABLES
SINGLE BOARDS
SCREW TERMINAL CONNECTIONS
PCI-20024T-2
ANALOG I/O CUSTOMIZER PANEL
• UP TO 32 CHANNELS
• SUPPORTS THERMOCOUPLES & EXTENSIVE SIGNAL CONDITIONING
• SPACE AVAILABLE FOR ADDING CUSTOM CIRCUITRY
PCI-20015A-1
ANALOG I/O CABLE
• FULLY SHIELDED RIBBON CABLE
• CAN BE USED FOR INPUTS OR OUTPUTS
• 4 FEET (1.2 METERS) LONG
DECISION BLOCKS
PC BUS
PCI-20089W-1
ANALOG INPUT BOARD
• 16 SINGLE-ENDED CHANNELS OR 8 DIFFERENTIAL CHANNELS
• 12-BIT RESOLUTION
• PROGRAMMABLE GAINS: 1, 10, 100
• 32kHz SAMPLE RATE
• INTERNAL TIMEBASE GENERATOR
• BASIC LANGUAGE S/W DRIVERS INCL.
1
PCI-20043T-1
ISOLATED ANALOG SIGNAL CONDITIONING PANEL
• ADDS 4 DIFFERENTIAL CHANNELS TO PCI-20042T-1 OR PCI-20044T-1
• 750V CHANNEL-TO-CHANNEL & INPUT-TO-OUTPUT ISOLATION
• TWO UNITS STACK TOGETHER & TAKE ONLY ONE PHYSICAL SPACE
SCREW TERMINAL CONNECTIONS
PCI-20012A-1
ANALOG I/O CABLE
• FULLY SHIELDED RIBBON CABLE
• CAN BE USED FOR INPUTS OR OUTPUTS
• 6 FEET (2 METERS) LONG
PC BUS
PCI-20042T-1
ISOLATED ANALOG INPUT PANEL
• 4 DIFFERENTIAL INPUT CHANNELS
• 750V CHANNEL-TO-CHANNEL & INPUT-TO-OUTPUT ISOLATION
• SELECTABLE GAINS: 1, 10, 100, 1K
• PROVISIONS FOR BRIDGES & THERMOCOUPLES
• BRIDGE EXCITATION
SCREW TERMINAL CONNECTIONS
PCI-20091W-1
HI-SPEED ANALOG INPUT BOARD
• 8 SINGLE-ENDED CHANNELS
• 12-BIT RESOLUTION
• 89kHz SAMPLE RATE
• INTERNAL TIMEBASE GENERATOR
• BASIC LANGUAGE S/W DRIVERS INCL.
PCI-20012A-2
ANALOG I/O CABLE
• FULLY SHIELDED RIBBON CABLE
• CAN BE USED FOR INPUTS OR OUTPUTS
• 12 FEET (4 METERS) LONG

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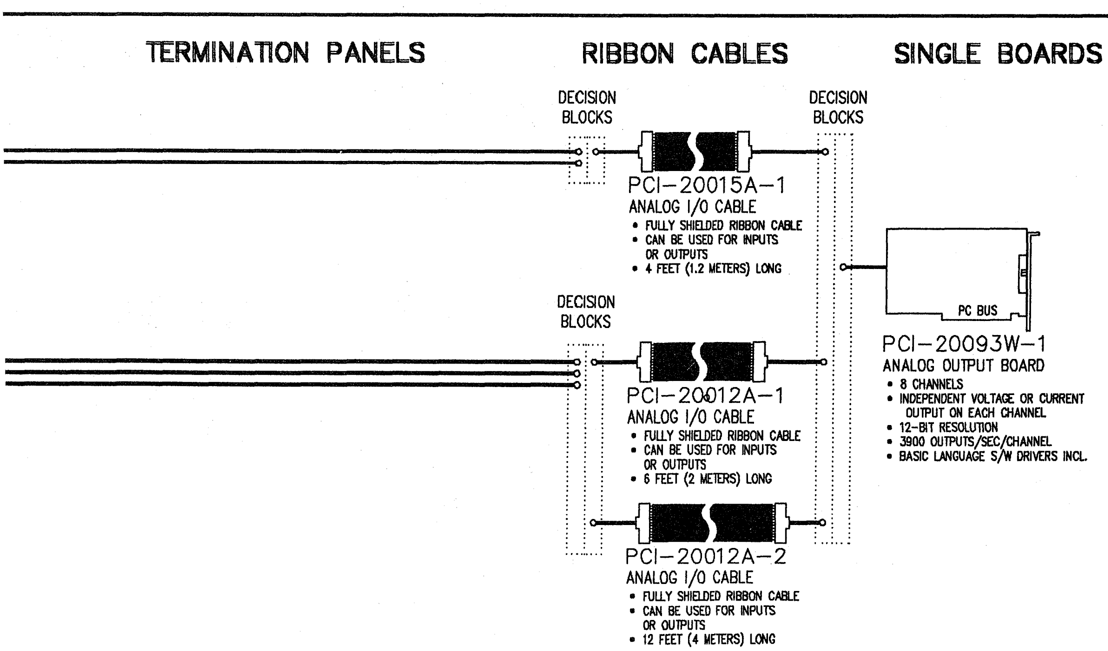

TERMINATION PANELS
RIBBON CABLES
SINGLE BOARDS
DECISION BLOCKS
DECISION BLOCKS
PCI-20015A-1
ANALOG I/O CABLE
• FULLY SHIELDED RIBBON CABLE
• CAN BE USED FOR INPUTS OR OUTPUTS
• 4 FEET (1.2 METERS) LONG
PC BUS
DECISION BLOCKS
PCI-20093W-1
ANALOG OUTPUT BOARD
• 8 CHANNELS
• INDEPENDENT VOLTAGE OR CURRENT OUTPUT ON EACH CHANNEL
• 12-BIT RESOLUTION
• 3900 OUTPUTS/SEC/CHANNEL
• BASIC LANGUAGE S/W DRIVERS INCL.
PCI-20012A-1
ANALOG I/O CABLE
• FULLY SHIELDED RIBBON CABLE
• CAN BE USED FOR INPUTS OR OUTPUTS
• 6 FEET (2 METERS) LONG
PCI-20012A-2
ANALOG I/O CABLE
• FULLY SHIELDED RIBBON CABLE
• CAN BE USED FOR INPUTS OR OUTPUTS
• 12 FEET (4 METERS) LONG

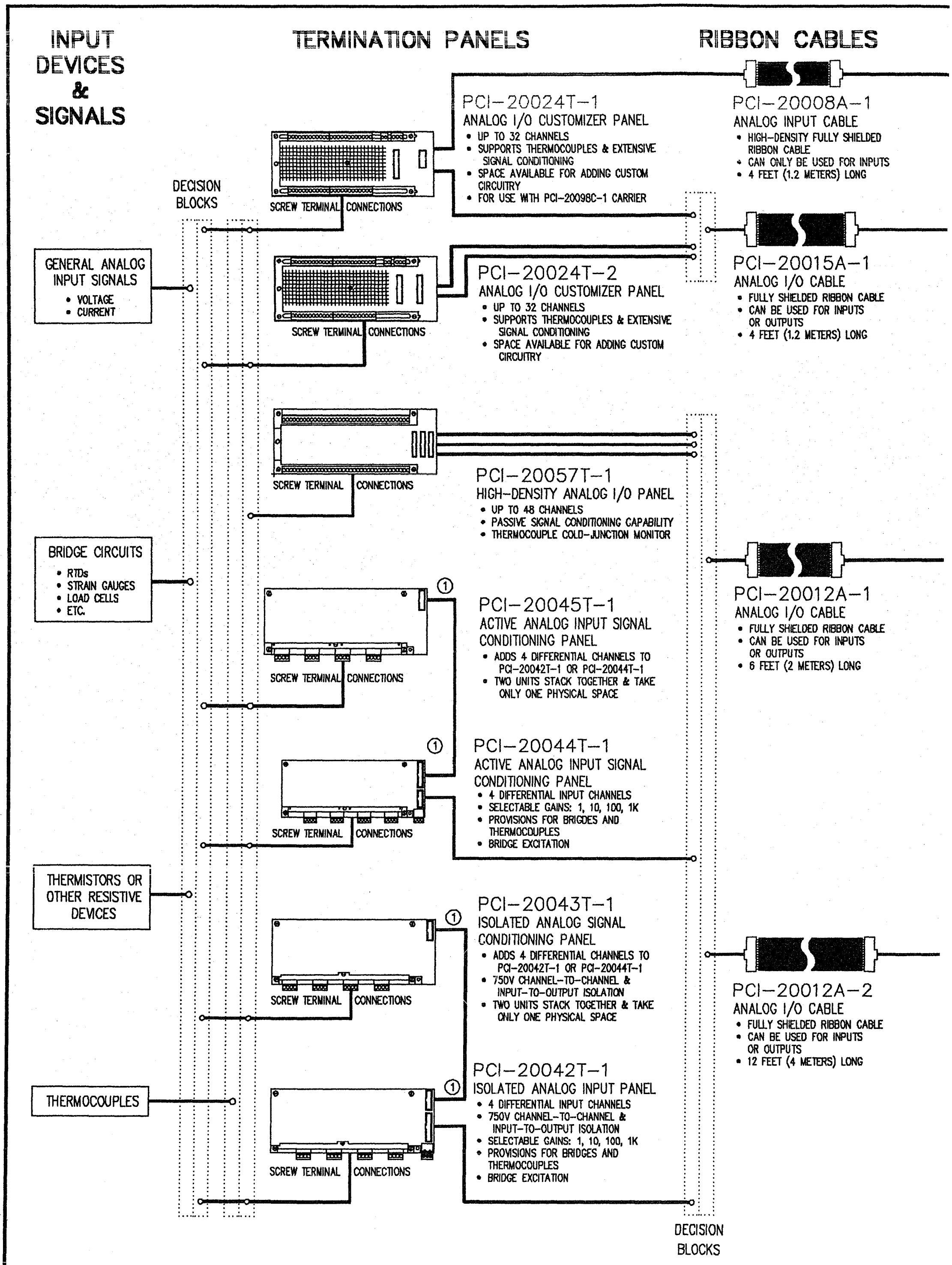
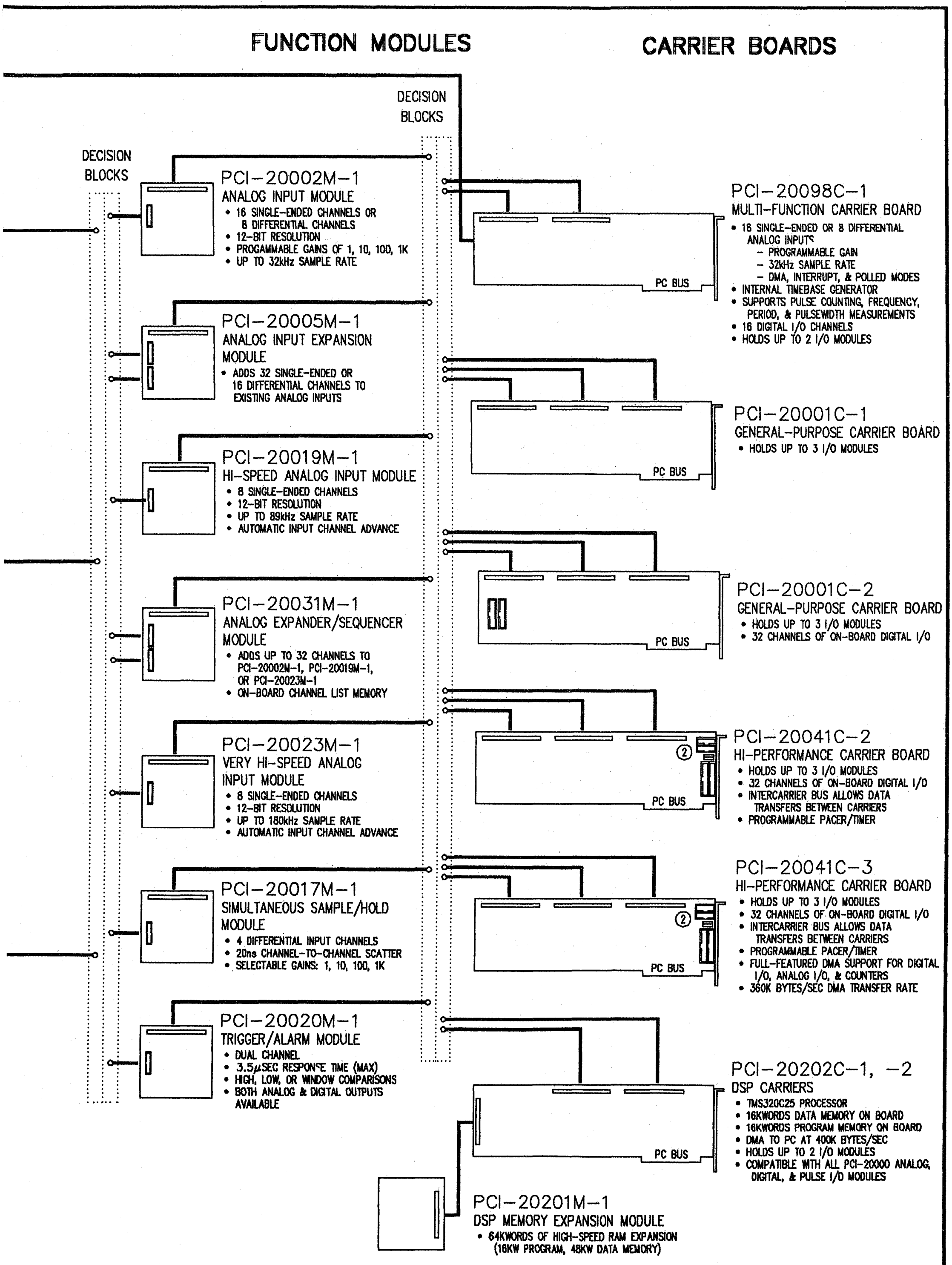


FIGURE 10.2c. PCI-20000 System Component Configuration Chart--Analog Input Modules and Carriers.


FUNCTION MODULES
CARRIER BOARDS
DECISION BLOCKS
DECISION BLOCKS
PCI-20002M-1
ANALOG INPUT MODULE
• 16 SINGLE-ENDED CHANNELS OR 8 DIFFERENTIAL CHANNELS
• 12-BIT RESOLUTION
• PROGAMMABLE GAINS OF 1, 10, 100, 1K
• UP TO 32kHz SAMPLE RATE
PCI-20005M-1
ANALOG INPUT EXPANSION MODULE
• ADDS 32 SINGLE-ENDED OR 16 DIFFERENTIAL CHANNELS TO EXISTING ANALOG INPUTS
PCI-20019M-1
HI-SPEED ANALOG INPUT MODULE
• 8 SINGLE-ENDED CHANNELS
• 12-BIT RESOLUTION
• UP TO 89kHz SAMPLE RATE
• AUTOMATIC INPUT CHANNEL ADVANCE
PCI-20031M-1
ANALOG EXPANDER/SEQUENCER MODULE
• ADDS UP TO 32 CHANNELS TO PCI-20002M-1, PCI-20019M-1, OR PCI-20023M-1
• ON-BOARD CHANNEL LIST MEMORY
PCI-20023M-1
VERY HI-SPEED ANALOG INPUT MODULE
• 8 SINGLE-ENDED CHANNELS
• 12-BIT RESOLUTION
• UP TO 180kHz SAMPLE RATE
• AUTOMATIC INPUT CHANNEL ADVANCE
PCI-20017M-1
SIMULTANEOUS SAMPLE/HOLD MODULE
• 4 DIFFERENTIAL INPUT CHANNELS
• 20ns CHANNEL-TO-CHANNEL SCATTER
• SELECTABLE GAINS: 1, 10, 100, 1K
PCI-20020M-1
TRIGGER/ALARM MODULE
• DUAL CHANNEL
• 3.5µSEC RESPONSE TIME (MAX)
• HIGH, LOW, OR WINDOW COMPARISONS
• BOTH ANALOG & DIGITAL OUTPUTS AVAILABLE
PCI-20098C-1
MULTI-FUNCTION CARRIER BOARD
• 16 SINGLE-ENDED OR 8 DIFFERENTIAL ANALOG INPUTS
– PROGRAMMABLE GAIN
– 32kHz SAMPLE RATE
– DMA, INTERRUPT, & POLLED MODES
• INTERNAL TIMEBASE GENERATOR
• SUPPORTS PULSE COUNTING, FREQUENCY, PERIOD, & PULSEWIDTH MEASUREMENTS
• 16 DIGITAL I/O CHANNELS
• HOLDS UP TO 2 I/O MODULES
PC BUS
PCI-20001C-1
GENERAL-PURPOSE CARRIER BOARD
• HOLDS UP TO 3 I/O MODULES
PC BUS
PCI-20001C-2
GENERAL-PURPOSE CARRIER BOARD
• HOLDS UP TO 3 I/O MODULES
• 32 CHANNELS OF ON-BOARD DIGITAL I/O
PC BUS
PCI-20041C-2
HI-PERFORMANCE CARRIER BOARD
• HOLDS UP TO 3 I/O MODULES
• 32 CHANNELS OF ON-BOARD DIGITAL I/O
• INTERCARRIER BUS ALLOWS DATA TRANSFERS BETWEEN CARRIERS
• PROGRAMMABLE PACER/TIMER
PC BUS
PCI-20041C-3
HI-PERFORMANCE CARRIER BOARD
• HOLDS UP TO 3 I/O MODULES
• 32 CHANNELS OF ON-BOARD DIGITAL I/O
• INTERCARRIER BUS ALLOWS DATA TRANSFERS BETWEEN CARRIERS
• PROGRAMMABLE PACER/TIMER
• FULL-FEATURED DMA SUPPORT FOR DIGITAL I/O, ANALOG I/O, & COUNTERS
• 360K BYTES/SEC DMA TRANSFER RATE
PC BUS
PCI-20202C-1, -2
DSP CARRIERS
• TMS320C25 PROCESSOR
• 16KWORDS DATA MEMORY ON BOARD
• 16KWORDS PROGRAM MEMORY ON BOARD
• DMA TO PC AT 400K BYTES/SEC
• HOLDS UP TO 2 I/O MODULES
• COMPATIBLE WITH ALL PCI-20000 ANALOG, DIGITAL, & PULSE I/O MODULES
PC BUS
PCI-20201M-1
DSP MEMORY EXPANSION MODULE
• 64KWORDS OF HIGH-SPEED RAM EXPANSION (16KW PROGRAM, 48KW DATA MEMORY)

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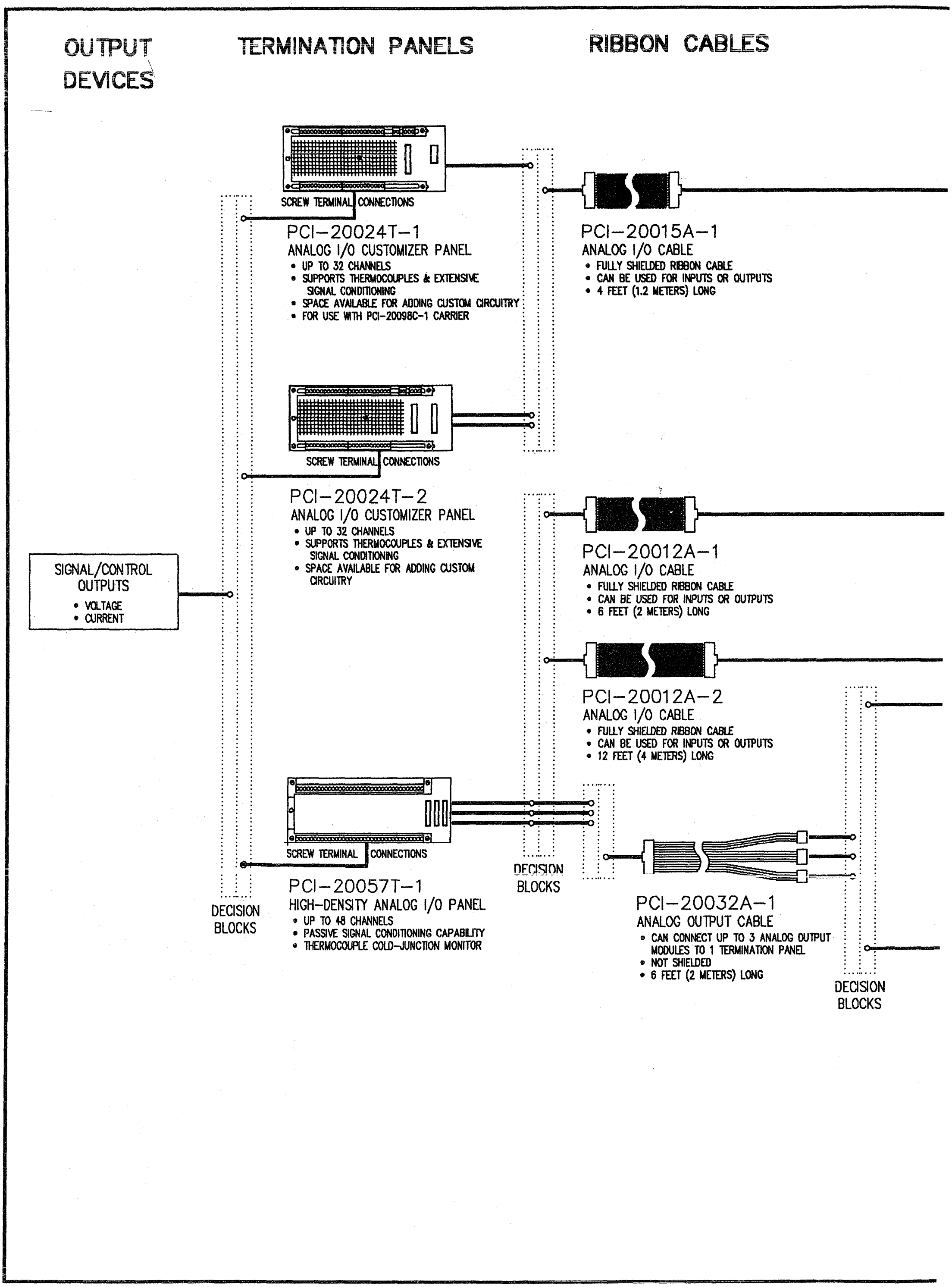
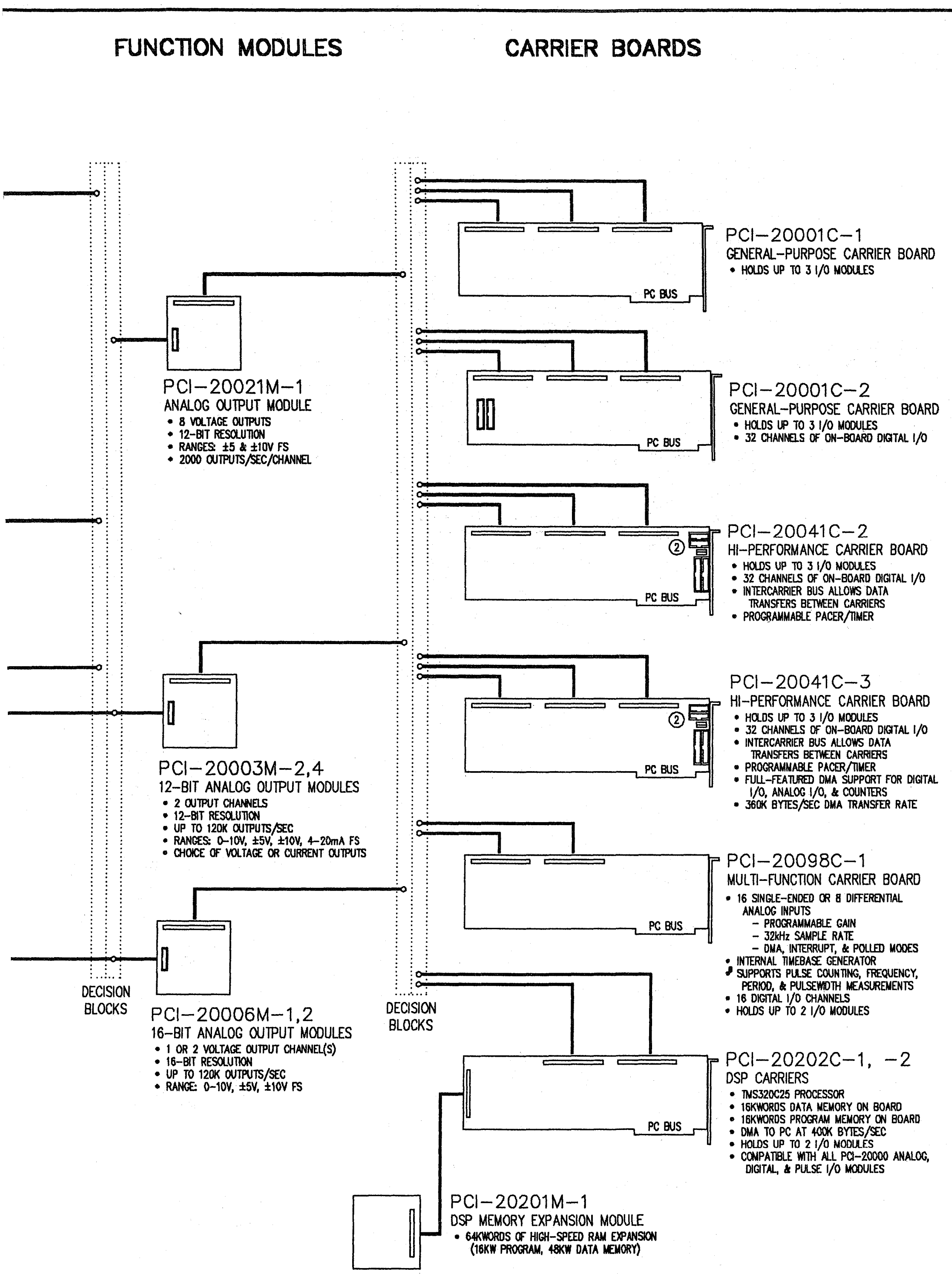


FIGURE 10.2d. PCI-20000 System Component Configuration Chart--Analog Output Modules and Carriers.



FUNCTION MODULES
CARRIER BOARDS
PCI-20001C-1
GENERAL-PURPOSE CARRIER BOARD
• HOLDS UP TO 3 I/O MODULES
PC BUS
PCI-20021M-1
ANALOG OUTPUT MODULE
• 8 VOLTAGE OUTPUTS
• 12-BIT RESOLUTION
• RANGES: ±5 & ±10V FS
• 2000 OUTPUTS/SEC/CHANNEL
PCI-20001C-2
GENERAL-PURPOSE CARRIER BOARD
• HOLDS UP TO 3 I/O MODULES
• 32 CHANNELS OF ON-BOARD DIGITAL I/O
PCI-20041C-2
HI-PERFORMANCE CARRIER BOARD
• HOLDS UP TO 3 I/O MODULES
• 32 CHANNELS OF ON-BOARD DIGITAL I/O
• INTERCARRIER BUS ALLOWS DATA TRANSFERS BETWEEN CARRIERS
• PROGRAMMABLE PACER/TIMER
PCI-20041C-3
HI-PERFORMANCE CARRIER BOARD
• HOLDS UP TO 3 I/O MODULES
• 32 CHANNELS OF ON-BOARD DIGITAL I/O
• INTERCARRIER BUS ALLOWS DATA TRANSFERS BETWEEN CARRIERS
• PROGRAMMABLE PACER/TIMER
• FULL-FEATURED DMA SUPPORT FOR DIGITAL I/O, ANALOG I/O, & COUNTERS
• 360K BYTES/SEC DMA TRANSFER RATE
PCI-20003M-2,4
12-BIT ANALOG OUTPUT MODULES
• 2 OUTPUT CHANNELS
• 12-BIT RESOLUTION
• UP TO 120K OUTPUTS/SEC
• RANGES: 0-10V, ±5V, ±10V, 4-20mA FS
• CHOICE OF VOLTAGE OR CURRENT OUTPUTS
PCI-20098C-1
MULTI-FUNCTION CARRIER BOARD
• 16 SINGLE-ENDED OR 8 DIFFERENTIAL ANALOG INPUTS
– PROGRAMMABLE GAIN
– 32kHz SAMPLE RATE
– DMA, INTERRUPT, & POLLED MODES
• INTERNAL TIMEBASE GENERATOR
• SUPPORTS PULSE COUNTING, FREQUENCY, PERIOD, & PULSEWIDTH MEASUREMENTS
• 16 DIGITAL I/O CHANNELS
• HOLDS UP TO 2 I/O MODULES
DECISION BLOCKS
PCI-20006M-1,2
16-BIT ANALOG OUTPUT MODULES
• 1 OR 2 VOLTAGE OUTPUT CHANNEL(S)
• 16-BIT RESOLUTION
• UP TO 120K OUTPUTS/SEC
• RANGE: 0-10V, ±5V, ±10V FS
DECISION BLOCKS
PCI-20202C-1, -2
DSP CARRIERS
• TMS320C25 PROCESSOR
• 16KWORDS DATA MEMORY ON BOARD
• 16KWORDS PROGRAM MEMORY ON BOARD
• DMA TO PC AT 400K BYTES/SEC
• HOLDS UP TO 2 I/O MODULES
• COMPATIBLE WITH ALL PCI-20000 ANALOG, DIGITAL, & PULSE I/O MODULES
PCI-20201M-1
DSP MEMORY EXPANSION MODULE
• 64KWORDS OF HIGH-SPEED RAM EXPANSION (16KW PROGRAM, 48KW DATA MEMORY)

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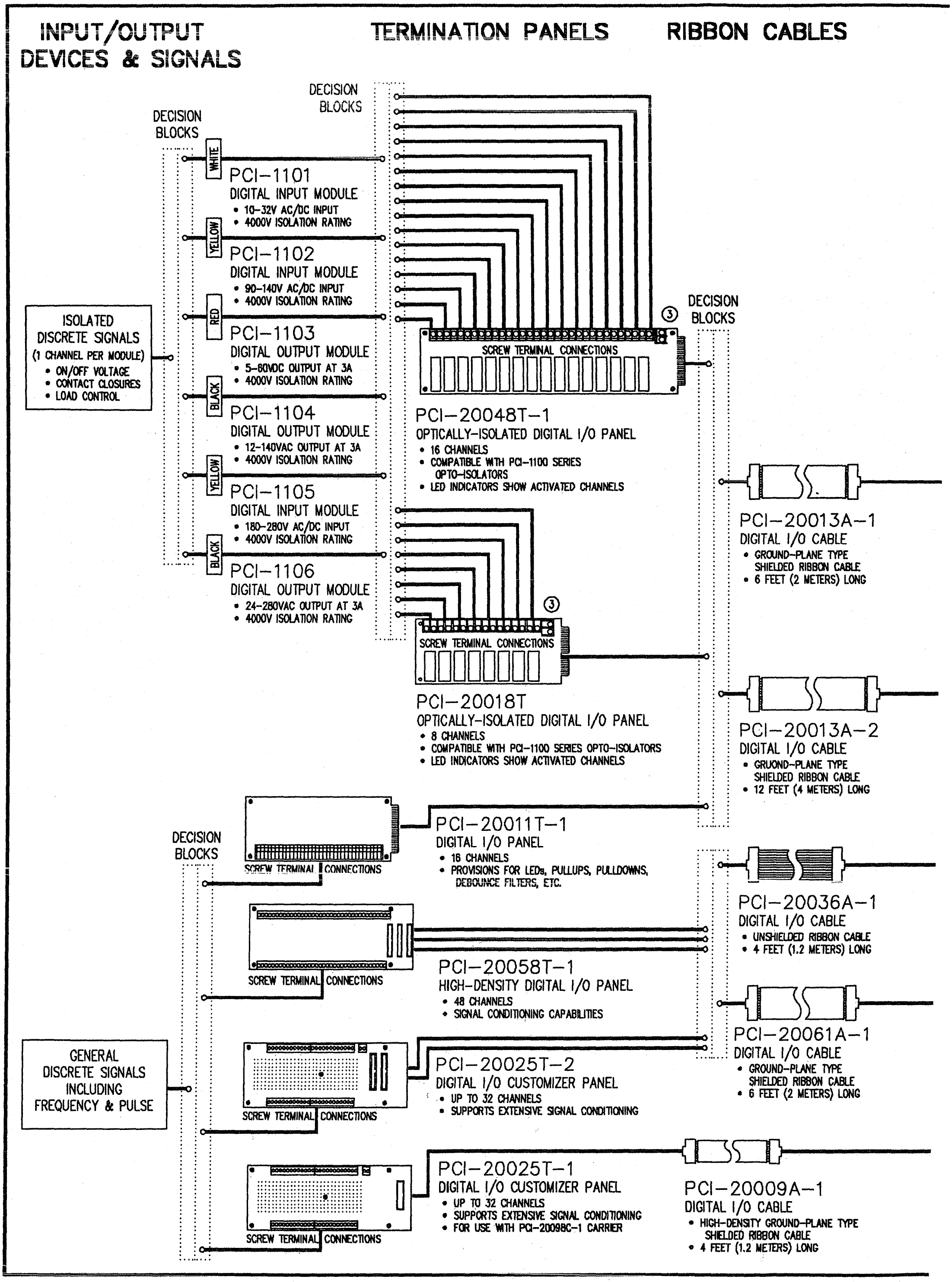

FIGURE 10.2e. PCI-20000 System Component Configuration Chart--Digital I/O Modules and Carriers.

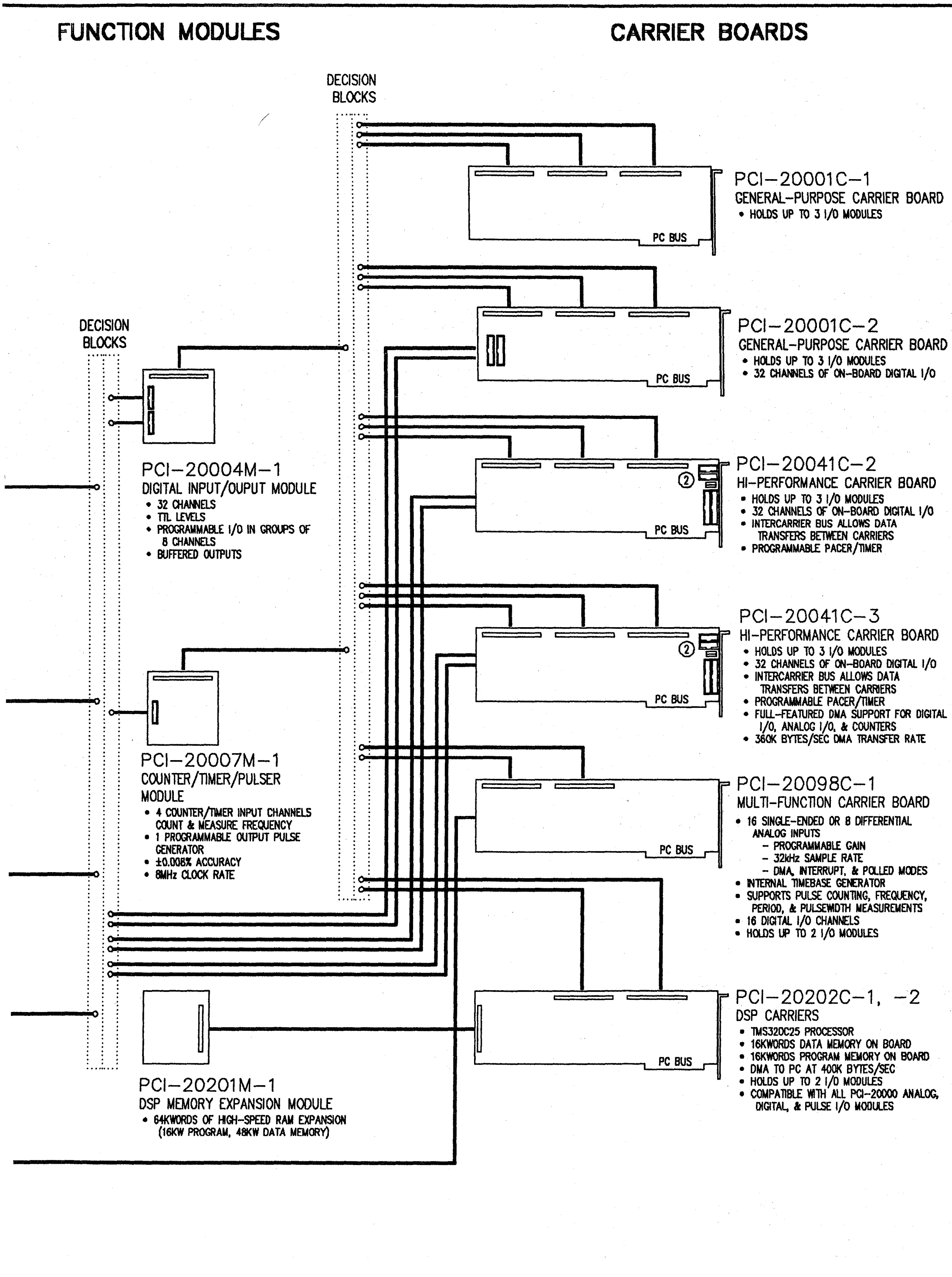
FUNCTION MODULES
CARRIER BOARDS
DECISION BLOCKS
PCI–20001C–1
GENERAL–PURPOSE CARRIER BOARD
• HOLDS UP TO 3 I/O MODULES
PC BUS
PCI–20001C–2
GENERAL–PURPOSE CARRIER BOARD
• HOLDS UP TO 3 I/O MODULES
• 32 CHANNELS OF ON–BOARD DIGITAL I/O
PC BUS
DECISION BLOCKS
PCI–20041C–2
HI–PERFORMANCE CARRIER BOARD
• HOLDS UP TO 3 I/O MODULES
• 32 CHANNELS OF ON–BOARD DIGITAL I/O
• INTERCARRIER BUS ALLOWS DATA TRANSFERS BETWEEN CARRIERS
• PROGRAMMABLE PACER/TIMER
PC BUS
PCI–20004M–1
DIGITAL INPUT/OUPUT MODULE
• 32 CHANNELS
• TTL LEVELS
• PROGRAMMABLE I/O IN GROUPS OF 8 CHANNELS
• BUFFERED OUTPUTS
PCI–20041C–3
HI–PERFORMANCE CARRIER BOARD
• HOLDS UP TO 3 I/O MODULES
• 32 CHANNELS OF ON–BOARD DIGITAL I/O
• INTERCARRIER BUS ALLOWS DATA TRANSFERS BETWEEN CARRIERS
• PROGRAMMABLE PACER/TIMER
• FULL–FEATURED DMA SUPPORT FOR DIGITAL I/O, ANALOG I/O, & COUNTERS
• 360K BYTES/SEC DMA TRANSFER RATE
PC BUS
PCI–20007M–1
COUNTER/TIMER/PULSER MODULE
• 4 COUNTER/TIMER INPUT CHANNELS COUNT & MEASURE FREQUENCY
• 1 PROGRAMMABLE OUTPUT PULSE GENERATOR
• ±0.008% ACCURACY
• 8MHz CLOCK RATE
PCI–20098C–1
MULTI–FUNCTION CARRIER BOARD
• 16 SINGLE–ENDED OR 8 DIFFERENTIAL ANALOG INPUTS
– PROGRAMMABLE GAIN
– 32kHz SAMPLE RATE
– DMA, INTERRUPT, & POLLED MODES
• INTERNAL TIMEBASE GENERATOR
• SUPPORTS PULSE COUNTING, FREQUENCY, PERIOD, & PULSEWIDTH MEASUREMENTS
• 16 DIGITAL I/O CHANNELS
• HOLDS UP TO 2 I/O MODULES
PC BUS
PCI–20202C–1, –2
DSP CARRIERS
• TMS320C25 PROCESSOR
• 16KWORDS DATA MEMORY ON BOARD
• 16KWORDS PROGRAM MEMORY ON BOARD
• DMA TO PC AT 400K BYTES/SEC
• HOLDS UP TO 2 I/O MODULES
• COMPATIBLE WITH ALL PCI–20000 ANALOG, DIGITAL, & PULSE I/O MODULES
PC BUS
PCI–20201M–1
DSP MEMORY EXPANSION MODULE
• 64KWORDS OF HIGH–SPEED RAM EXPANSION (16KW PROGRAM, 48KW DATA MEMORY)

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TABLE 10.3. CONFIGURATION OUTLINE

A) Define the application's input/output requirements:
  The number of analog inputs?
  Single-ended or differential?
  The number od digital outputs?
  Analysis and control?
  Display?
  Speed? ....etc.

B) Define available resources:
  Dollar budget?
  Time available?
  Skills and expertise of system integrators?
  Skills of operators? ....etc.

C) Select appropriate software drivers or software applications packages.

D) Select appropriate PCI-20000 Modules in conjunction with appropriate Active Signal Conditioner Termination Panel requirements.

E) Select appropriate PCI-20000 Carriers.

F) Select appropriate Termination Panels, Cables and Enclosures.

G) Select appropriate accessories (i.e., brackets, power supplies, etc.).

TABLE 10.4. SOFTWARE PACKAGES -- MAJOR FUNCTIONS

See page 10-15 for table legend.

Product Name	PCI Number	Menu Driven	H/W Driver	Data Acquisition	Signal Output	Process Control	Analysis/ Graphics	Digital Scope	Special Applications
Drivers-BASIC	PCI-20026S-1	no	yes	***	***	*	-	-	**
Drivers-C	PCI-20026S-2	no	yes	***	***	*	-	-	**
Drivers-Pascal	PCI-20026S-3	no	yes	***	***	*	-	-	**
Drivers-BASIC	PCI-20027S-1	no	yes	***	***	-	-	-	***
Drivers-C	PCI-20027S-2	no	yes	***	***	-	-	-	***
Drivers-Pascal	PCI-20027S-3	no	yes	***	***	-	-	-	***
LABTECH Notebook	PCI-20040S-1	yes	yes	***	**	**	***	-	**
ControLOGraph	PCI-20056K-1	yes	yes	***	*	*	**	-	***
REAL TIME ACCESS	PCI-20065S-1	yes	no	-	-	**	**		***
DADiSP	PCI-20067S-1	yes	-	-	-	-	***	-	***
SNAPSHOT STORAGE SCOPE	PCI-20068S-1	yes	yes	***	*	*	**	***	**
SNAP-CALC	PCI-20068S-2	yes	-	***	-	*	***	***	**
SNAP-FILTER	PCI-20068S-4	yes	-	-	-	-	*	-	***
SNAP-ACTION	PCI-20068S-5	yes	-	-	**	***	**	-	***
SNAP-GENERATOR	PCI-20068S-7	yes	-	-	***	-	-	-	***
SNAP-STREAM	PCI-20068S-8	yes	-	***	-	-	-	*	***
RELAY LADDER LOGIC	PCI-20073S-1	no	yes	***	*	***	**	-	***
TURBO Stream-BASIC	PCI-20096S-1	no	yes	***	***	-	-	-	***
TURBO Stream-C	PCI-20096S-2	no	yes	***	***	-	-	-	***
TURBO Stream-PACAL	PCI-20096S-3	no	yes	***	***	-	-	-	***
LABTECH Control	PCI-20097S-1	yes	yes	***	**	***	***	-	***
DSP Library-BASIC	PCI-20203S-1	no	yes	***	-	-	**	*	***
DSP Library-C	PCI-20203S-2	no	yes	***	-	-	**	*	***
DSP Library-PASCAL	PCI-20203S-3	no	yes	***	-	-	**	*	***
DSP Library-FORTRAN	PCI-20203S-4	no	yes	***	-	-	**	*	***
DSP Development Pak	PCI-20204S-1	no	no	***	***	***	**	*	***
DSPview, FFT Analyzer	PCI-20205S-1	yes	yes	**	-	-	**	**	***

Continued...

Product Name	PCI Number	Menu Driven	H/W Driver	Data Acqui-sition	Signal Output	Process Control	Analysis/ Graphics	Digital Scope	Special Applica-tions
Smart Drivers-BASIC	PCI-20206S-1	no	yes	-	-	-	-	-	***
Smart Drivers-C	PCI-20206S-2	no	yes	-	-	-	-	-	***
Smart Drivers-PASCAL	PCI-20206S-3	no	yes	-	-	-	-	-	***
Smart Drivers-FORTRAN	PCI-20206S-4	no	yes	-	-	-	-	-	***
Macro Assembler	PCI-20208S-1	no	no	-	-	-	-	-	***
ASYST Language Series	PCI-20301S-1,2,3	no	yes	***	**	**	***	-	***
THE FIX	Order Direct	yes	yes	**	*	***	**	-	**
GENESIS	Order Direct	yes	yes	**	*	***	**	-	**
LABTECH CHROM	Order Direct	yes	-	-	-	-	**	-	***
LOTUS 1-2-3	Order Direct	no	no	-	-	-	**	-	***
ONSPEC	Order Direct	yes	yes	***	**	***	**	-	**
UNKELSCOPE	Order Direct	yes	yes	***	*	**	**	***	**

HARDWARE CONFIGURATION TABLES

The next table offers a speed summary of the various Analog Input/Expander combinations. "Total Channels" refers to the selected configurations (Single-Ended/Differential). "Hardware Speed" denotes the maximum capabilities of the hardware modules (Readings/Sec). "PCI S/W Speed" reflects the system's attainable performance using the PCI-20026S and PCI-20027S series software drivers (Readings/Sec). A 80286 type computer (running at 12MHz) and a 80386 type computer (running at 16MHz) were used to produce these benchmarks.

Tables for other components of the PCI-20000 System follow. These tables are NOT specification sheets. Execution speed is a function of many factors, some of which are beyond the scope of a simple table. The speeds indicated here are offered as guidelines to assist the user in estimating the appropriateness of the PCI-20000 in a given application.

TABLE 10.5. ANALOG INPUT AND MULTIPLEXER SPEED SUMMARY TABLE

For information about the Data Professional products please refer to the PCI-20202C Data Sheet.

Configuration	Total Channels	Hardware Speed	PCI S/W Speed (286)	PCI S/W Speed (386)
PROGRAM MODE -- Gain=1 unless otherwise noted.				
PCI-20001C and PCI-20041C Series Carriers				
PCI-20002M-1, alone	16/8	13kHz	11kHz	12kHz
Single Channel (any Gain)	1/1	32kHz	32kHz	32kHz
PCI-20002M-1 and 2 PCI-20005M-1	48/24	13kHz	8kHz	9kHz
PCI-20019M-1, alone	8	89kHz	89kHz	89kHz
PCI-20019M-1 and 2 PCI-20031M-1	32	89kHz	89kHz	89kHz
PCI-20023M-1, alone	8	180kHz	130kHz	180kHz
PCI-20023M-1 and 2 PCI-20031M-1	32	180kHz	130kHz	180kHZ
PCI-20089W-1	1	32kHz	32kHz	32kHz
	16/8	32kHz	11kHz	12kHz
PCI-20091W-1	8	89kHz	89kHz	89kHz
PCI-20098C-1, alone	16/8	38kHz	38kHz	38kHz
PCI-20098C-1 and 2 PCI-20031M-1	80/40	38kHz	38kHz	38kHz
DMA MODE -- Gain=1 unless otherwise noted.				
PCI-20041C-3 Carrier				
PCI-20002M-1, alone (any Gain)	1/1	32kHz	32kHz	32kHz
PCI-20002M-1 and 2 PCI-20031M-1	64/32	14kHz	12kHz	12kHz
PCI-20019M-1, alone(1)	8	89kHz	89kHz	89kHz
PCI-20019M-1 and 2 PCI-20031M-1	64	89kHz	89kHz	89kHz
PCI-20023M-1, alone(1)	8	180kHz	91kHz	110kHz
PCI-20023M-1 and 2 PCI-20031M-1	64	180kHz	91kHz	110kHz
PCI-20091W-1	8	89kHz	89kHz	89kHz
PCI-20098C-1, alone	16/8	38kHz	38kHz	38kHz
PCI-20098C-1 and 2 PCI-20031M-1	80/40	38kHz	38kHz	38kHz

NOTE: (1) The DMA transfer speed in a PC/AT type computer is highly dependent upon the particular DMA circuit design and the amount of data transferred. Please refer to the Speed Summary tables in the previous section for more information.

TABLE 10.6. ANALOG OUTPUT BOARDS and MODULES SUMMARY TABLE

For information about the Data Professional products please refer to the PCI-20202C Data Sheet.

Module Type	Number of Channels	V_{OUT}	I_{OUT} 4-20mA	Max Speed(1)	Resolution	Linearity
PCI-20003M-2	2	Yes	No	80K	12-bits	.5LSB
PCI-20003M-4	2	Yes	Yes	40K(2)	12-bits	1LSB
PCI-20006M-1	1	Yes	No	80K	16-bits	.002% FS
PCI-20006M-2	2	Yes	No	80K	16-bits	.002% FS
PCI-20021M-1	8	Yes	No	2K	12-bits	.5LSB
PCI-20093W-1	8	Yes	Yes	4K	12-bits	.5LSB

NOTES: (1) Output points/sec in a 12MHz PC/AT computer. (2) The PCI-20003M-4 is jumper programmable so that either channel can be used for voltage or current output. The specs shown are for the current mode. For the voltage mode see the PCI-20003M-2.

TABLE 10.7. SPECIAL PURPOSE MODULES -- SUMMARY TABLE

For information about the Data Professional products please refer to the PCI-20202C Data Sheet.

Module Type	Number of Function	Channels	Special Features
PCI-20004M-1	Digital I/O	32	TTL levels, programmable in bytes (8 bits), buffered outputs
PCI-20007M-1	Counter/Timer	5	4 independent counters (8MHz), 1 programmable clock generator
PCI-20017M-1	Simultaneous Sample/Hold	4	Differential Inputs, BW = 30kHZ, G = 1-1K, 20ns channel-to-channel scatter
PCI-20020M-1	Trigger/Alarm	1/2	Window mode (1 channel) hi-low mode, 3.5us response time

TABLE 10.8. CARRIER -- SUMMARY TABLE

For information about the Data Professional products please refer to the PCI-20202C Data Sheet.

Carrier Type	I^3 Bus On Carrier	Inter-Carrier Extension of I^3 Bus	Digital I/O	DMA	External Sync/ Interrupt	Pacer Clock
PCI-20001C-1	Yes	No	No	No	No	No
PCI-20001C-2	Yes	No	Yes	No	No	No
PCI-20041C-2	Yes	Yes	Yes	No	Yes	Yes
PCI-20041C-3	Yes	Yes	Yes	Yes	Yes	Yes
PCI-20098C-1	Yes	No	Yes	Yes	Yes	Yes
PCI-20202C-1	Yes	No	No	Yes	Yes	Yes
PCI-20202C-2	Yes	No	No	Yes	Yes	Yes

TABLE 10.9. TERMINATION PANELS AND SIGNAL CONDITIONERS SUMMARY TABLE

For information about the Data Professional products please refer to the PCI-20202C Data Sheet.

Panel Type	Function	Number Channels	T.C.	Bridge	Conditioning Active	Conditioning Passive	Notes(1)
PCI-20010T-1	Analog I/O	16/8	No	No	No	Yes	
PCI-20010T-2	Analog/Thermocouple	0/7	Yes	No	No	Yes	
PCI-20011T-1	Digital I/O	16	No	No	No	Yes	
PCI-20018T-1	OPTO-Digital I/O	8	No	No	Yes(2)	No	
PCI-20024T-1	Analog Customizer	32/16	Yes	Yes	Yes	Yes	For PCI-20098C-1
PCI-20024T-2	Analog Customizer	32/16	Yes	Yes	Yes	Yes	
PCI-20025T-1	Digital Customizer	32	No	No	Yes	Yes	For PCI-20098C-1
PCI-20025T-2	Digital Customizer	32	No	No	Yes	Yes	
PCI-20048T-1	OPTO-Digital I/O	16	No	No	Yes(2)	No	Use PCI-20051A-1 Enclosure
PCI-20042T-1	Isolated Active Conditioner	0/4	Yes	Yes	Yes	Yes	
PCI-20043T-1	Isolated Active Expander	0/4	Yes	Yes	Yes	Yes	
PCI-20044T-1	Active Signal Conditioner	0/4	Yes	Yes	Yes	Yes	
PCI-20045T-1	Active Signal Expander	0/4	Yes	Yes	Yes	Yes	
PCI-20057T-1	Analog I/O	48/24	Yes	No	No	Yes	
PCI-20058T-1	Digital I/O	48	No	No	No	Yes	

NOTE: (1) All Panels use the PCI-20029A-1 Enclosure unless otherwise noted. (2) Individual opto-isolator modules are required for each channel. See a description of the PCI-1100 Series below.

TABLE 10.10. DIGITAL OPTO-ISOLATION MODULES SUMMARY TABLE

For information about the Data Professional products please refer to the PCI-20202C Data Sheet.

Module Type	Function	Input Range	Output Range	No. Chn.	Isolation Rating
PCI-1101	AC/DC Input	10-32V	TTL	1	4000V
PCI-1102	AC/DC Input	90-140V	TTL	1	4000V
PCI-1105	AC/DC Input	180-280V	TTL	1	4000V
PCI-1103	DC Output	TTL	5-60V/3A	1	4000V
PCI-1104	AC Output	TTL	12-140V/3A	1	4000V
PCI-1106	AC Output	TTL	24-280V	1	4000V

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TABLE 10.11. CABLES -- SUMMARY TABLE

For information about the Data Professional products please refer to the PCI-20202C Data Sheet.

Cable Type	Analog/ Digital	Number of Channels	Length	Shield	Mating Modules PCI-200XXX	Mating Terminations PCI-200XXX
PCI-20008A-1	Analog	32/16	4ft (1.2m)	Yes	98C-1 Carrier	24T-1
PCI-20009A-1	Digital	16(1)	4ft (1.2m)	Yes	98C-1 Carrier	25T-1
PCI-20012A-1	Analog	16/8	6ft (2m)	Yes	2M, 3M, 5M, 6M, 17M, 19M, 20M, 21M, 31M	10T, 42T, 44T, 57T
PCI-20012A-1	Analog	18.8	12ft (4m)	Yes	2M, 3M, 5M, 6M, 17M, 19M, 20M, 21M, 31M	10T, 42T, 44T, 57T
PCI-20013A-1	Digital	16	6ft (2m)	Yes	1C, 41C, 4M, 7M	11T, 18T, 48T
PCI-20013A-2	Digital	16	12ft (4m)	Yes	1C, 41C, 4M, 7M	11T, 18T, 48T
PCI-20015A-1	Analog	16/8	4ft (1.2m)	Yes	2M, 3M, 5M, 6M, 17M, 19M, 20M, 21M, 31M	24T
PCI-20032A-1	Analog	6	6ft (2m)	No	3M, 6M	10T, 57T
PCI-20036A-1	Digital	16	4ft (1.2m)	No	1C, 41C, 4M, 7M	58T, 25T-2
PCI-20061A-1	Digital	16	6ft (2m)	Yes	1C, 41C, 4M, 7M	58T
PCI-20062A-1	Special	--	5in (13cm)	Yes	Inter-Carrier	None
PCI-20062A-2	Special	--	10in(25cm)	Yes	Inter-Carrier	None

Notes: (1) The PCI-20009A-1 cable is used only with the PCI-20098C-1 carrier. It connects all digital signals including digital I/O, counters and external sync.

These configurations require only one expansion slot within the host PC. When modules are installed onto a carrier, the added thickness of the modules may result in mechanical intrusion into the adjacent expansion slot area provided for another expansion board. Whether this interference actually does occur depends upon the computer used, the carrier selected, the number of modules used, the location of the modules, and the length of the board in the adjacent slot. If, for example, a short board (PCI-20087W-1, PCI-20089W-1, Async, IEEE-488, etc.) is installed next to a PCI-20001C, PCI-20041C, or PCI-20202C carrier with the "rear" module position left open, no interference is encountered. In these cases, a carrier plus modules is still a single-slot device. When all three module locations are occupied on a carrier, the system normally requires the space of two expansion slots. The PCI-20098C-1 carrier alone, has a wide range of analog and digital functions built-in, yet takes only one slot position. However, two slots are required if any modules are installed on the PCI-20098C-1. Note that even if two slots are consumed, the functional capability of a carrier-based installation greatly exceeds that of any other combination of products that occupy only one or two slots. For example, a single carrier with three modules can provide 80 analog inputs or 128 digital I/O channels.

POWER REQUIREMENTS

Most modern personal computers provide several expansion slots for optional user-selected boards. A partial listing of IBM PC/XT/AT compatible machines and estimates of their available expansion slots can be found in Section 2 of this handbook. The PC's power supply is designed to provide a "reasonable" amount of current to the expansion slots. The amount of power available is determined by subtracting the base system's power requirements from the total power supply rating. Please consult your computer's documentation for this information. Each carrier and module in the PCI-20000 system has its power requirements specified on its data sheet. It is a simple matter to sum the individual power terms (current times voltage) to determine the total load. Some modules require ±15V power. These levels are not attainable directly from the computer. Each carrier has a DC/DC converter, on-board, to generate these voltages from the computer's raw +5V line. When determining total power requirements, be sure to select the "equivalent" +5V current which appears at the bottom of each module's specification sheet. This number includes the conversion efficiency of the DC/DC converter. Because of the thousands of possible PCI-20000 configurations and the different computer power supply ratings, it is not practical to generate a compatibility table. In general, however, adequate power is available for all boards that will physically fit in a given PC.

SAMPLE CONFIGURATION EXAMPLE

In order to demonstrate the use of Table 10.3 (Configuration Outline), a hypothetical example will be defined and an appropriate system configuration will be found.

Given:

- A manufacturing plant produces "widgets". In addition to process control, both the quantity and quality of the product must be monitored on all three production lines.
- Each line consists of a conveyer belt, a four-zone furnace, two raw-material flow controllers, two raw-material weighing scales, four control valves, six product position indicators, and 12 status indicator lights.
- The control algorithm requires five PID loops and four On-Off loops. On-screen graphics display of product output and major system parameters is required.

SOLUTION (Please Refer to Table 10.3)

A) Define the I/O Requirements

Evaluation of the above facts, along with additional information obtained after further investigation, yields these I/O requirements:

1 - Frequency Input (conveyer speed)
4 - Thermocouple Inputs (furnace temperature)
5 - Analog Outputs (furnace and speed control)
2 - 4 to 20mA Analog Inputs (flow rate)
2 - 200 Ohm strain gage (scales)
6 - Digital Inputs (position switches)
16 - Digital Outputs (valves and indicators)

- The frequency input is in the range of 5kHz to 10kHz.
- The T.C. inputs must be isolated for 440V AC.
- All digital inputs are dry switch contacts.
- The 12 "status light" digital outputs must switch 240V AC at 1A.
- The existing motor controller accepts 0-10V inputs.
- The existing furnace controllers accept 0-10V inputs.
- All inputs and outputs must be updated once each second.

B) Define Resources

- System will be designed and implemented by "Henry".
- Henry is a process engineer, but he has NO programming experience.
- Mechanical and electrical installers are available.
- The system operators are unskilled.
- The system must be operational in six weeks.

C) Select Software

Because Henry has no programming experience, one of the available "Application Packages" will be selected. Refer to Table 10.4, SOFTWARE PACKAGES. Several products including LT/Control and LABTECH Notebook satisfy the above requirements. Other possible choices include THE FIX, GENESIS, and ONSPEC. Note that these products are menu driven (no programming is required) and they support data acquisition, process control, data analysis and graphics display. For this example LT/Control will be selected.

D) Select Modules and Active Signal Conditioner Termination Panels

Refer to the appropriate HARDWARE CONFIGURATION SUMMARY Tables.

1 - Frequency Input. Select a PCI-20007M-1 module.

4 - Thermocouple (TC) Inputs. Because isolation is required, a PCI-20042T-1 will be selected. This signal conditioner termination panel supports all four TCs. Select a PCI- 20002M-1 (A/D)module to accept the PCI-20042T-1 output.

5 - Analog Outputs. Several choices exist. Select the PCI- 20021M-1 (the most space-and cost-efficient).

2 - Strain Gage Inputs. The single-element strain gages employed require both bridge completion and excitation. Isolation is not required. Select a PCI-20045T-1 to mate with the PCI-20042T-1 and thus provide up to four additional input channels with the desired characteristics. Note that another A/D module is not required.

2 - 4 to 20mA Inputs. While normally not required, the most efficient way to accommodate these inputs is to use the spare channels on the existing PCI-20045T-1. No additional hardware is required.

6 - Digital Inputs. A carrier can be selected with 32 digital I/O points on-board. This option will be selected.

16-Digital Outputs. Each eight-bit group of digital I/O can be configured as either inputs or outputs. Therefore, the remainder of the carrier's digital I/O ports will be utilized as outputs. No additional hardware is required.

E) Select Carriers

Three modules (total) have been specified in addition to four digital I/O ports (eight bits each). The PCI-200001C-2 provides the required digital I/O and accommodates the three modules.

F) Select Termination Panels, Cables and Enclosures

In addition to the two signal conditioner panels selected above, terminations for the analog outputs, frequency input and digital I/O are also required. Remember to refer to Figure 10.3 (Configuration Chart) for information about the compatibility of the various components.

5 - Analog Outputs. Select the PCI-20010T-1 termination panel. A PCI-20012A-1 cable connects the panel to the PCI-20021M-1.

1 - Frequency Input. Select the PCI-20058T-1 termination panel. This panel has three connectors and accommodates a total of 48 channels (two bytes per connector). Many of the extra terminals will be used for the required digital I/O. A PCI-20061A cable connects the panel to the PCI-20007M-1.

6 - Digital Inputs. The second bank of the above PCI-20058T-1 panel will be used for this purpose. Provisions exist on the panel to install "pull-up" resistors to "wet" the input switch contacts. A PCI-20061A-1 cable connects the panel to one of the two digital I/O connectors on the carrier.

4 - Digital Outputs. These are for the valve controls. The second bank of the above PCI-20058T-1 panel is shared for this purpose. Remember that each digital I/O connector on the carrier accommodates two bytes (16 channels). Each byte can be programmed as either inputs or outputs. Therefore, the same cable that is used for the digital inputs also supports this digital output function.

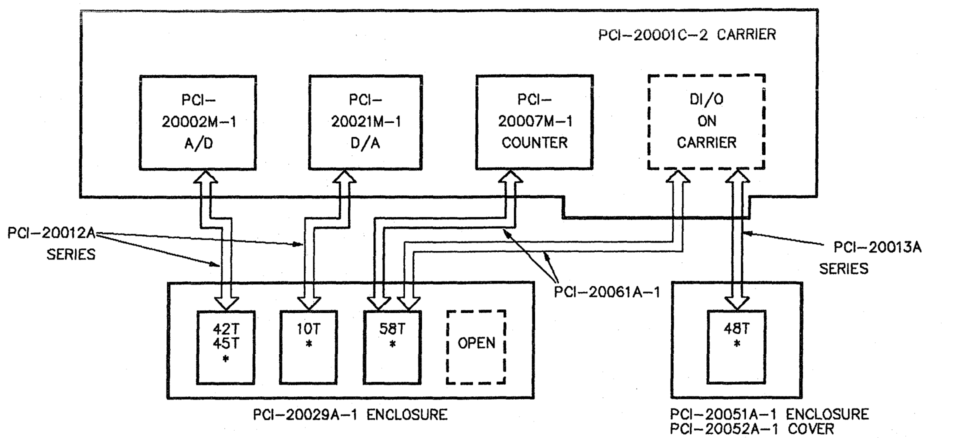
12- Digital Outputs. These are for the process indicators. Recall that these outputs must switch 240VAC at 1A. To accomplish this, digital opto-isolators will be used. The PCI-1106 modules meets the requirements. A separate opto module is used for each channel. The modules plug into the PCI- 20048T-1 termination panel. A PCI-20013A-1 cable connects the panel to the second digital I/O connector on the carrier.

Select Enclosures - A total of five termination panels have been selected. From the standpoint of mounting space, the PCI-20042T-1 and the PCI-20045T-1 are one panel (they stack). These panels as well as the PCI-20010T-1 and the PCI-20058T-1 fit inside one PCI-20029A-1 enclosure (one spare space remains). A cover is included with this enclosure. The PCI-20048T-1 is a different style panel and is accommodated by the PCI-20051A-1 Enclosure. The mating cover is the PCI-20052A-1.

G) Select Accessories

Referring again to Figure 10.3 (Configuration Chart), two accessories are noted.

1-A Power Supply is required to provide $\pm 15V$ to the active signal conditioner termination panels. The PCI-20038A series is selected (choose the appropriate dash number depending upon the required AC line voltage). The power supply can mount either inside or on the rear of the PCI- 20029A-1 Enclosure.



ADDITIONAL ITEMS:
PCI-20028A-3 BRACKET
PCI-20097S-1 SOFTWARE
PCI-20038A-X POWER SUPPLY

* ONLY THE LAST TWO DIGITS OF THE MODEL NUMBER ARE SHOWN ON THE TERMINATION PANELS.

HARDWARE CAPABILITIES: 4-DIFFERENTIAL ANALOG INPUTS
4-ISOLATED, DIFFERENTIAL ANALOG INPUTS
4-COUNTER/TIMERS
8-ANALOG OUTPUTS
16-DIGITAL I/O (NON-ISOLATED)
16-DIGITAL I/O (ISOLATED)

SAMPLE CONFIGURATION

1 - An additional strain relief bracket is recommended to support the cables exiting from the rear of the computer. Each carrier comes with one bracket. To make assembly as easy as possible, it is suggested that only the digital I/O cables be routed through this clamp. The remaining cables should be clamped with a PCI-20028A-3 accessory bracket. This bracket is positioned in the adjacent expansion slot's mounting location.

ADDITIONAL INFORMATION -- DETAILED ANALYSIS OF THE CONFIGURATION PROCESS

This material is provided for additional assistance to first-time users of data acquisition and control systems. The notes below are keyed to Table 10.3, the Configuration Outline, that was presented earlier in this section.

A) DEFINE THE APPLICATION

List the project requirements in terms of the electrical signals involved. Remember that temperature, pressure, displacement and speed, etc. will be converted to voltages or currents by sensors and transducers. While these devices are an important part of the "total" system, only their signals are significant in the selection and definition of the data acquisition and control components.

The distinguishing features of **every** input and output signal (current or voltage, amplitude, frequency components, dynamic range, resolution and accuracy requirements, etc.) must be clearly known. How many channels of each different type are required? Are the analog inputs to be treated as single-ended or differential? (As a general rule, voltage levels below 1 volt should use differential connections for high accuracy.) When producing outputs for control or alarm purposes, attention must be given to the "drive" demands of the valves, motors, relays, lamps, etc. (i.e., voltage swing, load current, and so on).

The User Interface

Many of us will find it easier to focus on the electrical I/O requirements of the application. Often, however, these represent just a portion of the project. After all, the purpose of "monitoring" is to gain information that will allow appropriate action to be taken. Action can consist of statistical analysis, implementing a control algorithm, generating a report, graphics display, etc. The hardware elements comprising the PCI-20000 are primarily intended to translate outside (real-world) signals to the personal computer to obtain access to its data processing, manipulation and storage capabilities. It is usually the software within the PC that makes decisions and defines conditions. The software also controls, shapes, and produces the human interface. The human interface determines how the user communicates with the computer; how much product training and how much computer knowledge is required. In most cases the operator is "insulated" from the details of the data acquisition and control operations by the "buffering" features of the software interface.

Remember

Given today's modern PCs and the associated software sophistication, there still remain important tasks that are beyond current PC speed capabilities. Examples might include high-speed pulse detection or counting, event triggering, interrupt creation and waveform generation. Fortunately, there are ways to enhance the overall system performance. In the PCI- 20000 approach, "hardware solutions" are often available to solve or circumvent personal computer and software limitations. As an example, the new Data Professional carriers have their own high speed processor on-board to supplement the PC's capabilities.

B) ASSESSING RESOURCES

Who are you? What is your background? Are you familiar with computers, electronics, writing software, installing cable, interfacing transducers, etc.? If not, will these skills be required on this particular job? Who can be recruited to join your team? Look to your vendors not only for the quality of their products but also for their commitment to customer support, both before and after the sale.

Hardware Versus Software

A computerized data acquisition and/or control system consists of several major parts. These include the computer hardware, the input/output hardware and the software. It is important to remember that all hardware must be directed or controlled by software. In fact, there is an interdependence that renders either essentially useless without the other. So then, which is selected first -- hardware or software? For many this can invoke a spirited debate. However, when specifying a DA&C system, the choice is made much simpler by the significant degree of standardization inspired by the IBM PC. The almost universal acceptance of the PC's architecture has generated a synergism between independent computer, "add-in", "add-on" and software vendors. The bottom-line result is that virtually all DA&C hardware and software packages run on IBM or compatible PCs. An extensive variety of consumer, commercial and industrial PCs is available. Distinguishing characteristics include: the number of accessible expansion slots, power supply size, tolerance to vibration and air contaminants, operating temperature range and cost.

C) TYPES OF SOFTWARE

The term "software" can take on different meanings, In the simplest of terms, software is either a complete "applications- specific" product or a set of general-purpose "tools". "Applications packages", as they are called, comprise the first category. They can be ready-to-use, "turn-key" products, or they can be "adaptable". The adaptable packages are usually menu driven so that they require no programming skills. These are designed to support one of a number of related functions: for example, LABTECH Notebook (for data acquisition), LT/CONTROL (for process control), DADiSP (for analysis), and SNAPSHOT STORAGE SCOPE (for waveform capture), etc. When an appropriate applications package is available, high performance is usually obtained with a minimum of time and expense. Projects requiring special or unique software features fall into the "custom program" category. Program quality and development time can be enhanced by utilizing available software tools (an important type of "tool" is the software "driver").

Custom programs can take many forms. They can be written in low- level languages such as machine or assembly language. While offering the highest performance, low-level programming usually requires the largest investment in software skills and time. High-level languages, such as BASIC, C, and Turbo Pascal, provide a friendlier environment for most people. The use of easy-to- learn mnemonics and other recognizable phrases, to represent complex operations, explains their popularity.

As mentioned above, "software drivers" assist in the development of custom programs. Drivers usually consist of a family of programs or subroutines. The drivers bridge the gap between the project programmer and the DA&C hardware. While drivers are actually separate programs, their features are attainable upon request of the main program. They are written and optimized, often in assembly language, by people who have expertise with the particular hardware. This relieves the requirement for the project programmer to become intimately familiar with the I/O system. Most popular high-level languages, as well as assembly language, can "call" these drivers to facilitate all of the PCI-20000 hardware functions.

D) SELECTING MODULES

Most of the time, it is an individual board or module (or carrier, in the case of digital I/O) that determines a channel's I/O features. There are, however, important characteristics that are dramatically altered by other devices. For example, we may want to convert a differential signal to single-ended, strip away a high common-mode voltage (isolation), amplify a low-level signal, convert a voltage to a current, and detect a predetermined level crossing. Signal conditioning operations such as these can result from preprocessing the input signal with an active signal conditioner termination panel or with another PCI module. What is the significance of this? Can an analog input voltage module (A/D module) with single-ended inputs and no amplifier, accurately process a thermocouple (producing a 10mV, differential signal) attached to a motor winding at 440V AC? Absolutely, YES! The flexibility of the

PCI-20000 accommodates this and many other difficult applications. The requirements of this example can be provided by an Active Signal Conditioner Termination Panel (PCI-20042T-1). Cold-junction monitoring is included along with differential inputs, signal gain, and complete input-to-output and channel-to-channel isolation. The output signal is ideally suited to any analog input module.

Single-Ended Versus Differential

The PCI-20002M-1 analog input module can be configured for either single-ended or differential use. All of the channels are set as a group, yielding either 16 or 8 channels, respectively. Naturally, a differential input can be used with a single-ended signal, but the opposite is not true. The need for just one differential channel divides the original single-ended channel count by two. One alternative consists of using the PCI-20017M-1 (Simultaneous Sample/Hold Module) as a preamplifier to the PCI-20002M-1. The PCI-20017M-1 has a separate instrumentation amplifier for each of its four channels. These can convert differential inputs to single-ended, without altering the original 16 channels provided by the PCI-20002M-1. However, as described in Subsection F below, there are exceptions to consider. For example, the PCI-20042T-1 through PCI-20045T-1 Active Signal Conditioner Termination Panels) also use on-board amplifiers to convert from differential to single-ended signals. Despite this, the number of input channels is limited to a total of eight for each **input module connector**. Because of the many possible combinations of PCI components, please be sure to account for the proper number of accessible channels. The PCI- 20098C-1 presents still another option. The on-board analog input is totally software programmable. This permits individual channels to be set for differential operation while others are single-ended. It is this type of innovation that you can expect from Burr-Brown PCI products.

Finding the Right Combination of Specifications

Depending upon the complexity of the application, the selection of modules may be an iterative process. Experience suggests that "speed" is often the most difficult parameter to satisfy. Therefore, channels requiring the fastest response should be specified first. Basic distinguishing information for each module can be found in the SPECIFICATION SUMMARY (Table 10.1). However, because there are many ways to interconnect the various PCI-20000 components, "complete specifications" must take into account the particular configuration. In particular, please refer to the SPEED SUMMARY TABLES (Table 10.2) including the MULTIPLEXER SPEED TABLE (Table 10.5). Figure 10.3 graphically shows all of the components that comprise the PCI-20000 system. Also indicated are the associated options and accessories. Compatibility of each group of components is indicated by the interconnecting lines.

Multiplexer Selection

Analog input multiplexers or expanders can be used as a low-cost way of increasing the number of system channels. Figure 10.1 suggests how the analog portion of the I^3 Bus can connect the multiplexer outputs to an existing input module (PCI-20002M-1, etc.

Two different types of Analog Input Expanders are available in the PCI-20000 system: the PCI-20005M-1 and the PCI-20031M-1. The PCI-20005M-1 is a general-purpose multiplexer, primarily intended to extend the channel count of the PCI-20002M-1 Analog Input Module, while the PCI-20031M-1 is high-speed mux tailored to the PCI-20019M-1 and the PCI-20023M-1 (however, it can be used with the PCI-20002M-1). It is characteristic of the PCI-20005M-1 that it is "software driven". This means that the controlling program must issue separate instructions to the PCI-20005M-1 each time a new channel is to be selected. In contrast, the PCI- 20031M-1 includes an automatic, internally driven, channel scanner that sequences through the desired inputs without computer intervention. The major consequence of this hardware difference is that systems incorporating the PCI-20031M-1 can operate much faster than they can using the PCI-20005M-1.

There are several combinations of Input and Expander modules that are of particular interest. The user can decide from a variety of choices how best to optimize the system for a given task. Some arrangements offer the most channels at the lowest cost, while others provide the highest possible speed. It should be noted that, for a given hardware set, the total number of accessible channels can be depended upon the maximum speed desired.

Digital Input/Output

Digital I/O function blocks (whether on a PCI-20087W-1 board, a PCI-20004M-1 module or on a carrier) can be software configured for either input or output use, in groups of eight points (byte size). Thus, a 32-point module can be used for eight inputs and 24 outputs or 16 inputs and 16 outputs or 32 outputs.

E) SELECTING CARRIERS

Once the number of modules is known, it is a simple matter to determine the required carriers. Remember that carriers have provisions for two or three modules. The choice among carriers is a function of desired features. The seven currently available carriers are designated as either "General Purpose" (PCI-20001C series), "High Performance" (PCI-20041C series), "Multi Function" (PCI-20098C-1), or "*Smart*" (PCI-20202C series).

By referring to the CARRIER SUMMARY TABLE (Table 10.8) the major distinctions can easily be noted. A carrier with digital I/O is often selected, even if no initial digital requirements are known. Experience has shown that, in the long term, most applications will benefit from (if not require) digital I/O. Two major advantages are derived by including this capability on the carrier: lower cost and higher functional density. The alternative to on-board digital I/O is to add a digital I/O module or board. While this is always a viable option, a separate unit does have a higher cost per channel and consumes an otherwise open plug-in position.

Pacer Clock / Burst Generator

A Pacer Clock is a crystal-controlled, frequency programmable timing generator. In some applications the computer's clock can be used to trigger interrupts, and to pace data acquisition, etc. This is described in the Applications section of this handbook. However, at high speeds or when high stability is necessary, an independent time-base is often required. This is the main purpose of the on-board pacer clock (PCI-20041C series), or alternately, the "Rate Generator" portion of the PCI-20007M-1 Counter/Timer Module.

A burst generator differs from a rate generator in that it can be programmed to produce a group of closely spaced pulses at an independent repetition frequency. For example, what if we want to read eight inputs "simultaneously", but we want to repeat the measurement only once each second. Of course, the meaning of "simultaneous" is application dependent. But, let us say that 30uS between readings is fast enough (240uS to read all eight channels). This is a very small fraction of the total time. Taking data with a conventional rate generator would result in mostly unneeded data. Using a burst generator provides the required data without the waste of valuable processing and storage resources. The PCI-20098C-1 carrier includes a programmable burst generator. It is also possible to "build" a burst generator with the PCI-20007M-1 and some external logic (contact the factory Applications Engineering group for details). Again, whenever needed features are available on a carrier, there is a savings in cost and space.

Inter-Carrier Bus

In "larger" applications, the inter-carrier bus feature (an extension of the I^3 Bus) on the High Performance Carriers allows up to five carriers to be connected together. Thus, a number of multiplexer modules on more than one carrier can "feed" one analog input module (A/D). This significantly contributes to the reduction in cost per channel for larger systems.

External Sync

The "High Performance Carriers" and the fixed-board products also have a separate connector to provide support for external interrupts, start conversions, start/stop DMA and other related synchronization signals.

Direct Memory Access (DMA)

Not all PCI boards and carriers support DMA. The PCI-20041C-3 has the most general type of DMA. This proprietary DMA technique has distinct advantages and unique capabilities. These include the ability to transfer either input or output data from analog, digital and counter sources simultaneously, at speeds up to 360K bytes per second. The PCI-20091W-1 and the PCI-20098C-1 also support analog input (only) DMA. In certain applications, performance limitations and constraints are imposed by the design of the PC itself. Most notable of these PC restrictions is that DMA transfers can only proceed in one direction at a time (input or output). Also, despite the higher clock rate of the PC AT compared to the PC, internal computer circuit differences actually result in a reduction of the DMA transfer rate. Please refer to the SPEED SUMMARY TABLES (Table 10.2) and the Product Data Sheets for complete information.

F) SELECTING TERMINATION PANELS

Field signals are readily mated to the PCI-20000 system through the use of optional termination panels and signal conditioners. All panels offer easy-to-use screw connections and provide passive signal conditioning capabilities. Some panels are called signal conditioners and offer active functions such as amplification, isolation and bridge excitation. Panels are also available in different sizes to suit a range of applications.

Why Use Termination Panels?

The function and utility of termination panels are often understated. Termination panels are used as a connection point to the outside world. Why not avoid this intermediary step and connect the field signals directly? The answer to this question lies in the need for signal conditioning. These panels are designed to support a wide range of user-installed signal conditioning networks. Appropriate units are tailored for voltage division, filtering, surge suppression, current to voltage conversion, contact wetting, etc. Extensive information on this subject is found elsewhere in this handbook. (Please see the section on signal conditioning.)

Cables, General

Each termination panel also has one or more cable connectors which interface the panel to the appropriate PCI board, carrier, or module. A family of cables is available to support this purpose. The cables can be divided into three categories: analog I/O, digital I/O and special purpose. Most analog cables are fully shielded, ribbon cables fitted with 26 pin connectors. Digital cables are "ground-plane" type ribbon cables fitted with 34 pin connectors. Special, high-density cables are provided for the on-board functions of the PCI-20098C-1 carrier. These have different connector configurations. As a general rule, each cable accommodates 16 channels. In the case of differential analog inputs, two physical channels on the input multiplexer are used for each signal. Therefore, one cable will support eight differential analog inputs. When a module hosts fewer than 16 channels, (i.e., counter-timer, analog output, trigger/alarm), this rule does not apply. Rather, a complete cable will be used for that module regardless of the number of conductors actually used. There are, however, exceptions. For example, a high-speed analog output module can provide up to two channels each. In some systems it is common for two or three of these modules to be used together on one carrier. Several cables and termination panels could be used to connect this configuration. Another option would be to use the special "three-headed" cable (PCI- 20032A-1) which permits up to three 1- or 2-channel modules to be connected to a single termination panel. Depending upon type, cables are offered in 4, 6, and 12-foot lengths (1.2m, 2m, and 4m). For those who wish to fabricate their own cables, full "pin-out" information is provided in the applicable user manuals.

Active Signal Conditioner Analog Termination Panels

There are two basic types of active analog signal conditioner termination panels. They have similar capabilities with the exception that one provides channel-to-channel isolation. Both families have precision, differential input, instrumentation amplier front ends. The instrumentation amplifiers are jumper programmable for gains of 1, 10, 100, and 1000. There is a separate amplifier for each channel. Provisions have been made for "bridge completion" and each channel has its own adjustable excitation current source. Passive networks are also accommodated.

The amplifiers, isolators and power supplies on an active signal conditioner panel take considerably more area than simple passive networks alone. High-voltage isolation imposes additional spacing requirements. As a result, the channel density (channels per board) and the cable configuration of these panels have some unique features.

Each type consists of a pair of panels. One panel can be thought of as a "master" (PCI-20042T-1 or PCI-20044T-1 and the other an "expander" (PCI-20043T-1 or 45T-1). Each has four input channels. When up to four channels are required, a single PCI-20042T/44T is used alone. A connector on the panel mates with a standard PCI-20012A cable which couples with an analog input module or board. Under these conditions, the remaining input channels associated with the unused wires in the cable are not available for use. However, four more channels can be added by using the PCI-20043T/45T expander panels. The master/expander panels are designed to "stack", one above the other, to conserve mounting space. A short ribbon cable, supplied with the expanders, joins the two panels together. The result is that all eight channels are merged together in a single PCI-20012A cable going to the remainder of the system. It is acceptable to interconnect isolated and non-isolated panels together, if desired. Additional channel expansion on a single cable is not possible.

While the inputs to an active signal conditioner panel are differential, the outputs are always single-ended. Therefore, be sure that the mating analog input module or board is configured for single-ended operation. In applications where very high voltage-gain or maximum bandwidth is desired, it is permissible to utilize the gain blocks on both the termination panel and the input module.

All analog, active signal conditioner termination panels require a source of external ±15V power. Please refer to the Signal Conditioner data sheets, the "accessory" notes below, and the PCI-20038A data sheet.

Opto-Isolation

The digital Opto-Isolation Termination Panels (PCI-20018T-1 and 48T-1) require a separate PCI-1100 series module to be installed for each channel. Models for both AC and DC, Inputs and Outputs, are available. The six different units are summarized in Table 10.10.

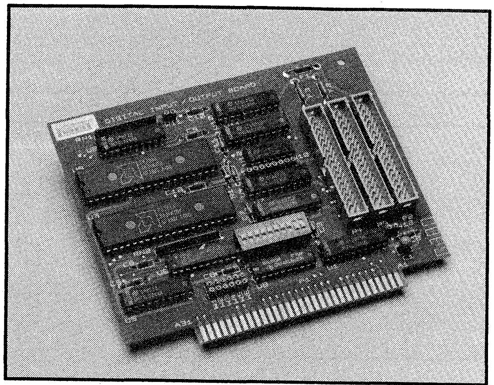
Enclosures

Termination panels are usually installed outside of the computer in existing facilities or in PCI enclosures. Two basic types of enclosures are now provided. Both are designed to be placed in standard 19-inch racks or in a table-top configuration. The so- called "quad" enclosure can, in general, accommodate any four of the many PCI termination panels. One exception to this rule is the 16-channel digital opto-isolation panel. This large panel is housed in a companion enclosure that holds one each.

G) Selecting Accessories

When several cables are required to exit the PC, it is often convenient to make use of the unused, expansion board mounting locations. An accessory strain relief bracket is well suited to secure the ribbon cables and to help protect internal components (PCI-20028A-3). In general, one accessory bracket is recommended per carrier.

The active, analog signal conditioning termination panels require an external source of ±15V power. Power supplies are available to serve this purpose. Two models cover the world-wide AC line input requirements (PCI-20038A-1 and PCI-20038A-3). The .8A output is sufficient for most applications. Each can be mounted inside or on the rear of the PCI-20029A-1 Termination Panel Enclosure.



BURR-BROWN®

PCI-20087W-1
Digital I/O Board

FEATURES

- 40 Digital I/O Channels with TTL Compatible Levels
- Software Programmable for Inputs/Outputs
- BASIC Language Software Drivers Included
- Synchronization/Handshaking Capability
- Interrupt on Din, Event or Handshake Signal
- Compatible with Industry Standard Opto-Isolators
- Half-size board fits into PC/XT short slot
- Suitable as an OEM Component

DESCRIPTION

The PCI-20087W-1 Digital Input/Output Board plugs directly into an expansion slot of any IBM compatible Personal Computer. These computers include PC's from IBM, AT&T, Olivetti, Zenith, Siemens, Compaq, PC's Limited, etc.. In addition, the IBM PS/2 model 30 also supports this and all other PCI-20000 products.

40 channels of TTL compatible signals are accommodated in 5 groups of 8 bits each. Each 8-bit byte can be independently software programmed for use as either an input or output port. Data transfer on two of these ports can be synchronized to external hardware events. This is accomplished by utilizing the channels in the fifth port as handshake control lines. All ports are initialized as inputs at "power-on".

The PCI-20087W-1 is also equipped to generate interrupts to the PC upon receipt of various hardware signals. These include a high or low I/O transition on channel 0(bit 0) and a request from either handshake port. An interrupt can be directed to the PC via interrupt lines 2 thru 7.

Because of its small size, the PCI-20087W-1 can be installed in the "short" slot of computers such as the IBM PC/XT. Signal connections are made to the board through standard ribbon-cable connectors. The PCI-20087W-1 is compatible with PCI digital termination components including the PCI-20011T-1, 18T-1, 25T-2, 48T-1 and 58T-1 termination panels and the PCI-20013A-1, 13A-2, 36A-1 and 61A-1 cables. The PCI-20036A-1 is a low cost cable for digital applications. This 4 foot (1.2m) long, unshielded cable is intended for use with the PCI-20058T-1and PCI-20025T-2 Termination Panels.

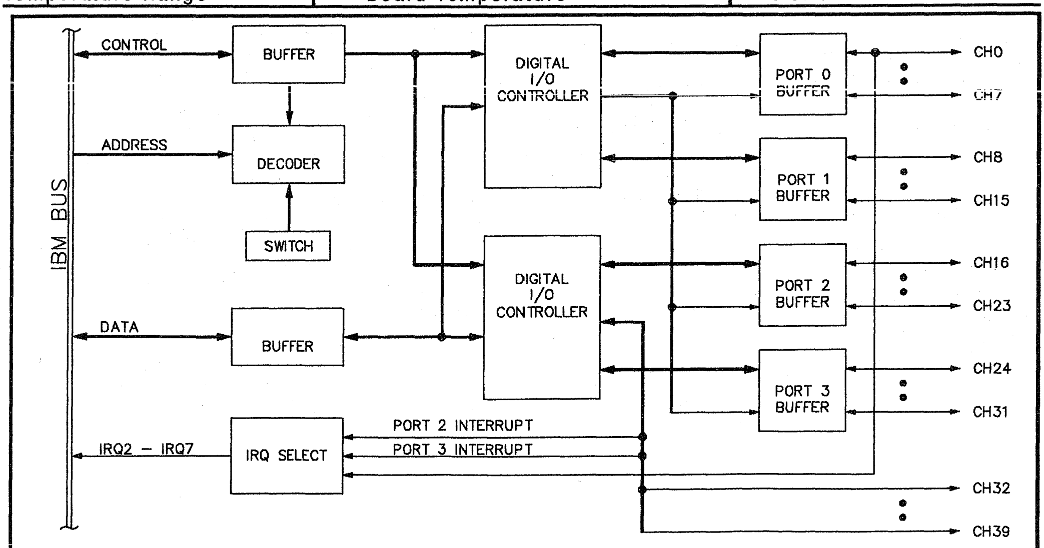
To utilize all of the available channels on the PCI-20087W-1 three cables are required, one cable for each group of two bytes (16 channels). Because the PCI-20058T-1 accommodates up to 48 channels, it is ideally suited for use with the PCI-20087W-1. Optical isolation can be added to selected ports by using the optional PCI-20018T or 48T series of panels. The PCI-20013A series of cables are used to make connections to these panels. Six different isolation modules are available (the PCI-1100 series) which can be installed on the opto panels to determine the individual channel's I/O capabilities. Please refer to the Termination panel section for additional information on the complete PCI family of termination components.

A family of BASIC language software support drivers is included with the hardware. The current version of this software supports both setup and read/write functions for the first 32 channels.

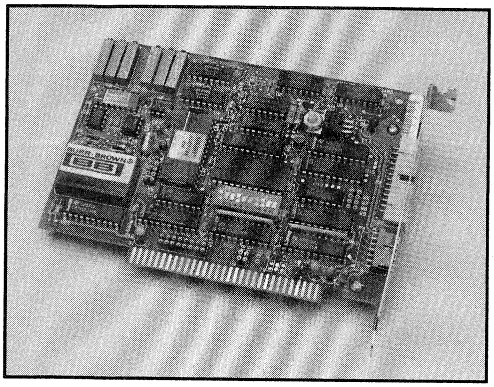
SPECIFICATIONS - PCI-20087W-1

All specifications are typical at 25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Software Drivers	Interface Language	BASIC
	Included with Board	PCI-20088S-1
Functions Supported	Channels 0-31	Read/Write
I/O Configuration	Each Port is programmable as either Inputs or Outputs	40 Channels total
Number of Ports	8 Bits each	5
Digital I/O	Fully Buffered	32 Channels
I/O or Handshake	Nonbuffered	8 Channels
I/O Cable Connector	Mating cable connector (T&B Ansley or equivalent)	# 609-3430
Input Characteristics		
High-Level Voltage	Minimum	2V
Low-Level Voltage	Maximum	0.8V
Iin, High-level	Maximum	20 uA
Iin, Low-Level	Maximum	200 uA
Output Characteristics		
Buffered Ports	Initialized as inputs	
High-Level Voltage	Iout = MAX	2V
Low-Level Voltage	Iout = MAX	0.5V
Current Source	Vout = Low	15mA
Current Sink	Vout = High	24mA
Tri-State Current	Vout = 2.7V	20uA
Tri-State Current	Vout = 0.4V	200uA
Output Characteristics		
Nonbuffered Ports	Initialized as inputs	
High-Level Voltage	Iout = MAX	2.4V
Low-Level Voltage	Iout = MAX	0.45V
Current Source	Vout = Low	200uA
Current Sink	Vout = High	1.7mA
Tri-State Current	Vout = 2.7V	10uA
Tri-State Current	Vout = 0.4V	10uA
Power Requirements	+5V supply	425 mA Max
Physical Size	Length x Height (One Slot)	5.0"x4.2" (12.7x10.7cm)
Temperature Range	Board Temperature	0 to 70°C



Block Diagram of the PCI-20087W-1 Digital I/O Board.



BURR-BROWN®

PCI-20089W-1 Analog Input Board

FEATURES

- 16 / 8 Analog Input Channels
  - Single-Ended / Differential
  - 12-Bit Resolution
  - Programmable Gain Amplifier
  - Gain = 1, 10, 100
  - Up to 32kHz Sample Rate
  - Start-Convert Via Software, Internal Rate Generator or External Hardware Signal
  - FET Input, 500pA Bias Current
- Internal Timebase / Rate Generator
- Independent Counter Channel
- Interfaces to PC Interrupt Levels 2 thru 7
- Half-size board fits into PC/XT short slot
- Suitable as an OEM Component
- BASIC Language Software Drivers are Included
- Also Compatible with PCI-20026S Series and PCI-20027S Series Software which supports an expanded set of functions in BASIC, C and TURBO PASCAL.

DESCRIPTION

The PCI-20089W-1 is a high performance analog input subsystem with an internal timebase generator and auxiliary pulse counter. Typical applications for this product include: data acquisition, process monitoring, and test systems. A wide variety of voltage and current signals can be accepted from thermocouples, RTD's, strain gages, load cells, and optical/magnetic pickups, etc. The board plugs directly into an expansion slot of any IBM compatible Personal Computer (PC). Compatibles are available from IBM, AT&T, Olivetti, Zenith, Siemens, Compaq, and PC's Limited, to name just a few. These include the 386-type machines. In addition, the IBM PS/2 model 30 also supports this and all other PCI-20000 products. Because of its small size, the PCI-20089W-1 can be installed in the "short" slot of computers such as the IBM PC/XT. A functional block diagram of the product is shown below.

The PCI-20089W-1 performs the necessary analog to digital (A/D) conversions required to make analog input data compatible with your personal computer. The input multiplexer can select from among 16 single-ended or 8 differential channels. Signal scaling and common-mode rejection are provided by a high performance, differential input, programmable gain amplifier. Gains of 1, 10 and 100 are available under software control. The 12-bit A/D converter can be configured for input ranges of ±5, 0 to 10 or ±10 Volts full scale. A standard 26 pin connector is provided for analog input signal connections. Optional ribbon cables and termination panels are available to help facilitate external connections. These include the PCI-20010T-1,-2 (panels) and the PCI-20012A-1 (cable), which are ideal for most analog input applications. All interconnection components are keyed to prevent incorrect assembly.

The digital section of the board contains the computer bus interface circuitry, a programmable rate generator and a general purpose counter. The rate generator is very useful for establishing an accurate and dependable timebase for data acquisition. Two 16-bit, divide by "n" counters, scale the computer's crystal clock to the desired frequency. Clock rates in the range of 0.01Hz to 1MHz can be selected. An additional, independent counter is provided for general purpose applications. The maximum input clock rate for this counter is 8MHz. Typical operations include event counting as well as speed and frequency measurement. Separate CLOCK, GATE and OUTPUT connections are furnished for maximum utility. To insure that the digital signals do not contaminate (degrade) the analog inputs, a separate connector is provided for these functions. A mating cable connector is included.

A family of BASIC language software support drivers is included with the hardware. The current version of this software supports a wide range of functions including: System Initialization, Channel Configuration, Analog Read, High Speed Analog Block Read, Set Rate Generator, Read Counter and Read Frequency. Optional software drivers are available offering additional functions and support for other programming languages. These include the PCI-20026S and PCI-20027S families, which offer extended capabilities for BASIC, C and TURBO PASCAL.

Comprehensive documentation is included covering all aspects of installation, calibration and programming. Each board is shipped, at no extra charge, with Burr-Brown's innovative *SYSCHECK*, the system assurance utilities and diagnostics software package. This menu-driven product easily verifies proper installation and utilization of all PCI-20000 system components. Not only does the SYSCHECK greatly reduce the time required to confirm appropriate operation but it provides a permanent resource for test and calibration. In addition, the SYSCHECK provides non-programmers with a fundamental way of exercising the input/output capabilities of the system. This can be useful as both a product tutorial and in performing modest test and simulation functions.

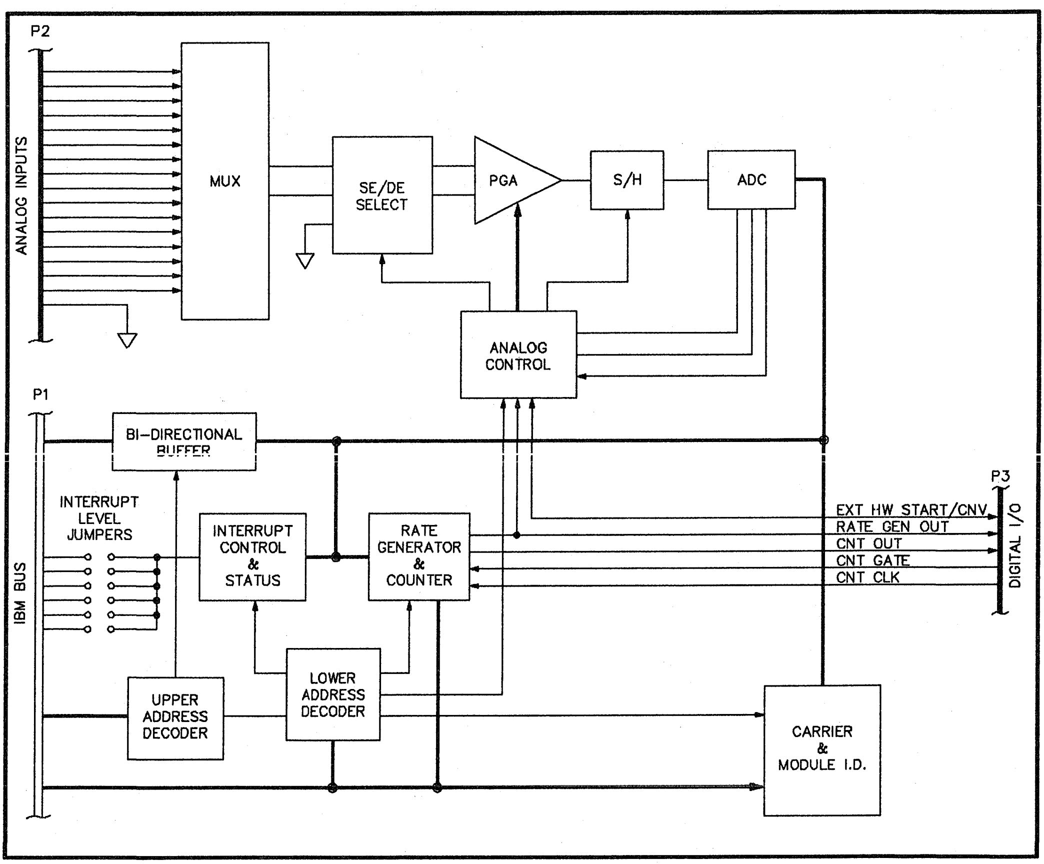


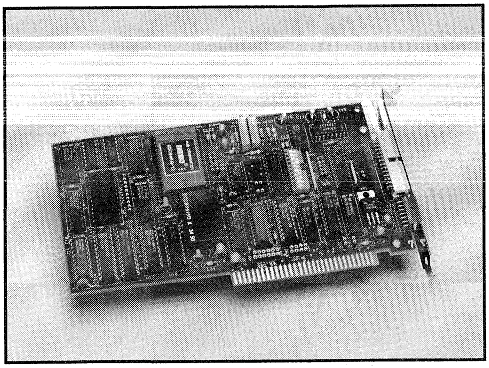
Diagram of the PCI-20089W-1 Analog Input Board

SPECIFICATIONS - PCI-20089W-1

All specifications are typical at 25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Board Level	Plugs inside IBM or compatible PC's	
Functions	Analog Input, Pulse Counter and Rate Generator	
Addressing	Memory Mapped, Switchable	1KByte required
Physical Size	Length x Height (One Slot)	5.8" x 4.2" (14.7cm x 10.7 cm)
Temperature Range	Board Temperature	0 to 70°C
I/O Interface	Mating cable connectors	
Analog Input	T&B Ansley or equivalent	#609-2630
Digital I/O	Methode Elec. #1300-107-422	Included
Power Requirements	From PC supply, +5V	2 A
	Quiescent (add load), +12V	5 mA
Analog Inputs		
Number of Channels	Single-Ended	16
	Differential	8
Signal Range	Linear Operation	±10V max
	Without Damage, Power On	±35V
	Power Off	±20V
Offset Voltage	Trimmable to 0	±.5 LSB
Drift		±.04 LSB/°C
Common Mode Range (1)	$V_{cm} = CM_{range} - (V_{diff} \cdot Gain)$	±12V
Rejection Error	60Hz, 100 ohm imbalance	
	Gain = 1	.5 LSB
	Gain = 10, 100	.1 LSB
Bias Current		500 pA
Input Impedance		10^{11} @ 60pF
Source Impedance, Max Recommended	For 1 LSB Error	
	At 32kHz Sample Rate	7.5K Ohms
	At 26kHz Sample Rate	10K Ohms
Crosstalk	Channel to Channel @ 1KHz	.5 LSB
Nonlinearity	Gain = 1, 10	.5 LSB
	Gain = 100	1 LSB
Gain, Ranges	Software Programmable	1, 10, 100
Inaccuracy	Trimmable to 0%	±.5 LSB
Drift		.1 LSB/°C
A/D Converter		
Resolution	(1 part in 4096)	12 Bits
Code	Unipolar	Binary
	Bipolar	Offset Binary
Ranges	Jumper Selectable	±5, ±10, 0-10V FS
PC Interrupts	PC Levels 2 thru 7	End of Conversion or Rate Generator
Dynamic Performance	12-Bit Accuracy	
Total Throughput	IBM PC/AT	32kHz
Mux Settling Time		5usec max
S/H Capture Time		6usec max
A/D Conversion Time		25usec max
PGA Settling Time	10 Volt Step, Gain = 1, 10	18usec
	Gain = 100	24usec
Rate Generator	(Timebase Generator)	1 Channel
Output Frequency	Software Programmable	TTL pulse output
Equation	F_{clock} = Computer Clock at bus connector	$F_{clock} / (2 \cdot n_1 . n_2)$
Frequency Range	Based upon a 6MHz Computer	.001Hz to 750kHz
Counter	General Purpose	1 Channel
Functions	Count, Divide by N (pulse or square-wave out), One-Shot, Interrupt on terminal count, Strobe	
Count Capacity	16-Bits	65535
Software Drivers	Interface Language	BASIC
	Included with Board	PCI-20090S-1
Functions Supported		Analog Input, Counter Rate Generator
Speed	With Supplied Software In an IBM PC/AT (12mHz)	
Analog Read	READ.CH, Interpreted BASIC	720 Ch/Sec
Block Read	RUN.HS, Interpreted BASIC	11,000 Ch/Sec
Read Counter	READ.CH, Interpreted BASIC	660 Reads/Sec

NOTES: 1) The allowable common-mode voltage (V_{cm}) is a function of the applied differential voltage (V_{diff}) multiplied by the Gain selected. The specified common-mode range (CM_{range}) is diminished by the applied differential voltage ($V_{cm} = CM_{range} - (V_{diff}.Gain)$).



BURR-BROWN®

PCI-20091W-1

High Speed Analog Input Board

FEATURES

- 8 Analog Input Channel, Single-Ended
  - Up to 89kHz Sample Rate Program & DMA Support
  - Automatic Channel Advance
  - 12-Bit Resolution
  - Start-Convert Via Software, Internal Rate Generator or External Hardware Signal
- Internal Timebase / Rate Generator
- Interfaces to PC Interrupt Levels 2 thru 7
- Suitable as an OEM Component
- BASIC Language Software Drivers are Included
- Also Compatible with PCI-20026S Series and PCI-20027S Series Software that supports an expanded set of functions in BASIC, C and TURBO PASCAL.

DESCRIPTION

The PCI-20091W-1 is a high speed analog input subsystem featuring Direct Memory Access (DMA) and an internal timebase generator. This board is intended for high-level signals and does not contain an input amplifier that could reduce its speed. Applications for the PCI-20091W-1 include data acquisition, transient capture, audio evaluation, and vibration analysis. The unit plugs directly into an expansion slot of any IBM compatible Personal Computer (PC). Compatibles are available from IBM, AT&T, Olivetti, Zenith, Siemens, Compaq, and PC's Limited, to name just a few. These include the 386-type machines. In addition, the IBM PS/2 model 30 also supports this and all other PCI-20000 products. A functional block diagram of the product is shown below.

The PCI-20091W-1 performs the required analog to digital (A/D) conversions necessary to make the input data compatible with your personal computer. The combination of an auto-sequencing multiplexer and a high-speed sample/hold and A/D converter allows input sampling speeds at up to 89,000 channels/second. This speed can be achieved in both PC/XT (using DMA) and PC/AT (without DMA) type computers. The multiplexer can select from among 8 different single-ended input channels. Resolution of the A/D converter is one part in 4096 (12-Bits). To enhance resolution, five full-scale input ranges are available: ±2.5, ±5, ±10, 0 to 5 and 0 to 10 Volts. Direct memory access is supported by two unique modes of operation: Start-On-Command, Stop-On-Terminal Count and Start-On-Command, Stop-On-Trigger with delay. The second method permits the capture of "pre-trigger" information. Data is stored continuously into a circular buffer until an external TTL command triggers the stop sequence. The user can define the number of new readings to be taken (Delay) after the trigger.

A standard 26 pin connector is provided for analog input signal connections. Optional ribbon cables and termination panels are available to facilitate external connections. These include the PCI-20010T-1 (panel) and PCI-20012A-1 (cable), which are ideal for most analog input applications. In addition, "active" units are available that can provide a differential front end to the system. Among other features, these panels furnish amplification and isolation, accommodating low level signals such as thermocouples, strain gages, load cells, and RTD's. All of the interconnection components are keyed to prevent incorrect assembly.

The digital section of the PCI-20091W-1 contains the channel sequencing and control circuitry and a programmable rate generator (RG). The RG is very useful for establishing an accurate and dependable timebase for data acquisition. Two 16-bit, divide by "n" counters, scale an 8MHz crystal clock to the desired frequency. Clock rates in the range of 0.01Hz to 1MHz can be selected. Both software and hardware control over programmed and DMA acquisition are supported. In the hardware modes, connections are provided for either internal (RG) or external "start." The board can generate an interrupt to the PC on "end of conversion." Interrupt levels 2 through 7 are supported. To insure that the digital signals (start convert, conversion inhibit, external interrupt, and RG) do not contaminate (degrade) the analog inputs, a separate connector is provided for these functions.

For ease-of-use a set of BASIC language software support drivers is included with the hardware. The current version of this software supports a wide range of functions including System Initialization, Channel Configuration, Analog Read, High Speed Analog Block Read, DMA Read and Set Rate Generator. Optional software drivers offer additional functions and support for other programming languages. These include the PCI-20026S family, along with the PCI-20027S family, which offer extended capabilities for BASIC, C and TURBO PASCAL.

Comprehensive documentation is included covering all aspects of installation, calibration, and programming. Each board is shipped, at no extra charge, with Burr-Brown's innovative *SYSCHECK*, the system assurance utilities and diagnostics software package. This menu-driven product easily verifies proper installation and utilization of all PCI-20000 system components. Not only does the SYSCHECK greatly reduce the time required to confirm appropriate operation but it provides a permanent resource for test and calibration. In addition, the SYSCHECK provides non-programmers with a fundamental way of exercising the input/output capabilities of the system. This can be useful as both a product tutorial and in performing modest test and simulation functions.

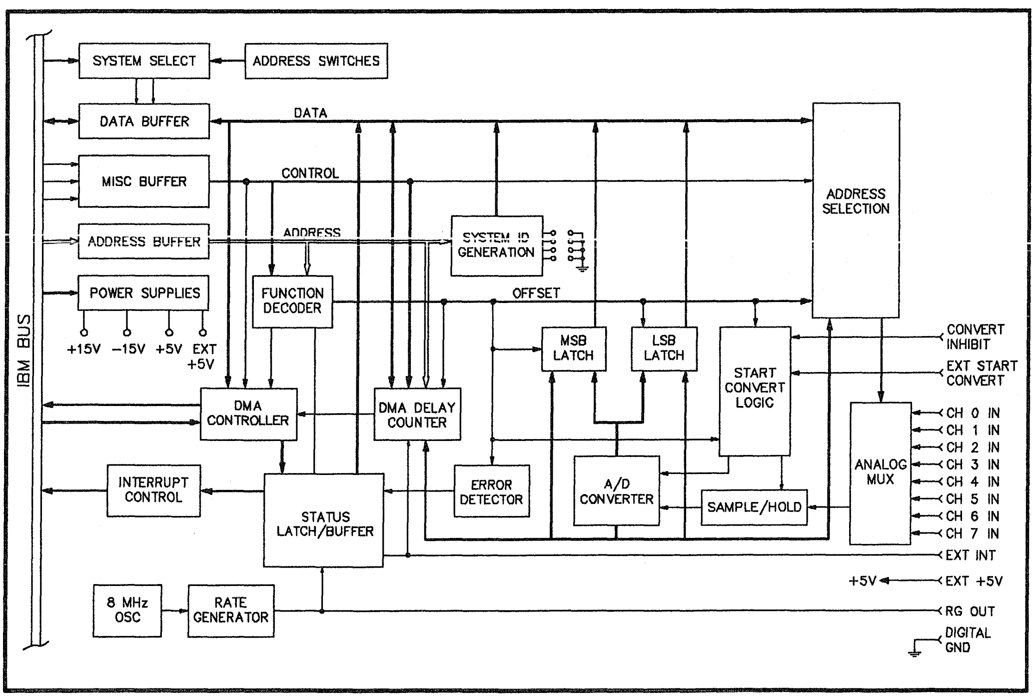
SPECIFICATIONS - PCI-20091W-1

All specifications are typical at 25°C unless otherwise noted.

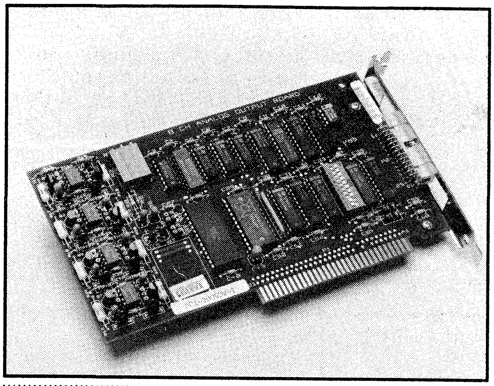
PARAMETER	CONDITIONS	SPECIFICATION
Board Level	Plugs inside IBM or compatible PC's	
Functions	Analog Input and Rate Generator	
Addressing	Memory Mapped, Switchable	1KByte required
Physical Size	Length x Height (One Slot)	7.5" x 4.2" (19cm x 10.7cm)
Temperature Range	Board Temperature	0 to 70°C
I/O Interface	Mating cable connectors	
Analog Input	T&B Ansley or equivalent	609-2630
Digital I/O	Methode Elec. #1300-107-422	Included
Power Requirements	+5V supply from PC	2 Amps Max
Analog Inputs		
Input Stage		
Number of Channels	Single-Ended	8
Input Multiplexer	Software Channel Select Mode	Any 1 of 8
	Auto Channel Scan Mode	"n" thru 7
Signal Range		±10V max
Offset Voltage	Trimmable to 0	±1 LSB
Drift	Unipolar	±3ppm/°C
	Bipolar	±15ppm/°C
Bias Current		100nA
Over Temperature	0 to 70 °C	300nA
Input Impedance		1 Meg @ 35pf
Source Impedance, Max Recommended	For 1 LSB Error At 89kHz Sample Rate	1K ohm
Crosstalk	Channel to Channel @ 1KHz	.5 LSB
A/D Converter		
Resolution	(1 part in 4096)	12 Bits
Code	Unipolar	Complementary Binary
	Bipolar	Complementary Offset Binary
Ranges	Jumper Selectable	±2.5, ±5, ±10, 0-5, 0-10V FS

Continued...

PARAMETER	CONDITIONS	SPECIFICATION
Dynamic Performance	12-Bit Accuracy	
Total Throughput	Hardware Performance	
Non-DMA Mode	IBM PC/AT @12MHz	89,000 Ch/Sec
DMA Mode	IBM PC/XT or PC/AT @ 12 MHz	89,000 Ch/Sec
Mux Settling Time		3.5usec max
S/H Capture Time		1.5usec max
A/D Conversion Time		10usec max
Rate Generator	(Timebase Generator)	
Output Frequency	Software Programmable	TTL pulse output
Equation		$8MHz/(n_1 n_2)$
Frequency Range		.002Hz to 2MHz
Output Voltage Levels	Digital High, Ioh = max	2.7V min
	Digital Low, Iol = max	0.5 max
Output Current	Capability, Sink	8 mA
	Source	400 uA
PC Interrupts	TTL High/Low Transition	DMA Terminal Count
Levels 2 thru 7		External Input
Software Drivers	Interface Language	BASIC
	Included with Board	PCI-20092S-1
Functions Supported		Analog Input (program & DMA), Rate Generator
Speed	With Supplied Software Using Interpreted BASIC	
Analog Input	READ.CH, IBM PC/AT	415 Ch/Sec
Block Read	RUN.HS, IBM PC/AT Mode 4	89,000 Ch/Sec
DMA Read	DMA.RUN, Continuous Mode IBM PC/AT @ 12MHz	89,000 Ch/Sec



Block Diagram of the PCI-20091W-1 Analog Input Board



BURR-BROWN®

PCI-20093W-1
8 Channel Analog Output Board

FEATURES

- 8 Analog Output Channels
  - Voltage & Current Outputs
  - Up to 31,200 Outputs/Sec, Total Throughput (Up to 3900 Outputs/Sec, Per Channel)
  - 12-Bit Resolution
- Suitable as an OEM Component
- BASIC Language Software Drivers are Included
- Also Compatible with PCI-20026S Series and PCI-20027S Series Software which supports an expanded set of functions in BASIC, C, and TURBO PASCAL

DESCRIPTION

The PCI-20093W-1 is an analog subsystem featuring eight channels of voltage or current output. This board is intended for a wide range of applications including: waveform generation, simulators, controllers, display drivers, and test systems. The PCI-20093W-1 plugs directly into an expansion slot of any IBM compatible Personal Computer (PC). Compatibles are available from IBM, AT&T, Olivetti, Zenith, Siemens, Compaq, and PC's Limited, to name just a few. These include the 386-type machines. In addition, the IBM PS/2 model 30 also supports this and all other PCI-20000 products. A functional block diagram of the product is shown below.

The PCI-20093W-1 accepts programmed digital instructions from your personal computer and performs the digital to analog (D/A) conversions necessary to generate corresponding analog output levels for external use. To reduce cost and size, one D/A converter is shared by eight channels. High performance is insured by the use of a proprietary, multiplexed, dynamic refreshing technique. This method provides "glitch free" updates to all eight channels within 256 μsec (3900 times/sec). Data is stored in onboard RAM allowing the system to operate as though eight independent converters exist. Additional RAM is available to store "waveform" files, with a capacity of 128, 8 channel frames. Output frames are switched upon software (program) command. The 12-bit D/A converter can be configured for output ranges of ±2.5, ±5, 0-5 volts full scale. When set to the 0-5V range, each channel can be optionally jumpered for 0-20 mA operation. With the introduction of a software offset, it is a simple matter to generate 4-20 mA. A standard 26 pin connector is provided for external connections.

Comprehensive documentation is included covering all aspects of installation, calibration and programming. For ease of use a set of BASIC language software support drivers is included with the hardware. The current version of this software supports functions including: System Initialization and Channel Write. Optional software drivers are available offering additional functions and support for other programming languages. These include the PCI-20026S family which offers extended capabilities for BASIC, C, and TURBO PASCAL.

Optional ribbon cables and termination panels are available to help facilitate external connections. These include the PCI-20010T-1 (panel) and PCI-20012A-1 (cable), which are ideal for most analog output applications. The PCI-20010T-1 provides convenient, screw terminal connections for up to 16 analog signals. When used with the PCI-20093W-1 it supports each of the eight outputs in any combination of voltage or current modes. In addition, the user can install separate signal conditioning components for each channel. Provisions for filters, voltage divides and protection networks are included. The PCI-20012A-1 is a 6 foot, shielded ribbon cable intended for all analog I/O signal connections. All of the interconnection components are keyed to prevent incorrect assembly.

Each board is shipped, at no extra charge, with Burr-Brown's innovative *SYSCHECK*, the system assurance utilities and diagnostics software package. This menu-driven product easily verifies proper installation and utilization of all PCI-20000 system components. Not only does the SYSCHECK greatly reduce the time required to confirm appropriate operation but it provides a permanent resource for test and calibration. In addition, the SYSCHECK provides non-programmers with a fundamental way of exercising the input/output capabilities of the system. This can be useful as both a product tutorial and in performing modest test and simulation functions.

SPECIFICATIONS - PCI-20093W-1

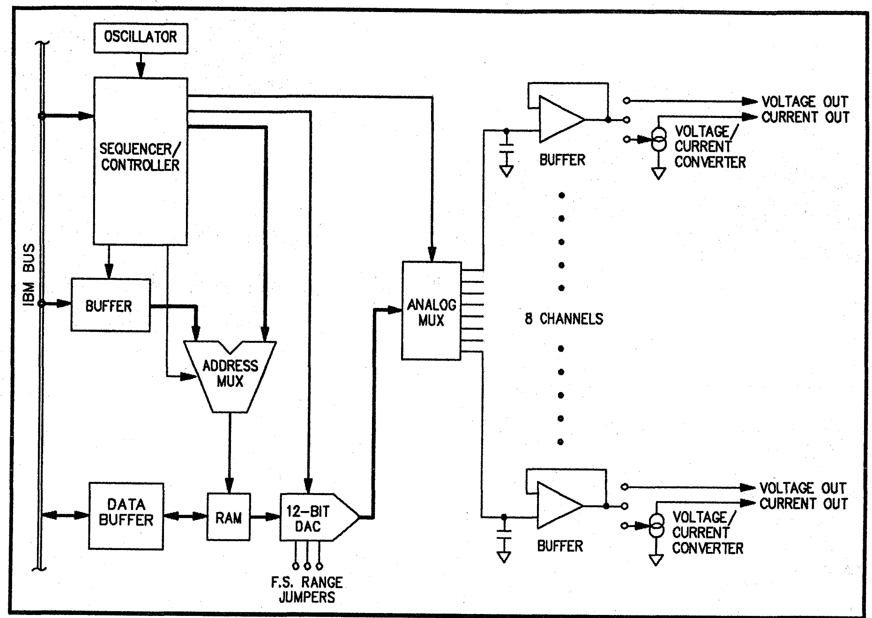
All specifications are typical at 25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Board Level	Plugs inside IBM or compatible PC's	
Function		Analog Output
Addressing	Memory Mapped, Switchable	1KByte required
Physical Size	Length x Height (One Slot)	7.2" x 4.2" (18.3 cm x 10.7 cm)
Temperature Range	Board Temperature	0 to 70°C
I/O Interface	Mating cable connectors T&B Ansley or equivalent	# 609-2630
Power Requirements	From PC supply, +5V	570 mA Max
	+12V	50 mA Max
Configuration		
Ranges	Voltage or Current Output (Jumper Selectable)	±2.5V, ±5V, 0-5V, or 0-20mA
Number of Channels		8
Resolution	(1 part in 4096)	12-Bits
Code	Unipolar	Binary
	Bipolar	Offset Binary
Accuracy		
Gain		±1/2 LSB
Over Temperature	10 Volt Range	±1 LSB
Linearity	Voltage Ranges	±1/2 LSB
	Current Range	±1 LSB
Offset Voltage	Voltage and Current Ranges	±1LSB
Noise	DC to 10kHz, Maximum	±1 LSB
Crosstalk	Channel to Channel	±1 LSB
Output Stage		
Output State (1)	At Power Up	Zero
Output Current	Voltage Mode	±1mA
Output Impedance	Voltage Mode @ 2 kHz	1 Ohm
	Current Mode	30 Megohm
Voltage Compliance	Current Mode	40V Max (2)
Dynamic Performance		
Total Throughput (3)	8 Channel Frames	31,200 Outputs/Sec
Update Rate (3)	Per Channel	3900 Outputs/Sec
Settling Time	To 12-bit Accuracy	256 μsec
Software Drivers	Interface Language Included with Board	BASIC
Functions Supported		Analog Output
Speed (3)	With Supplied Software	
Single Channel	WRITE.CH, Interpreted BASIC	1000 Outputs/sec

NOTES:1)When the system is first powered up, the outputs of this board are originally set to zero volts (or zero current) until reinitialized by software.

2)When operating in the current output mode, the minimum allowable external loop supply voltage depends upon the external load resistance as follows:
$V_{min} = 5.2 + .02\ R_l$.

3)Refers to "changes in the output" or "new outputs" per second.



Block Diagram of PCI-20093W-1 Analog Output Board.

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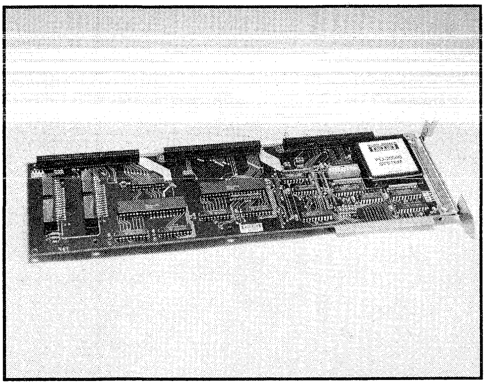


BURR-BROWN®

PCI-20001C SERIES

General Purpose Carrier Board

FEATURES

- Plugs into internal expansion slot of any IBM-compatible computer: IBM PC, XT, AT; COMPAQ; AT&T; ZENITH; etc.
- Functionality programmed via a family of plug-in I/O modules
- Provisions for up to three I/O modules per carrier
- No external power required
- On-board bus allows digital, analog and timing signals to be passed between modules
- Memory-mapped addressing allows a large number of carriers to be connected to one PC
- A module is available with 32 digital I/O points installed. This capability leaves all three module locations free for further expansion.

DESCRIPTION

The PCI-20001C-1 "basic" carrier is designed to interface directly with the IBM PC's internal bus through any available expansion slot. Major features of this carrier include the Intelligent Instrumentation Interface (I^3) Bus and its capacity for up to three modules. The I^3 bus supports digital, sync, and analog signal communication. The sync lines make possible the coordination (timing) of various system elements. The differential analog chain allows any module to condition its input signal and then pass the result to the next module. Bus translation circuitry links the IBM computer bus to the I^3 bus. Logic for interrupt control, carrier identification and module selection is also included. All power is derived from the +5V PC power supply. A DC/DC power converter on the carrier generates ±15V for use by the modules.

Several carriers can be installed in one PC, up to the limits on available expansion slots. However, the mechanical thickness of the carrier/module assembly, and power requirements can limit a practical installation to less than the number of slots. Each carrier is addressed into the memory map of the PC, and requires one kilobyte of space. DIP switches allow placing the carrier anywhere within the one megabyte of available memory address space.

The PCI-20001C-2 carrier possesses all of the physical and electrical characteristics of the PCI-20001C-1 plus one additional feature. The PCI-20001C-2 has 32 points of fully buffered digital I/O. (See block diagram.) The 32 points are arranged in four groups of eight bits (bytes). Each byte can, under software control, be configured for either input or output use. Field connections to these I/O points are made through two connectors on the carrier. Each connector supports two bytes. Ribbon cables are used to interconnect the carrier and the optional signal termination panels. This digital I/O capacity does not diminish any of the other functions, and leaves all three module positions free for further expansion.

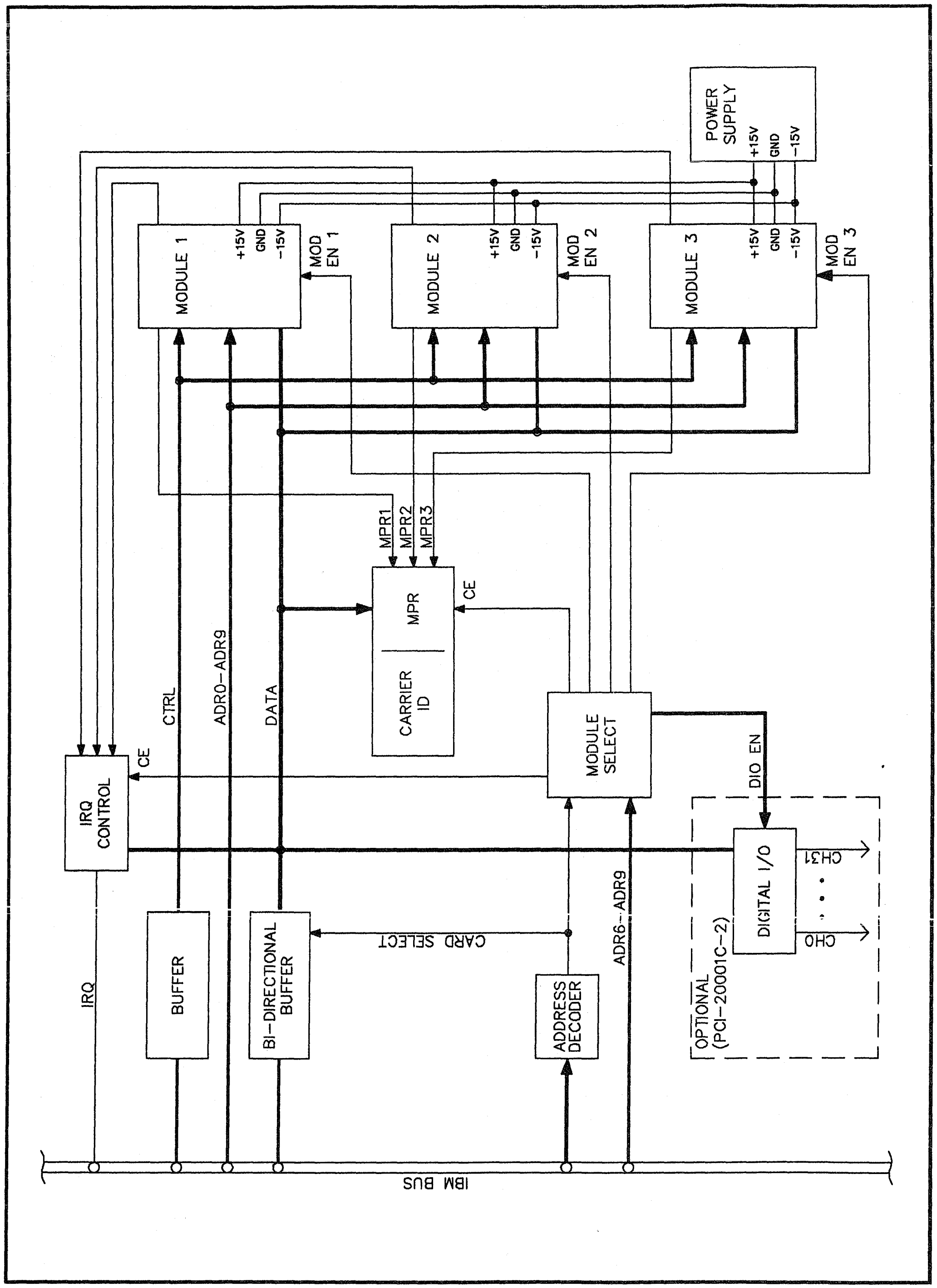
Comprehensive documentation covers all aspects of installation, and programming. Each carrier is shipped, at no extra charge, with Burr-Brown's innovative SYSCHECK, the system assurance utilities and diagnostics software package. This menu-driven product easily verifies proper installation and utilization of all PCI system components. Not only does the SYSCHECK greatly reduce the time required to confirm appropriate operation but it provides a permanent resource for test and calibration. In addition, the SYSCHECK provides non-programmers with a fundamental way of exercising the input/output capabilities of the system. This can be useful as both a product tutorial and in performing modest test and simulation functions.

SPECIFICATIONS —PCI-20001C-1, PCI-20001C-2

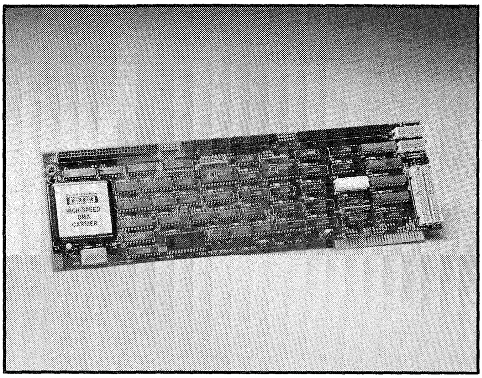
All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility	All IBM compatible PCs, including PC, XT, AT, AT&T, Compaq, Zenith, etc.	
Carrier Addressing		Memory Mapped
Size	Boundary on any 1K increment	1K bytes
I/O Configuration	Digital ports: programmable as In or Out in groups of 8 channels	Three I^3 Bus sockets plus 32 digital I/O on PCI-20001C-2
Digital Inputs	PCI-20001C-2 Only	
High-Level Voltage	Minimum	2V
Low-Level Voltage	Maximum	0.8V
I_{IN}, High-Level	Maximum	20µA
I_{IN}, Low-Level	Maximum	-0.2mA
Input Clamp Level		-1.5V
Digital Outputs(1)	PCI-20001C-2 Only	
High-Level Voltage	1_{out} = Max	2V
Low-Level Voltage	1_{out} = Max	0.5V
Current Source	V_{out} = Low	-15mA
Current Sink	V_{out} = High	24mA
Tri-State Current	V_{out} = 2.7V	10µA
	V_{out} = 0.4V	200µA
Power Requirements	From PC's +5V Supply	
PCI-20001C-1	No load on internal supply	210mA(2) Max
	Full load on internal supply	3.82A Max
PCI-20001C-2	No load on internal supply	560mA(2) Max
	Full load on internal supply	4.12A Max
Power Available to Modules	Internal +15V Supply	150mA Minimum(3)
	Internal -15V Supply	150mA Minimum(3)
	+5V Bus	Depends upon Host
Physical	Expansion Slot Requirements	One to two slots(4)
Size	Length x Height	13.1" x 3.9" (33.3cm x 9.9cm)
Temperature Range	Board Temperature	0 to 70° C

NOTES: (1) All digital I/O ports are "Inputs" at power up. (2) No Modules are installed on Carrier. (3) 150mA is a conservative rating. Typically 200mA is available, but this is not guaranteed. (4) The width of the PCI-20000 depends upon the I/O board configuration. With no modules, one slot is required. With three modules, two slots are required.



PCI-20001C Carrier Block Diagram.



BURR-BROWN®

PCI-20041C Series
High-Performance Carrier Boards

FEATURES

- Unique DMA technique supports high-speed transfers of analog, digital and counter data simultaneously on up to 5 carriers
- 360K bytes/sec DMA transfers
- Pre-trigger and post-trigger viewing of event data
- Inter-carrier bus allows data transfers between carriers
- DMA, interrupt-driven or polled modes of operation
- Plugs into expansion slot of IBM PC-compatible computers
- Functionality determined by up the three plug-in I/O modules
- On-board bus allows digital, analog and timing signals to pass between modules

DESCRIPTION

The PCI-20041C-2 and PCI-20041C-3 (DMA version) are carrier boards which interface directly with the internal bus of the IBM PC or compatible computers through any available expansion slot. Each carrier provides mounting space, power, and inter-module communications for up to three modules of the PCI-20000 Data Acquisition, Test, Measurement, and Control System. Digital, sync, and analog signals may be passed between modules via the on-board Intelligent Instrumentation Interface (I^3) bus. In addition, an inter-carrier communications port allows similar communications with up to 15 modules residing on multiple carriers. This allows the building of systems with a small number of I/O points and relative simplicity to those with several hundred I/O channels, high speed, and considerable sophistication.

The sync lines of the I^3 bus make possible the coordination of multiple modules to perform various signal processing functions The differential analog chain and the digital lines of this bus permit any module to condition its input signal and to pass the result to the next module. Bus translation circuitry on the carrier links the IBM PC bus to the I^3 bus. Logic for interrupt control, carrier identification and module selection is also included. All power is derived from the +5V DC power supply of the PC. A DC/DC converter on the carrier generates regulated ±15V DC power for use by the modules.

Both the PCI-20041C-2 and PCI-20041C-3 Carriers have 32 points of fully buffered digital I/O capability. The 32 points are arranged in four groups of eight bits (bytes). Each byte can, under software control, be configured for either input or output use. Field connections to these I/O points are made through two connectors on the carrier. Each connector supports two bytes. Ribbon cables are used to interconnect the carrier to optional signal termination panels. This digital I/O capacity does not diminish any of the other functions, and it leaves all three module positions free for further expansion.

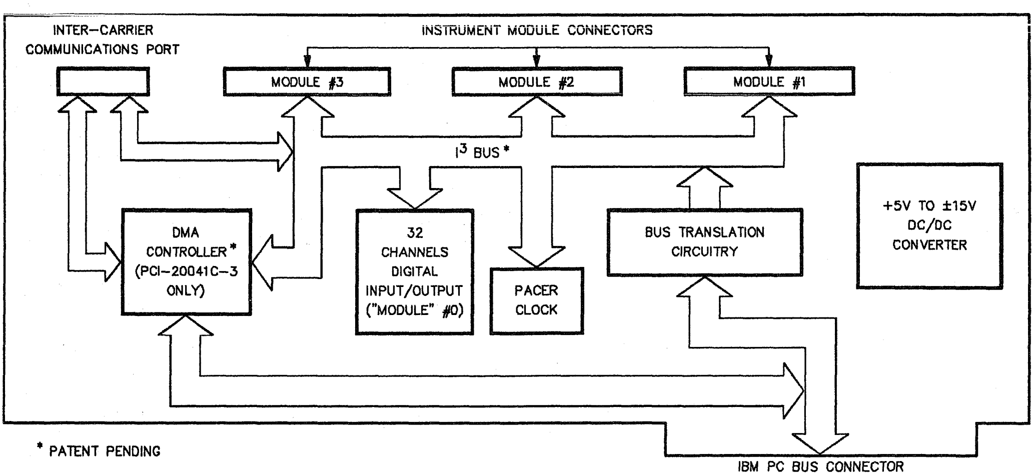
Both carrier models also include an 8MHz programmable pacer clock for use in the timing of data acquisition and transfers of data to and from memory. Both the PCI-20041C-2 and the PCI-20041C-3 can operate in the programmed transfer mode using either "polling" or "interrupt" techniques. Each carrier supports a single interrupt to the host computer. The interrupt can be jumpered to levels 2 through 7.

In addition to all of the above capabilities, a unique (patented) DMA technique gives the PCI-20041C-3 Carrier the ability to make very high speed transfers (up to 360K bytes/sec) of input (or output) data to or from the memory of the PC. The DMA controller in the host computer is used in conjunction with a controller on the carrier to accomplish the transfer invisibly to the host computer. Data is transferred to or from the memory of the host PC in frames of up to 64 bytes using DMA. For input transfers, frames of data from input modules on the I^3 bus are stored to sequential locations in the host computer's memory. For output transfers, frames of data from specified sequential locations in the host computer's memory are transferred to specified output modules on the I^3 bus. The "frame map" is stored in a block of memory on the carrier itself. This is a list of the up to 64 I^3 bus addresses which are to be in the frame, in the order in which they are to be read or written to. There is no need for this list of I^3 bus addresses to be sequential. This allows the high-speed scanning of analog or digital inputs in any desired order simply by loading the desired sequence of I^3 bus addresses into the "frame map" memory. Conversely, output DMA transfers may be made to any desired sequence of output devices on the I^3 bus simply by specifying the appropriate "frame map".

The inter-carrier communications port allows a designated carrier to operate as a "master" and to control DMA transfers from up to four other carriers which operate as "slaves". This is done by insertion of the appropriate jumpers on each carrier and by connecting the carriers together via inter-carrier ribbon cables By chaining carriers together in this way, it is possible to make DMA transfers to or from up to 15 modules residing on the carriers. The maximum frame size is still 64 bytes. The sequence of module addresses is once again arbitrarily determined by the user to meet the requirements of his application.

DMA transfers may be initiated on command or on the occurrence of an event after delay. Transfers may be terminated on command, on the occurrence of an event after delay, or after transferring a specified number of frames of data. Transfers can be timed by the on-board pacer clock, or by the occurrence of events. Transfers of data to a circular buffer can be used to give pre- and post-trigger information. This allows the analysis of conditions both before and after the occurrence of a random critical event.

Comprehensive documentation covers all aspects of installation, calibration and programming. Each carrier is shipped, at no extra charge, with Burr-Brown's innovative SYSCHECK, the system assurance utilities and diagnostics software package. This menu-driven product easily verifies proper installation and utilization of all PCI system components. Not only does the SYSCHECK greatly reduce the time required to confirm appropriate operation but it provides a permanent resource for test and calibration. In addition, the SYSCHECK provides non-programmers with a fundamental way of exercising the input/output capabilities of the system. This can be useful as both a product tutorial and in performing modest test and simulation functions.



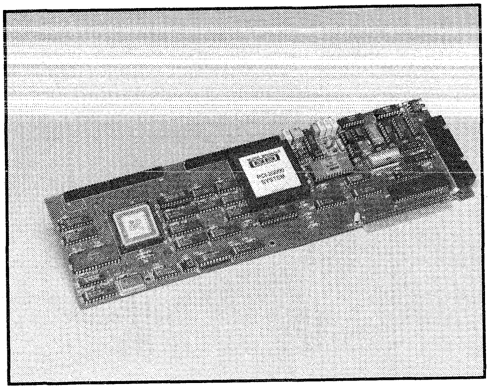
Block Diagram of the PCI-20041C Series Carrier.

SPECIFICATIONS —PCI-20041C-2A, PCI-20041C-3A

All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility		All IBM compatible PCs, including PC, XT, AT, AT&T, Zenith, etc.
Carrier Addressing		Memory Mapped
Size	Boundary on any 1K increment	1K Bytes
I/O Configuration		3 I^3 Bus sockets plus 32 digital I/O Digital ports: programmable as In or Out in groups of 8 bits
Digital Inputs		
High-Level Voltage	Minimum	2V
Low-Level Voltage	Maximum	0.8V
I_{IN}, High-Level	Maximum	70µ A
I_{IN}, Low=Level	Maximum	-0.25mA
Input Clamp Level		-1.5V
Digital Outputs(1)		
High-Level Voltage	I_{out} = MAX	2.4V
Low-Level Voltage	I_{out} = MAX	0.5V
Current Source	V_{out} = Low	-6.5V
Current Sink	V_{out} = High	24mA
Tri-State Current	V_{out} = 2.7V	70µ A
Tri-State Current	V_{out} = 0.4V	250µ A
Pacer Clock	Basic Frequency	8MHz ± .01%
Output Frequency	N_1 and N_2 are 16-bit integers	8MHz/(N_1·N_2)
Interrupts	Can be Latched	
Levels	Jumper Selectable	2 through 7
Sources	Via IRQ0*	Modules 1-3, Pacer Clock, External TTL
Sense		TTL high to low
DMA Transfers	PCI-20041C-3A Only	
Data Types	Analog, Digital, Counter	Inputs or Outputs
Speed	Maximum Rate(12)	360K Bytes/second
Transfer Modes	Linear or Circular Buffers	Start and Stop on Command or on Event After Delay
Frame Size	Maximum number of addresses	64 Bytes
Block Size	Maximum data stored in RAM	64K Bytes
Power Requirements	From PC's +5V Supply	
PCI-20041C-2	No Load on Internal Supply	1.7A(3) Typical, 2.7A(3) Maximum
	Full Load on Internal Supply	3.85A Typical, 4.85A Maximum
PCI-20041C-3A	No Load on Internal Supply	2.5A(3) Typical, 3.6A(3) Maximum
	Full Load on Internal Supply	4.65A Typical, 5.75A Maximum
Power Available to Modules	Internal +15V Supply	150mA Minimum(4)
	Internal -15V Supply	150mA Minimum(4)
	+5V Bus	Depends Upon Host
Physical	Expansion Slot Requirements	1 to 2 Slots(5)
Size	Length x Height	13.1" x 3.9" (33.3cm x 9.9cm)
Temperature Range	Board Temperature	0 to 70°C

NOTES: (1) All Digital I/O ports are "Inputs" at power up. (2) The obtainable DMA transfer rate depends upon several factors including the PC type, frame size, mode, etc. (3) No Modules are installed on Carrier. (4) 150mA is a conservative rating. Typically 200mA is available, but this is not guaranteed. (5) The width of the PCI-20000 depends upon the I/O board configuration. With no modules, one slot is required. With three modules, two slots are required.



BURR-BROWN®

PCI-20098C-1
Multifunction Carrier

FEATURES

- All Functions Software Programmable, No Jumpers Needed
- 16 / 8 Analog Input Channels
  - Single-Ended / Differential
  - Expandable to 80 / 40 Channels with PCI Modules
  - 12-Bit Resolution
  - Programmable Gain = 1, 10, 100
  - Up to 32kHz Sample Rate
  - DMA, Interrupt Driven or Polled Modes
- Internal Timebase/Burst/Rate Generator
- 2 Independent Counter Channels
  - 16/32 bit operation
  - Event Counter and Divider
  - Read Frequency, Period, and Pulsewidth
  - Variable Duty Cycle Generator
- 16 Channels of Digital I/O
- Interfaces to PC Interrupt Levels 2 thru 7
- Compatible with All PCI I/O Modules
- Comprehensive Software is Available
- Termination Panels and Cables Available

DESCRIPTION

The PCI-20098C-1 is a Multifunction Carrier Board that supports a wide range of analog and digital I/O functions. The carrier interfaces directly to the internal bus of any IBM PC/XT/AT type computer. In addition to its onboard I/O capabilities, each carrier has provisions for expansion through the use of PCI modules. The family of modules now supports analog inputs and outputs, digital I/O, counters, trigger/alarm and simultaneous sample and hold functions. Typical applications for this product include: data acquisition, process control, and test systems. Compatibility is insured for a wide variety of analog voltages and currents (thermocouples, RTD's, strain gages, load cells, etc.), as well as digital and pulse signals (switch closures, optical/magnetic pickups, etc.). All options and functions on the board are under software control. No "jumpers" are required. The carrier plugs into an expansion slot of any IBM compatible Personal Computer. Compatibles are available from IBM, AT&T, Olivetti, Zenith, Siemens, Compaq, and PC's Limited, to name just a few. These include the 386-type machines. In addition, the IBM PS/2 model 30 also supports this and all other PCI products. A functional block diagram of the product is shown below.

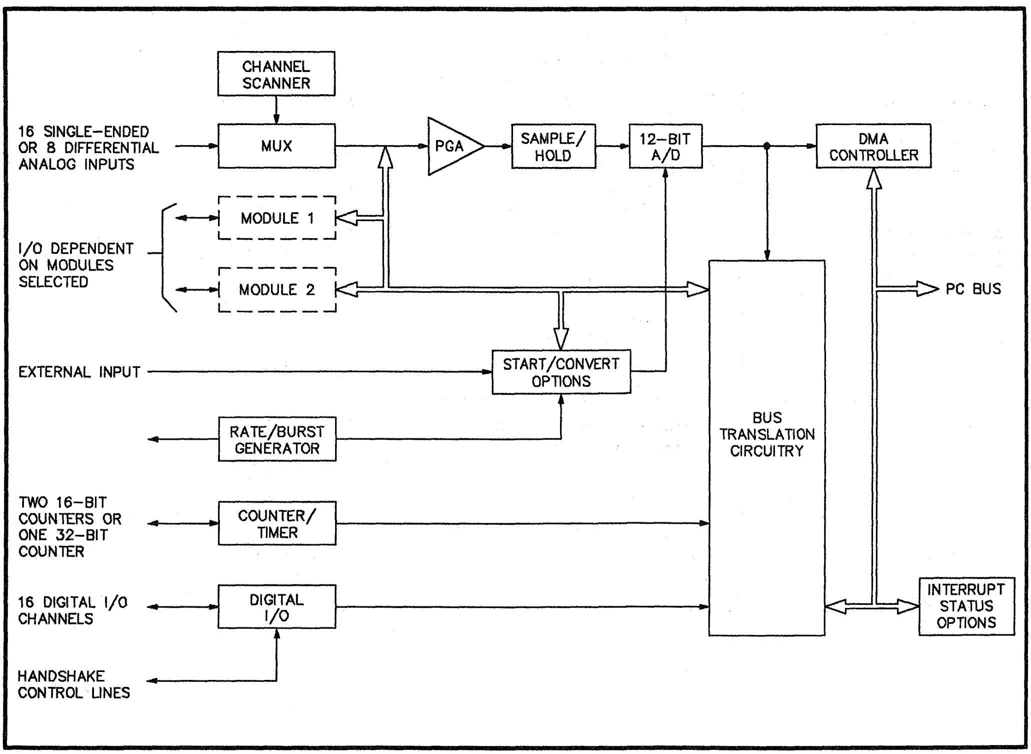
The PCI-20098C-1 performs the necessary signal interface functions required to make input/output data compatible with your personal computer. This includes analog to digital (A/D) conversion. The onboard analog input multiplexer can select from among 16 single-ended or 8 differential channels. This channel count can be expanded in 32 channel increments to a total of 80 channels using optional Expander Modules. Signal scaling and common-mode rejection are provided by a high performance, differential input, programmable gain amplifier. Gains of 1, 10 and 100 are available. The 12-bit A/D converter can be configured for input ranges of ± 5, 0 to 10 or ± 10 Volts full scale. In normal operation, the user has program control over every aspect of the data collection process. For each channel; gain, A/D range, and the choice of single-ended verses differential input are all programmable. A hardware channel scanner enhances high speed and DMA performance. Not only can channels be scanned in any sequence, but each channel can have independent gain settings.

The digital section of the carrier contains the computer bus interface circuitry, 16 channels of digital I/O, a programmable burst/rate generator and 2 general purpose counters. The crystal controlled burst/rate generator is very useful for establishing an accurate and dependable timebase for data acquisition. In addition to generating continuous clock rates in the range of 0.002Hz to 2MHz, the user can program bursts of pulses. Using this feature, a desired number of pulses can be generated with a specified pulse spacing and an independent repetition rate. This innovation makes it easy to perform a maximum-speed acquisition of a group of channels (in order to minimize time skew between channels) while the group is sampled at a slower rate that is independent of the channel-to-channel spacing.

The two 16-bit counters can be used separately or in combination to form a 32-bit counter. Typical operations include event counting and dividing as well as speed, frequency, pulse-width, and period measurement. Also, the counters can be configured to produce a variable duty cycle generator. The counter's separate clock, gate and output connections have independent fully programmable active-high/low states. Input clock rates up to 16MHz are supported.

The 16 channels of TTL compatible digital I/O are arranged in two byte size ports (8 channels each) that can be programmed for either input or output use. In addition, all outputs are buffered and full handshake and interrupt capabilities are supported.

Separate bulkhead connectors are provided for both the analog and the digital signals. This is to insure that digital signals do not contaminate (degrade) the analog inputs. Optional ribbon cables and termination panels are available to help facilitate external connections. These include the PCI-20024T-1 (analog) and the PCI- 20025T-1 (digital) Panels, as well as the PCI-20008A-1 and PCI-20015A- 1 (analog) and the PCI-20009A-1 and PCI-20061A-1 (digital) Cables. Additional information on members of the PCI termination family can be found in this Handbook. All interconnection components are keyed to prevent incorrect assembly.



Block Diagram of the PCI-20098C-1 Multifunction Carrier

Optional software drivers are available offering a wide range of capabilities for several programming languages. These include the PCI-20026S family, along with the PCI-20027S and the PCI-20096S families which offer extended capabilities for BASIC, C, TURBO PASCAL, and Assembler.

Comprehensive documentation covers all aspects of installation, calibration, and programming. Each Carrier is shipped, at no extra charge, with Burr-Brown's innovative SYSCHECK, the system assurance utilities and diagnostics software package. This menu-driven product easily verifies proper installation and utilization of all PCI system components. Not only does the SYSCHECK greatly reduce the time required to confirm appropriate operation but it provides a permanent resource for test and calibration. In addition, the SYSCHECK provides non-programmers with a fundamental way of exercising the input/output capabilities of the system. This can be useful as both a product tutorial and in performing modest test and simulation functions.

SPECIFICATIONS - PCI-20098C-1

All specifications are typical at 25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility	DMA and Program Control	All IBM compatible PC's, including PC, XT, AT, AT&T, Zenith, etc..
Carrier Addressing		Memory Mapped
Size		1K Bytes
I/O Configuration	Compatible with all Input/Output Modules	2 I^3 Bus sockets plus 16 DI/O, 16/8 Ain(SE/Diff), 2 Counters, 1 Rate Generator
Analog Inputs	Expandable with Modules	Fully Programmable
Number of Channels	Single-Ended	16
	Differential	8
Signal Range	Linear Operation	±10V max
	Without Damage, Power On	±35V
	Power Off	±20V
Offset Voltage	Trimmable to 0	±.5 LSB
Drift		±.04 LSB/°C
Common Mode Range	$V_{cm} = CM_{range} - (V_{diff} \cdot Gain)$	±12V
Rejection Error	60Hz, 100 ohm imbalance	
	Gain = 1	.5 LSB
	Gain = 10, 100	.1 LSB
Bias Current		500 pA
Input Impedance		10^{11} @ 75pF
Source Impedance, Max Recommended	For 1 LSB Error	
	At 32kHz Sample Rate	7.5K Ohms
	At 26kHz Sample Rate	10K Ohms
Crosstalk	Channel to Channel @ 1kHz	1 LSB
Nonlinearity	Gain = 1, 10	.5 LSB
	Gain = 100	1 LSB
Gain, Selections	Software Programmable	1, 10, 100
Inaccuracy	Trimmable to 0%	±.5 LSB
Drift		.1 LSB/°C
A/D Converter		Fully Programmable
Resolution	(1 part in 4096)	12-Bits
Code	Unipolar	Binary
	Bipolar	Offset Binary
Ranges		±5, ±10, 0-10V FS

Continued...

PARAMETER	CONDITIONS	SPECIFICATION
Dynamic Performance	12-Bit Accuracy	
Total Throughput		32kHz
Mux Settling Time		5μsec max
S/H Capture Time		6μsec max
A/D Conversion Time		25μsec max
PGA Settling Time	10 Volt Step, Gain = 1, 10	15μsec
	Gain = 100	20μsec
Digital I/O (1)		Fully Programmable
Number of Ports	8 Channels Each	2
Modes		Normal I/O, Strobed
Digital Inputs		
High-Level Voltage	Minimum	2.0V
Low-Level Voltage	Maximum	0.8V
I_{in}, High-level	Maximum	20μa
I_{in}, Low-Level	Maximum	-0.2mA
Digital Outputs(2)		
High-Level Voltage	I_{out} = MAX	2.0V
Low-Level Voltage	I_{out} = MAX	0.5V
Current Source	V_{out} = Low	-15mA
Current Sink	V_{out} = High	24mA
Strobe Outputs (2)	Handshake Lines	
High-Level Voltage	I_{out} = MAX	3.0V
Low-Level Voltage	I_{out} = MAX	0.4V
Current Source	V_{out} = Low	-4 mA
Current Sink	V_{out} = High	4 mA
Strobe Inputs	Handshake Lines	
High-Level Voltage	Minimum	2.0V
Low-Level Voltage	Maximum	0.8V
I_{in}, High-level	Maximum	1 μA
I_{in}, Low-Level	Maximum	-1 μA
Rate Generator	Fully Programmable	
Output Frequency		.002 to 2MHz
Resolution		125 nS
Stability	Crystal Clock	±.01%
Output Modes		Continuous & Burst
High-Level Voltage	I_{out} = MAX	2.0V
Low-Level Voltage	I_{out} = MAX	0.8V
Current Source	V_{out} = Low	-8mA
Current Sink	V_{out} = High	8mA
Counters	Fully Programmable	
Number		1-32 bit or 2-16 bit
Clock Speed	Maximum	16MHz
Functions		Event Counter; Divider; Frequency, Period, and Pulse-width Measurement; Variable Duty Cycle Generator

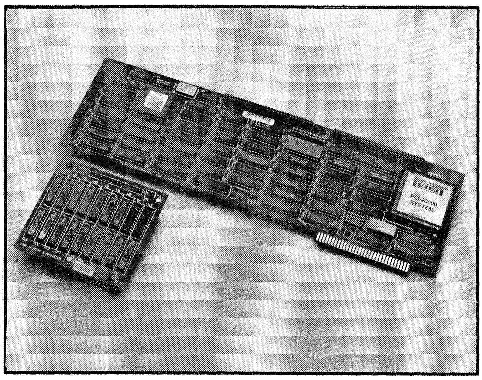
Continued...

PARAMETER	CONDITIONS	SPECIFICATION
Counter Outputs		
High-Level Voltage	I_{out} = MAX	2V
Low-Level Voltage	I_{out} = MAX	.8V
Current Source	V_{out} = Low	-8 mA
Current Sink	V_{out} = High	8 mA
Counter Inputs		Schmitt Trigger
High-Level Voltage	Minimum	1.8V
Low-Level Voltage	Maximum	1.4V
I_{in}, High-level	Maximum	10μa
I_{in}, Low-Level	Maximum	-10μA
Interrupts	Latched	Fully Programmable
PC Levels		2 through 7
Sources		Modules 1, 2 Rate Generator External TTL End of Convert End of Measurement
TTL Inputs	External Interrupts	
High-Level Voltage	Minimum	2.0V
Low-Level Voltage	Maximum	0.8V
I_{in}, High-level	Maximum	10μa
I_{in}, Low-Level	Maximum	-10μA
Power Requirements	From PC's +5V supply	
	No Modules Installed	1.45A
		1.70A Max
	Two Modules Installed	2.5 A
Power Available to Modules	Internal +15 Volt Supply	120mA Min
	Internal -15 Volt Supply	120mA Min
	+5 Volt Bus	Depends upon Host
Physical	Expansion Slot Requirements	1 to 2 Slots (3)
Size	Length x Height	13.35" x 3.9"
Connectors (Mating)	Mounted on Bulkhead	
	Analog	Amphenol #845C026SALA00
	Digital	Amphenol #845C050SALA00
Temperature Range	Board Temperature	0 to 70°C

NOTES: 1) All digital I/O points are programmable as either inputs or outputs in byte size groups (8 channels each).

2) All Digital I/O ports are "Inputs" at power up.

3) The "width" of the PCI-20098C-1 depends upon the combination of I/O and other expansion boards installed in the PC. With no modules, 1 slot is required. In most cases, when 2 modules are installed, 2 slots are required.



BURR-BROWN®

PCI-20202C Series *Smart* Carriers

PCI-20201M Series Memory Modules

DATA PROFESSIONAL BOARDS

FEATURES

- Multi-Channel, High Speed Analog Input and Output Capabilities via the PCI-20000 Family of I/O Modules
- Plugs Directly Inside IBM PC/XT/AT and Compatible PC's
- Based upon the Industry Standard TMS320C25 Processor, offering:
  - Up to 10 MIPS (100nS Instruction Cycle)
  - Comprehensive Software Support
- Both 28MHz and 40MHz models Available
- Up to 96KWords of internal High Speed Memory, Zero Wait State
- DMA Interface to Host PC at 400Kbytes/Sec
- Continuous Data Conversions to/from ALL Available Host Memory
- Serial Port for External connections
- Internal Timebase / Rate Generator
- Programmable from High-Level Languages. Extensive Subroutine Libraries and Hardware Drivers Available
- Menu-Driven FFT Analyzer Software Available
- Suitable as an OEM Component

Complete systems including the PCI-20202C Series are available. See PCI-20207K Series in section 11.

APPLICATIONS

- Data Acquisition & Control
- Audio Synthesis
- Fast Fourier Transforms
- Transient Analysis
- Digital Filtering
- Automotive Testing & Simulation
- Spectral Analysis
- High Speed Machine Control
- Biomedical Signal Analysis
- Vibration Analysis
- Automatic Test Equipment
- Waveform Generation
- Engine Control
- TMS320C25 Software Development

10

DESCRIPTION

The PCI-20202C series consists of high performance "*Smart*" carriers designed for the IBM Personal Computer (PC) bus. It is now possible, at low-cost, to utilize real-time data acquisition and digital signal processing (DSP) techniques in a wide variety of applications. These *Smart* Carrier boards are based upon the highly regarded Texas Instruments TMS320C25 processor. TMS320s are the most widely used, tested and supported processors available. By using this high performance signal processor, we are able to process data at rates 20 to 200 times faster than by using the PC alone. Furthermore, true background processing is provided. When used as an attached processor, both the control of the input/output process (ie., analog-to-digital and digital- to-analog conversion) and the desired mathematical analysis (ie., window, FFT, filter, etc.) can be performed independently of the host PC.

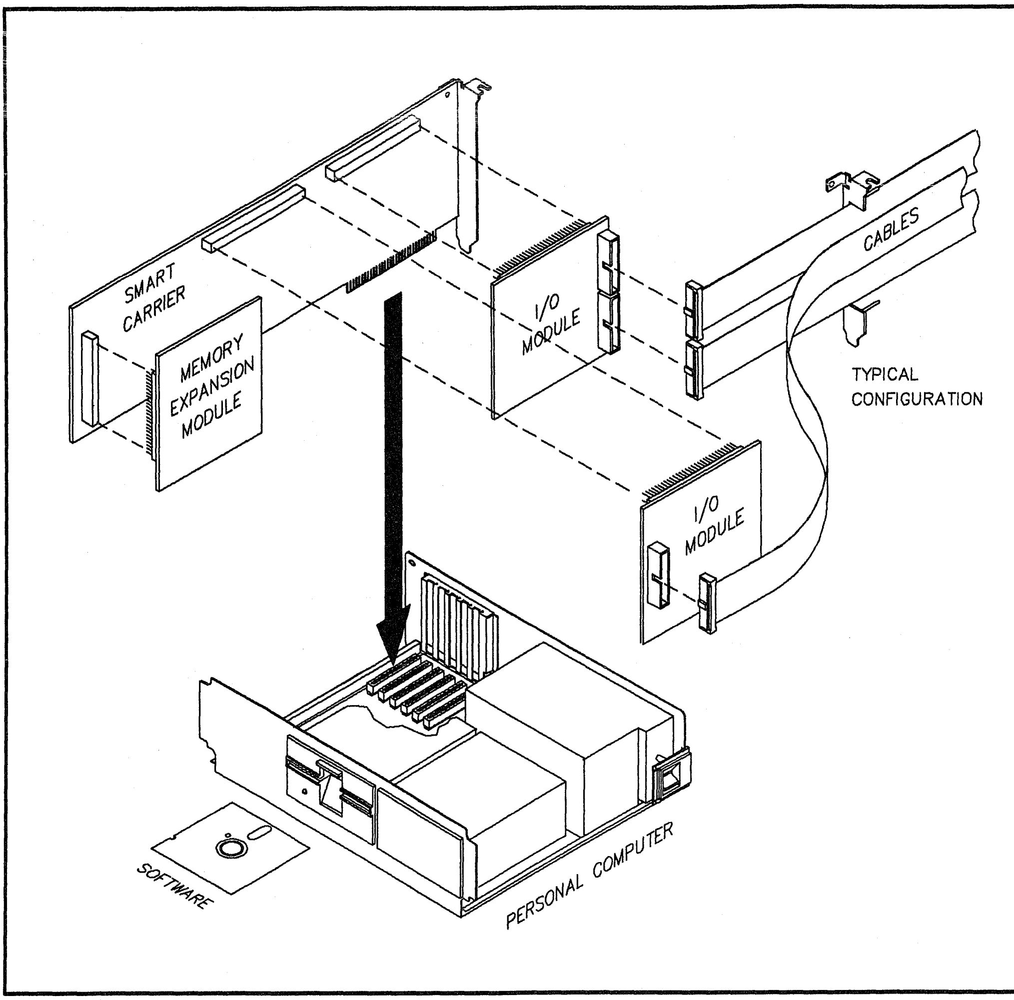


Figure 1. Data Professional System Configuration Example.

The PCI-20202C carrier is available in two versions. Running at 28MHz, the PCI-20202C-1 is optimized for high performance at the lowest possible cost. Its 140nS instruction cycle achieves 7MIPS (Million Instructions Per Second). The PCI-20202C-2 is equipped with 25nS memory and runs at 40MHz. The result is state-of-the-art 10MIPS operation. Both *Smart* carriers utilize a zero wait state memory design insuring the maximum data transfer rate.

The personal computer contributes just the human interface and supervisory functions. For example, the PC downloads programs to the TMS processor, exchanges control parameters, permanently stores data, and displays results. When used as a co-processor, the *Smart* carrier can transfer a data array from the host computer's memory, process the data, and return the result to the PC's memory using direct memory access (DMA). Applying high speed Data Acquisition, Control or DSP techniques has never been easier. The modular hardware supports analog inputs, analog outputs, digital inputs, digital outputs, counters and timers. With appropriate modules, up to 64 digital I/O, 40 analog inputs, or 16 analog outputs can be accommodated on a single board. Powerful software is available to suit a range of applications and user experience levels. For spectrum analysis our exclusive DSPview is menu-driven and ready-to-run. For other applications, complete programming tools are available. These include a comprehensive library of input/output, processing and analysis algorithms that are compatible with popular high-level languages including BASIC, C, TURBO PASCAL and FORTRAN. To program unique or special algorithms there are facilities for generating optimized assembly language

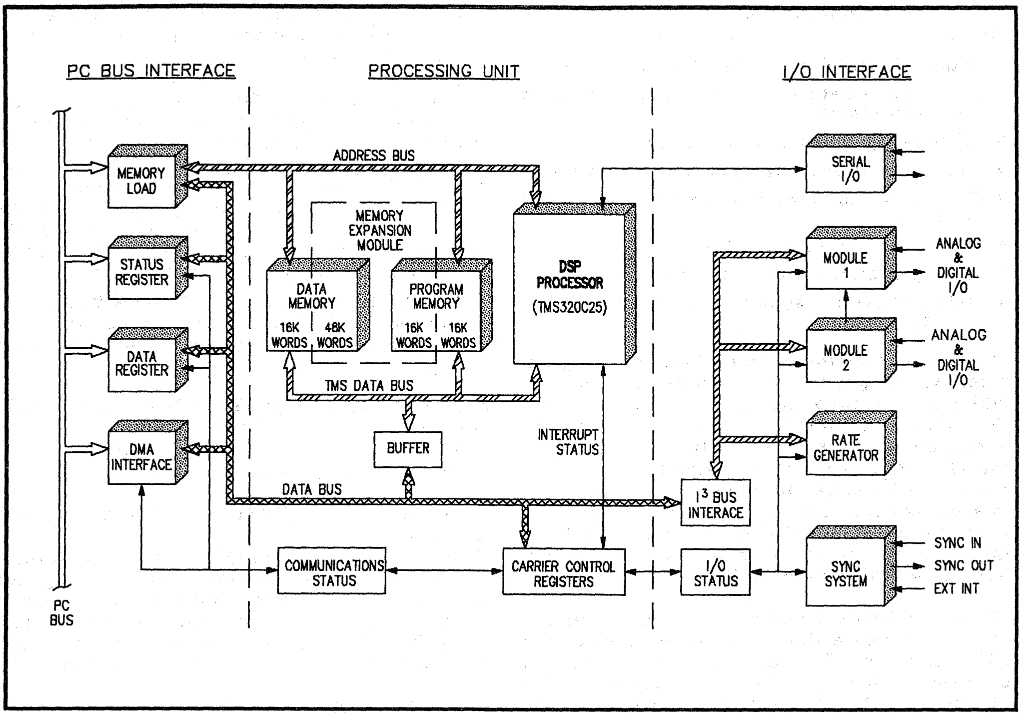


Figure 2. Block Diagram of the *Data Professional* Carrier.

code. Table 2 offers a summary of the appropriate software products now available from Burr-Brown.

DSP or other multiply/accumulate intensive algorithms can greatly benefit from the carrier's high speed capabilities. As an example, here are representative execution speeds using the PCI-20202C-2 *Smart* Carrier:

FFT	64 point	1.3 mSec
	256 point	2.5 mSec
	1024 point	20 mSec
FIR Filter	(80 Taps)	8 uSec

The carrier plugs directly into an expansion slot of any IBM compatible PC. See Figure 1. Each carrier can accept up to three plug-in modules. Two module locations are for input/output functions while the third is for high speed RAM expansion. The RAM modules, the PCI-20201M series, add 64KWords of memory. The PCI-20201M-1 contains 55nS memory to run at 28MHz on the PCI-20202C-1 carrier. The PCI-20201M-2 contains 25nS memory to run at 40MHz on the PCI-20202C-2 carrier. A family of 12 different I/O modules is now available to support a wide variety of real-world signals. Of particular interest are the analog input and output modules that provide 12-bit data conversions at rates up to 180kHz. A summary of the modules appropriate to the *Data Professional* family are given below in Tables 3, 4, and 5. Optional termination panels and ribbon cables are available to help facilitate external connections. The items in Tables 6 and 7 are ideal for most analog and digital input/output applications. All interconnection components are keyed to prevent incorrect assembly.

In addition to the many input/output modules and signal termination components outlined, other accessory products are offered to further enhance the utility of the PCI-20000 system. A summary of these products can be found in Table 8. If desired, more than one PCI-20202C can be installed in the same computer. Compatible computers are manufactured by IBM, AT&T, Olivetti, Zenith, Siemens, Compaq, and PC's Limited, to name just a few. These include the 386-type machines, as well as the IBM PS/2 model 30. A functional block diagram of the PCI-20202C is shown in Figure 2.

Comprehensive documentation is provided for both the *Smart* carriers and the I/O modules, covering all aspects of installation, programming and calibration (I/O modules only). No calibration is ever required for the *Smart* carrier. While complete hardware documentation permits the programmer to communicate at the register level (directly to the individual hardware functions), if desired, high-level programming support is also available. In addition, one of the major advantages of selecting a DSP product based upon the Texas Instruments TMS320C25 processor is the extensive array of available software.

The major building blocks of the *Smart* carrier include:

- Digital Signal Processing Unit, TMS320C25
- High speed data and program memory, with zero wait states
- Memory Up/Down Load circuitry
- Communications interface to the Host PC
- DMA interface between the *Smart* Carrier and Host PC
- High speed serial I/O interface
- Analog/Digital I/O module positions
- Rate generator, synchronization and interrupt system

The carrier itself includes 16KWords of program memory, along with 16KWords of data memory. While this is adequate for most applications, the optional expansion module increases the data memory to the full 64KWords allowed by the TMS processor. At the same time, program memory is extended to 32KWords. All memory is accessed with zero wait states. An up/down load feature allows the PC to read or write to this memory directly. This allows the system to operate without on-board ROM.

The *Smart* Carriers can use the entire memory of the PC for data storage through a high speed DMA interface. This allows for uninterrupted data acquisition up to the limit of available RAM (16MByte in PC/AT and 1MByte in PC/XT computers). Data archiving applications requiring mass memory can also utilize floppy and hard disks. Data is then accessible for a wide range of post-process analysis and display operations.

Coordinated processing is enhanced by the internal, Intelligent Instrumentation Interface (I^3) Bus. This bus supports both analog and digital data flow between module positions, permitting synchronization and triggering of operations on selected events. Data transfers between the modules and the Digital Signal Processing Unit (DSPU) can be synchronized with interrupts, programmed I/O, and a hardware-implemented, wait-mode I/O which automatically synchronizes the processor to the incoming data by inserting wait cycles as needed.

The Rate Generator is very useful for establishing an accurate and dependable timebase for data acquisition. Two 16-bit, divide by n counters are used to scale the crystal clock frequency to a desired frequency. Clock rates in the range of 0.002Hz to 875kHz (1.25 MHz for PCI-20202C-2) can be programmed.

While a full range of analog and digital I/O is supported by the PCI-20000 family of modules, provisions for other interfaces are also provided. A high speed serial port gives the user access to the TMS processor. This can be useful when communicating with a codec, with a serial A/D, or with another *Smart* Carrier for multiprocessor applications. Also, an external trigger input is available for synchronization purposes. All necessary signals are available on a convenient connector. Both 8-bit and 16-bit communications are supported.

The functions of the TMS320C25 processor are controlled through 16 I/O ports on the Carrier. These ports also control any external, real world, input/output signals connected to optional I/O Modules. One or two standard PCI-20000 modules can be plugged into the available I^3 bus module positions. Any of the modules in the comprehensive PCI line can be used. The ports are used as follows:

PORT 0: TSR -- TMS STATUS REGISTER
Controls both the source and enabling of the TMS interrupts. Also enables/disables the on-board pacer clock.

PORT 1: ICM -- INTER-PROCESSOR COMMUNICATIONS REGISTER
Messages are sent to or received from the host computer through this register.

PORT 2: PBIO -- SELECT SOURCE OF BIO SIGNAL
The source of the TMS320C25's signal bit input (BIO) pin can be selected using this register. Potential signals which could be monitored include the IRQ, SYNC or Module Present output of either Module, and communication flags from the ICM register and DMA controller.

PORT 3: PADR -- SELECT I^3 MODULE FOR I/O
Writing to this register selects one of the two module positions. Reading or writing to ports 8-15 accesses the module selected by this register.

PORT 4: PDMA -- READ/WRITE DMA DATA
Data to be transferred to or from the host computer using DMA is written or read here.

PORT 5: TDR -- DMA CONTROL REGISTER
The direction and enabling of DMA is controlled by this register.

PORT 6: PEIR -- EXTERNAL INTERRUPT CLEAR
A write to this register clears the external interrupt.

PORT 7: UNUSED

PORT 8-15: MODULE I/O
Modules are controlled by I/O transfers to and from these ports. The PADR register is used to select the module to be controlled. Reading or writing to Port 8 will access Module offset 0. Reading or writing to Port 9 will access Module offset 1, and so on.

Included with every system is a menu-driven software package which automatically tests the key functions of the carrier.

An advanced communications channel connects the *Smart* Carrier's processing unit (DSPU) to the PC. This allows the DSPU and the host processor to perform independent tasks simultaneously, while providing an effective synchronization mechanism. Furthermore, background routines can be activated on both processors via interrupts. For example, this permits the PC to perform operations such as screen updates without interrupting the data collection process. The communications between the DSPU and the host PC are controlled by three registers:

- The Control and Status Register (CSR)
- The Interprocessor Communications Register (ICM)
- Load Program Address Register (LPA)

CONFIGURATION OUTLINE

The process of "configuring", or defining, the required elements of a system is summarized in the following outline. Tables 2 through 5 provide a concise presentation of the wide range of system options and capabilities. Each configuration is based upon a PCI-20202C series *Smart* carrier. It is recommended that you review the complete specifications for each individual hardware and software product prior to finalizing an actual configuration.

a) Define the application's input/output requirements:

  The number of analog inputs?
  Single-ended or differential?
  Display? etc.

b) Choose the software source (see Table 2)

  DSPview,
  Write your own code using the DSP Library Plus,
  Write your own code using the DSP Development tools,
  Other?

c) Select appropriate I/O modules. See Table 3 thru 5.

d) Select appropriate termination panels, cables, and enclosures. See Tables 6 and 7.

e) Select appropriate accessories (ie., brackets, enclosures, etc.). See Table 8.

For assistance in configuring a system, call our Applications Engineering Group at (602) 624-2434, or call one of the Burr-Brown offices listed in the back of this Handbook.

SOFTWARE SUPPORT

The PCI-20202C *Smart* carriers are supported by a complete set of software products. These packages were designed specifically for these carriers to aid the user in the complete software development cycle. The wide range of tools provides significant capabilities for all application and user levels. See Table 1. The types of products include:

- <u>DSPview</u>. A menu-driven instrument packages, requiring no programming.
- <u>DSP Library Plus</u> that permits extensive analog I/O and analysis while using only a high level language.
- <u>Software Development Pak</u> for custom TMS code generation.
- Family of <u>Hardware Drivers</u> to greatly ease the custom development process.

DSPview (PCI-20205S-1) is an FFT analyzer software package. It provides an introduction to typical applications and capabilities. Because it is menu-driven, DSPview brings a working demonstration of the system's key components to all users. Useful Instruments include:

- Display of a Time Signal and its Spectrum
- Display of a Power Spectrum in a One-shot Waterfall format
- Display of a Power Spectrum in a Running Waterfall format.

An extensive Digital Signal Processing Library, DSP Library Plus (PCI-20203S family), implements 75 functions, all callable from one of several popular high-level languages, including BASIC, C, TURBO PASCAL, and FORTRAN.

IF YOU WANT TO DO:				
No Programming	**High-Level Programming**	**TMS320 Programming**	**Product Name**	**PCI Number**
	Use	Also Suggested	DSP Library Plus*	PCI-20203S Series
		Use	Software Development Pak	PCI-20204S-1
Use			DSPview, FFT Analysis	PCI-20205S-1
		Use	Drivers	PCI-20206S Series
		Use	Macro Assembler	PCI-20208S-1
for Post Analysis only			DADiSP	PCI-20067S-1

*Library includes drivers

Table 1.

```
{ ACQUIRE 1024 ANALOG DATA, COMPUTE THE LOGARITHMIC SPECTRUM
  AND TRANSFER THE DATA TO THE HOST }
{$I c:\dspusl\dspdr_tp.hdr }
{$I c:\dspusl\dsplb_tp.hdr }

VAR

    PSPec: array[0..511] of integer;
    TimeF: array[0..1023] of integer;
    Time, AcqLen: array [0..1] of integer;
    LunIt, Len, Ier, IMod, Dummy, Trig, I: Integer;
    Chan, Gain, ScanMode: Integer;

BEGIN

    LunIt:=0;
    {----------------- RESTART THE DSP CARRIER --------------------------------}
    PCRES(LunIt)
    PCGO(LunIt);

    {------- SET THE A/D CONVERTER TO DESIRED VALUES ------
        SAMPLING FREQUENCY: 10 KHZ, CHANNEL: 0,
        WITHOUT SCAN, GAIN: 1 }

    Time[1]:=0;
    Time[0]:=1000;
    Chan:=0;
    Gain:=1;
    ScanMode:=0;
    SETAD(LunIt, Time[0], Chan, Gain, ScanMode,Ier);
    if (Ier <> 0) then
      Writeln('error in SETAD: ',Ier);

    {-------- ACQUIRE 1024 ANALOG DATA, NO TRIGGER, ------------------}
    { DATA TO STAY IN DSP CARRIER LOCAL MEMORY AND
      TO BE TRANSFERRED TO HOST FOR PRINTOUT }
    AcqLen[1]:=0;
    AcqLen[0]:=1024;
    IMod:=1;
    Trig:=0;
    ADIN(LunIt, TimeF[0] AcqLen[0], IMod, Trig, 0, 0, Ier);

    {---------WEIGHT DATA WITH HANNING WINDOW---------}
    { DATA INPUT AND OUTPUT LOCAL TO CARRIER }
    Len:=1024;
    IMod:=2;
    HANW(LunIt, Dummy, Dummy, Len, IMod, Ier);

    { --------- PERFORM AN FFT OF 1024 REAL VALUED DATA -------------}
    { DATA INPUT AND OUTPUT LOCAL TO THE CARRIER }
    IMod:=2;
    FF512(LunIt, Dummy, Dummy, 1, 1, 1, IMod, Ier);

    { --------- CALCULATE THE LOGARITHMIC POWER SPECTRUM ------}
    { SEND THE DATA BACK TO THE HOST }
    IMod:=1;
    DSPPWR(LunIt, Dummy, PSpec[0], Len, IMod, Ier);

    {---------- PRINT OUT THE POWER SPECTRUM -----------------------}
    Writeln ('Logarithmic Power Spectrum:');
    for I :=0 to 512 do
      WriteLn ('Component ',I,': ', PSpec[I]);

end.
```

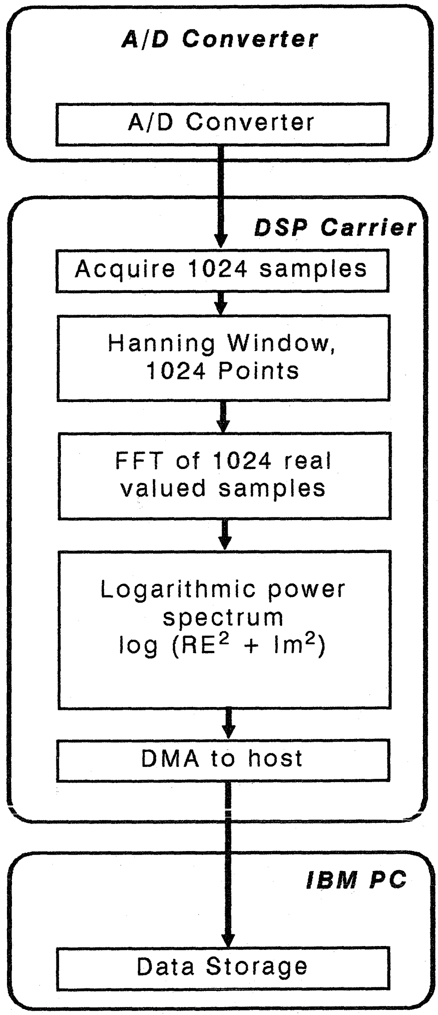


Figure 3. An Example of High-Level Programming using the DSP Library Plus.

This library allows the user to perform the following tasks very quickly:

- Data Acquisition & Control
- Transient Capture
- Digital Filtering
- Spectral Analysis
- Waveform Generation
- Data Compression and Interpolation

Each function is performed with proven algorithms, without having to write any DSP-specific code. No detailed knowledge of the hardware is required, and no TMS320 code need be generated.

The major Library functions include:

- FFT Routines for 64 to 8192 data points
- Windowing Functions
- A/D and D/A Conversion including Triggering
- FIR and IIR Filter Design and Execution
- Auto- and Cross-correlation
- General Vector Operations
- Data Compression and Interpolation

Figure 3 illustrates a typical DSP data acquisition and FFT analysis task. This complete function can be performed using the PCI-20203S DSP Library Plus, without a detailed knowledge of the hardware and without writing any TMS320 Assembly code. In addition to a flowchart, an example of a working program listing is included. This example is shown in Turbo Pascal. Alternatively, BASIC, C, or FORTRAN could be used in a similar fashion.

The DSP Software Development Pak (PCI-20204S-1) is available for those who wish to create their own algorithms. This package operates with the industry standard Microsoft Macro Assembler and includes:

- TMS320C25 Crossassembler
- Linker, Program Loader and Disassembler
- Monitor/Debugger with single-step and breakpoint functions

Companion DSP Carrier Drivers (PCI-20206S family) assist the programmer in communicating with the *Smart* carriers from a high-level language. While they do not perform any DSP functions themselves, they are used to download TMS programs, to transfer data between the carrier and the PC, and to monitor and control many other carrier functions.

A more complete description of the available DSP software can be found in Section 12 of this Handbook.

The Burr-Brown family of Hardware Drivers and Library functions will continue to grow. Please refer to the detailed PCI-20203S data sheet in Section 11 for a listing of those modules that are currently supported by high-level software. However, all of the modules in Tables 3, 4, and 5 are fully compatible with the Data Professional system. I/O modules not listed in the PCI-20203S data sheet require the user to generate appropriate TMS320 code.

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Table 2. Software Products -- Major Functions

Product Name	PCI Number	Menu Driven	H/W Driver	Data Acquisition	Signal Output	Analysis	Graphics	Special Function
DSP Library Plus, BASIC	PCI-20203S-1	No	Yes	Yes	Yes	Yes	No	No
DSP Library Plus, C	PCI-20203S-2	No	Yes	Yes	Yes	Yes	No	No
DSP Library Plus, Turbo Pascal	PCI-20203S-3	No	Yes	Yes	Yes	Yes	No	No
DSP Library Plus, FORTRAN	PCI-20203S-4	No	Yes	Yes	Yes	Yes	No	No
DSP Library Plus, All Languages	PCI-20203S-5	No	Yes	Yes	Yes	Yes	No	No
Software Development Pak	PCI-20204S-1	No	No	Yes	Yes	Yes	No	No
DSPview, FFT Analysis	PCI-20205S-1	Yes	Yes	Yes	No	Yes	Yes	Yes
Drivers, BASIC	PCI-20206S-1	No	Yes	--	--	No	No	Yes
Drivers, C	PCI-20206S-2	No	Yes	--	--	No	No	Yes
Drivers, Turbo Pascal	PCI-20206S-3	No	Yes	--	--	No	No	Yes
Drivers, FORTRAN	PCI-20206S-4	No	Yes	--	--	No	No	Yes
Macro Assembler	PCI-20208S-1	No	No	No	No	No	No	Yes
DADiSP	PCI-20067S-1	Yes	No	No	No	Yes	Yes	Yes

Table 3. Analog Input Modules -- Summary

CONFIGURATION	TOTAL CHANNELS	HARDWARE SPEED	DSP LIBRARY PLUS SPEED
PCI-20002**M**-1 alone	16SE/8Diff	32kHz (single channel)	32 kHz
PCI-20002**M**-1 + PCI-20031**M**-1	48SE/24Diff	32kHz	32 kHz
PCI-20019**M**-1 alone	8	89kHz	89 kHz
PCI-20019**M**-1 + PCI-20031**M**-1	40	89kHz	89 kHz
PCI-20023**M**-1 alone	8	180kHz	180kHz
PCI-20023**M**-1 + PCI-20031**M**-1	40	180kHz	180 kHz

Table 4. Analog Out Modules -- Summary

Module Type	# Chn	Vout	Iout 4-20 mA	Max Speed	Resolution	Linearity
PCI-20003**M**-2	2	Yes	No	120 kHz	12 bits	0.5 LSB
PCI-20003**M**-4	2	Yes	Yes	40 kHz	12 bits	1 LSB
PCI-20006**M**-1	1	Yes	No	120 kHz	16 bits	0.002% FS
PCI-20006**M**-2	2	Yes	No	120 kHz	16 bits	0.002% FS
PCI-20021**M**-1	8	Yes	No	2 kHz	12 bits	0.5 LSB

Table 5. Special Purpose Modules -- Summary

Module Type	Function	# Chn	Special Features
PCI-20004**M**-1	Digital I/O	32	TTL levels, programmable in Bytes (8 bits), buffered outputs
PCI-20007**M**-1	Counter/Timer	5	4 independent counters (8 MHz), 1 programmable clock generator
PCI-20017**M**-1	Simultaneous Sample/Hold	4	Differential inputs, BW=30kHz (G-1), G=1-1000, 20nS Chn-Chn Scatter.

Table 6. Termination Panels -- Summary

Panel Type	Function	Number of Channels	Thermocouples
PCI-20010**T**-1	Analog I/O	16SE/8Diff	No
PCI-20010**T**-2	Analog/T.C.	0SE/7 Diff	Yes
PCI-20011**T**-1	Digital I/O	16	No
PCI-20024**T**-2	Analog I/O	32SE/16 Diff	Yes
PCI-20025**T**-2	Digital I/O	32	No
PCI-20057**T**-1	Analog I/O	48SE/24 Diff	Yes
PCI-20058**T**-1	Digital I/O	48	No

Table 7. Cables - Summary

Cable Type	Analog/ Digital	#Chn	Length	Shield	Mating Modules (PCI-200XX)	Mating Terminations (PCI-200XX)
PCI-20012**A**-1	Analog	16/8	6'(2m)	Yes	2M, 3M, 6M, 17M, 19M, 21M, 23M, 31M	10T, 57T
PCI-20012**A**-2	Analog	16/8	12'(4m)	Yes	2M, 3M, 6M, 17M, 19M, 21M, 23M, 31M	10T, 57T
PCI-20013**A**-1	Digital	16	6'(2m)	Yes	4M, 7M	11T
PCI-20013**A**-2	Digital	16	12'(4m)	Yes	4M, 7M	11T
PCI-20015**A**-1	Analog	16/8	4'(1.3m)		2M, 3M, 6M, 17M, 19M, 21M, 23M, 31M	24T-2
PCI-20032**A**-1	Analog	6	6'(2m)	No	3M, 6M	10T, 57T
PCI-20061**A**-1	Digital	16	6'(2m)	Yes	4M, 7M	58T, 25T-2

Table 8. Accessories -- Summary

Model Number	Description
PCI-20028**A**-3	Strain-Relief Bracket for cables
PCI-20029**A**-1	Enclosure for termination panels, 4 position
PCI-20033**A**-1	Module Extender (useful for Module calibration purposes)
PCI-20055**H**-3	Expansion Enclosure, PC BUS, 7 Slots, 120VAC
PCI-20055**H**-4	Expansion Enclosure, PC BUS, 7 Slots, 240VAC
PCI-20063**A**-1	PC Bus Host Interface Board for use with PCI-20055H Expansion Enclosure

SPECIFICATIONS -- PCI-20202C Series and PCI-20201M Series

All specifications are typical at 25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Board Level		
Compatibility		IBM compatible PC/XT/AT
Functions		I/O and DSP
Addressing	I/O mapped, switchable	8 bytes
Physical Size	Carrier Without Modules	One Slot
	Smart Carrier With Modules	Two Slots
Temperature Range	Board Temperature	0 to 55°C
Power Requirements	From PC supply, +5V	
	Carrier & Memory Module	3 Amps
	Including A_{in} & A_{out}	4.6 Amps
DSP Processor	Texas Instruments	TMS320C25
Speed	PCI-20202C-1	
	Clock Speed	28MHz
	Time/Instruction Cycle	142nSec
	Instructions/Sec	7 million
	PCI-20202C-2	
	Clock Speed	40MHz
	Time/Instruction Cycle	100nSec
	Instructions/Sec	10 million
Memory, On-Board	Zero Wait State	
	On-Carrier, Program Space	16KWords
	Data Space	16KWords
	Including Expansion Module	PCI-20201M-1/-2
	Program Space	32KWords
	Data Space	64KWords
Memory Expansion, External	In the Host PC	Speed Set by PC
	RAM	All Available RAM
	Disk	All Available Disk
DMA, Speed	To/From Host PC RAM	400KBytes/Sec
DMA, Data Space	PC/XT, Available RAM	1MByte
	PC/AT, Available RAM	16MByte
Analog Inputs	Dependent Upon Modules Selected	
Number of Channels		Up to 40
Acquisition Speed		Up to 180kHz
Resolution		12-Bits
Analog Outputs	Dependent Upon Modules Selected	
Number of Channels		Up to 16
Acquisition Speed		Up to 120kHz
Resolution		12- or 16-Bits
Rate Generator	(Timebase Generator)	1 Channel
Output Frequency	Software Programmable	TTL Pulse Output
Equation	$2 \leq n_1, n_2 \leq 65535$	
	PCI-20202C-1	$3.5MHz/(n_1 \cdot n_2)$
	PCI-20202C-2	$5MHz/(n_1 \cdot n_2)$
Frequency Range	PCI-20202C-1	.001Hz to 875kHz
	PCI-20202C-2	.001Hz to 1.2MHz
Output Voltage Levels	Digital High, I_{oh} = max	2.7V min
	Digital Low, I_{ol} = max	0.5V max
Output Current	Capacity, Sink	24mA
	Source	3mA
PC Interrupts	PC Levels 2 thru 7	High/Low Edge

Continued...

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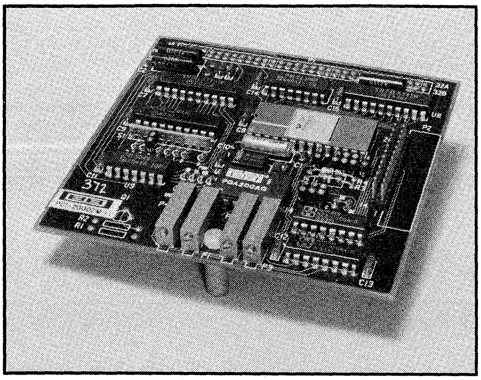
PARAMETER	CONDITIONS	SPECIFICATION
Serial I/O Port	Buffered TMS320C25 Port	
Speed	PCI-20202C-1	3.5Mbaud
	PCI-20202C-2	5Mbaud
External Inputs	Interrupt to TMS	TTL, Deglitched
	Clock Inputs	To Any Module
Software Libraries	BASIC Language	PCI-20203S-1
	C Language	PCI-20203S-2
	TURBO PASCAL Language	PCI-20203S-3
	FORTRAN Language	PCI-20203S-4
	All Four Languages	PCI-20203S-5
Development Pak	Including: Crossassembler, Disassembler and Monitor/ Debugger (RequiresMacro Assembler)	PCI-20204S-1
Macro Assembler	Microsoft	PCI-20208S-1
Hardware Drivers	BASIC Language	PCI-20206S-1
	C Language	PCI-20206S-2
	TURBO PASCAL Language	PCI-20206S-3
	FORTRAN Language	PCI-20206S-4
Menu Driven Analysis	Software	
DSPview	FFT Analyzer Software	PCI-20205S-1
DADiSP	Scientific Spreadsheet	PCI-20067S-1



BURR-BROWN®

PCI-20002M-1 Analog Input Module for General Purpose Use and for Low-Level Inputs

PCI-20033A-1 Extender Board

FEATURES

- 16 single-ended or 8 differential inputs
- 12-bit resolution
- 0.04% linearity error
- Up to 32kHz sample rate
- Compatible with I^3 Bus
- Directly plugs into PCI-20000 Series Carriers
- Suitable as an OEM component

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DESCRIPTION

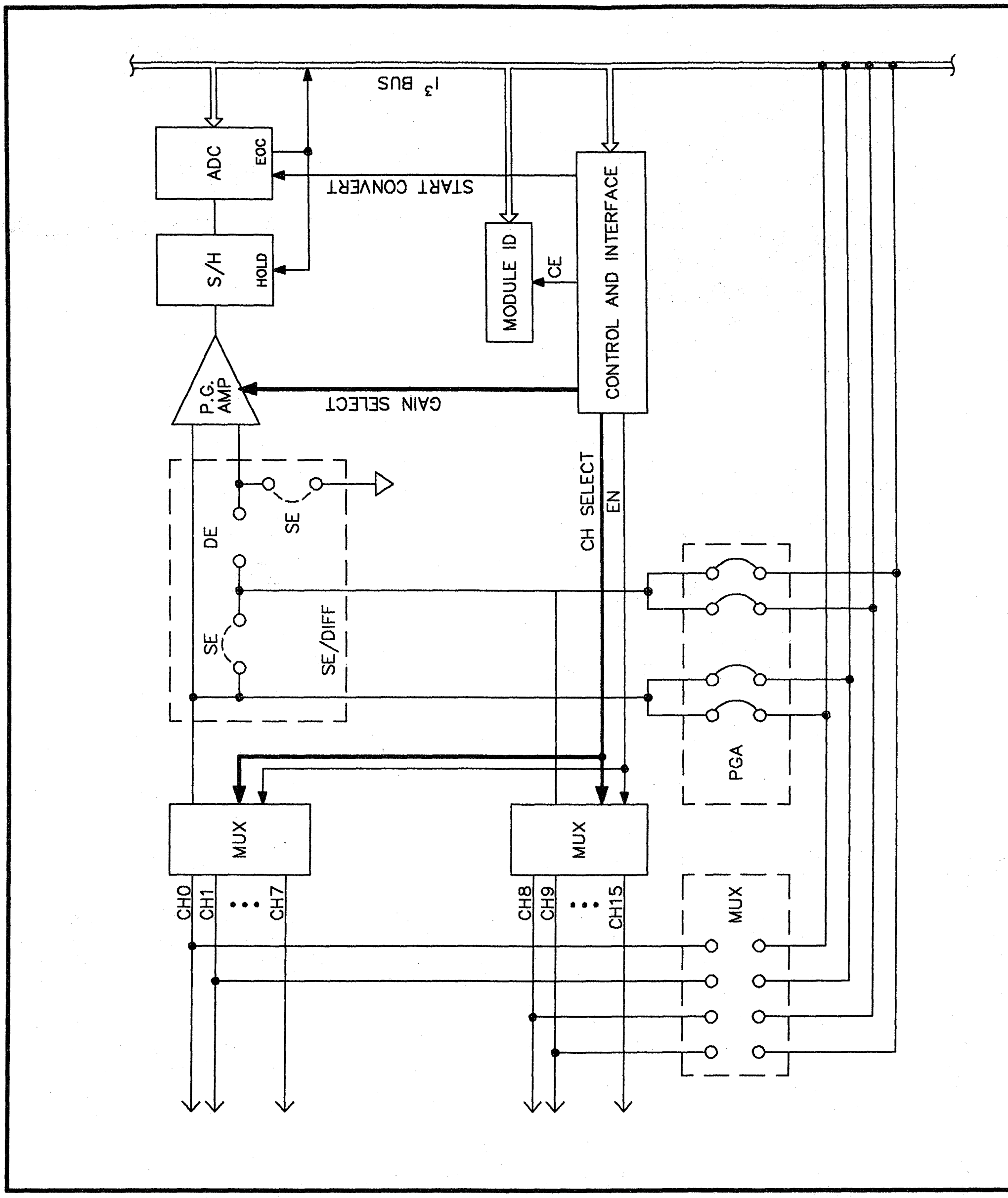
This module accepts a wide range of analog input signals and performs the A/D conversions necessary to make the data compatible with digital computers. Below is a functional block diagram of the module. Input multiplexers select any one of 16 single-ended input channels. Alternatively, the mux can be jumper-programmed for eight differential channels. Additional input channels can be obtained by using the optional PCI-20005M-1 or PCI-20031M-1 Expansion Modules. Each Expansion Module adds 32 single-ended (16 differential) channels. A high-performance, differential input, programmable gain amplifier provides signal scaling and common-mode rejection. Gains of 1, 10, 100 and 1000 are available under software control. The 12-bit A/D converter can be set up for an input range of ±5V, 0 to 10V or ±10V full scale. Input signals are usually connected to external termination panels, and brought to the module via shielded ribbon cable. The PCI-20033A-1 is a module extender board designed to allow easy access to the calibration potentiometers on the PCI-20002M-1 module. The extender board fits between the connectors on the carrier on the module. The PCI-20033A-1 can also be useful with other modules in system troubleshooting situations.

SPECIFICATIONS —PCI-20002M-1

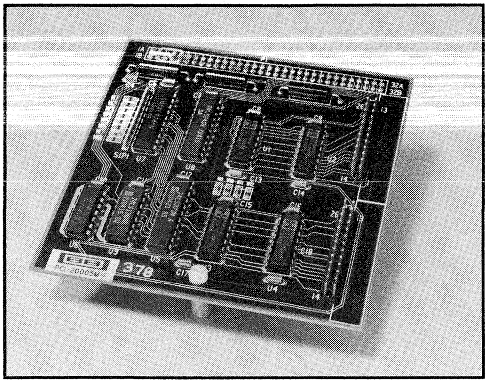
All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility		All PCI-20000 Carriers
I/O Configuration		Analog Input
Number of Channels	Single-ended	16
	Differential	8
Resolution		12-Bits
Code	Unipolar	Binary
	Bipolar	Offset Binary
Input Stage	Programmable Gain Amplifier	G - 1, 10, 100, 1k
Offset Voltage		Trimmable to 0
Offset Drift	RTI: G=1	110ppm/°C
	G=10-1k	20ppm/° C
Common-Mode Rejection (1)	60Hz, 100Ω unbalance:	80dB
	G=1k	96dB
Common-Mode Range		10V, DC + peak AC
Bias Current		30nA
	vs Temperature	0.2nA/ °C
	vs Supply Voltage	0.1nA.V
Offset Current		30nA
	vs Temperature	0.5nA/° C
Linearity Error	G=1, 10	±0.04 (1.6LSB)
	G=100	±0.05 (2LSB)
	G=1000	±0.065% (2.7LSB)
Gain Accuracy		Trimmable to zero
Drift		75ppm/° C
Input Impedance		10GΩ at 40pF
Crosstalk		-60dB
Input Range	Linear	±5, ±10V, 0-10V
	Without Damage	20V above supplies
Conversion Time	Single-Channel	31μs
	Acquisition Time	6μs
	Conversion Time	25μs
	Multi-Channel:	
	G=1, 10	74.5μs
	Acquisition Time	6μs
	Conversion Time	25μs
	Mux Settling Time	3.5μs
	PGA Settling Time	40μs
	G=100	114.5μs
	Acquisition Time	6μs
	Conversion Time	25μs
	Mux Settling Time	3.5μs
	PGA Settling Time	80μs
	G=1000	704.5μs
	Acquisition Time	6μs
	Conversion Time	25μs
	Mux Settling Time	3.5μs
	PGA Settling Time	650μs
Power Requirements (2)	+15V Supply	32mA Max
	-15V Supply	56mA Max
	+5V Supply	200mA Max
Size	Length x Height x Thickness	3.9" x 3.9" x 1.3"
		9.9cm x 9.9cm x 3.3cm
Temperature Range	Module Temperature	0 to 70° C

NOTES:
(1) For a single PCI-20002M module without multiplexers connected through I^3 Bus. Connections to the Bus can reduce CMR. (2) If a module is powered from a PCI-20000 Carrier, the ±15V requirements are satisfied by the internal AC/DC converter, and the equivalent load on the computer's +5V supply will be 730mA, maximum. This takes into account the efficiency of the DC/DC converter.



PCI-20002M-1 Module Block Diagram.



BURR-BROWN®

PCI-20005M-1
Analog Input Expansion Module

FEATURES

- Adds 32 (SE) or 16 (DIFF) channels to existing analog input count
- Can be used as a general-purpose multiplexer
- Inputs protected to ±35V
- Compatible with I^3 Bus
- Directly plugs into PCI-20000 Series Carriers
- Suitable as an OEM component

DESCRIPTION

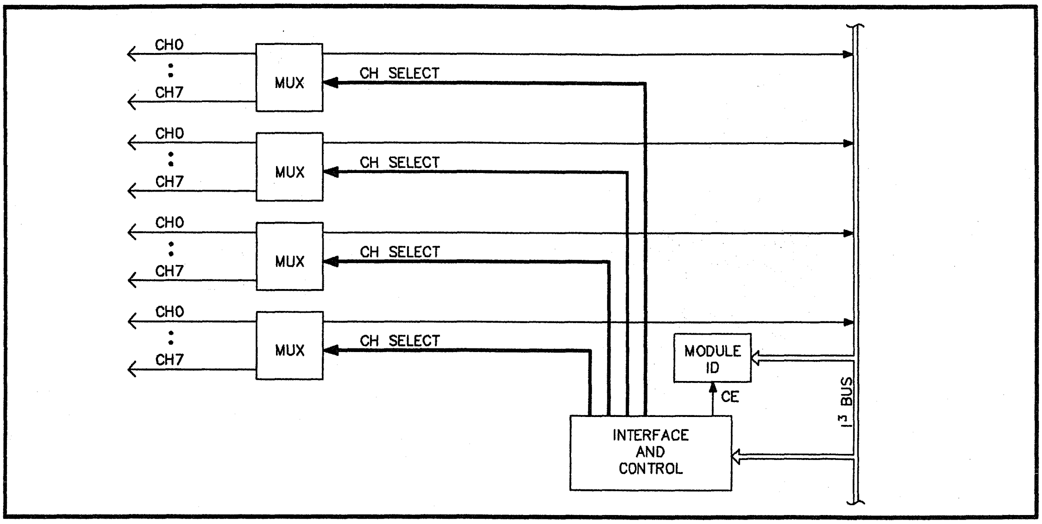
This expansion module is useful in applications that require more analog input channels than can be supported by the PCI-20002M-1 module alone. Please refer to the functional block diagram below. The PCI-20005M-1 consists primarily of software-controlled multiplexers. One of 32 single-ended (SE), or one of 16 differential inputs can be selected for further processing. Configuring the module for SE or differential operation is also under software control.

The chain feature of the I^3 bus makes it possible to connect the output of an expansion module directly to the PGA inputs on the analog input module. This adds additional channels without consuming any of the original analog inputs.

Note that when chaining analog input and analog expansion modules together, both must be configured alike with respect to SE or differential use.

It is appropriate to consider using the expansion module for other, more general, multiplexing applications. As a system building block, one can envision custom requirements, which could even include "fan-out" functions.

Field signals are usually connected to external termination panels, and brought to the expansion module via shielded ribbon cables. Various termination-panel options exist depending on the number of channels required.



PCI-20005M-1 Analog Expansion Module, Functional Block Diagram.

SPECIFICATIONS —PCI-200005M-1

All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility	Primarily designed as an Input Multiplexer for the PCI-20002M-1 A/D Module	All PCI-20000 Carriers
I/O Configuration Number of Channels	 Single-Ended Differential	Analog Expander 32 16
Analog Signal Range	Linear Operation Without Damage	±10V 20V above supply
Input Capacitance(1)	Channel "On": Single-Ended Differential Channel "Off"	100pF 50pF 5pF
"On" Resistance "Off" Isolation	Maximum Frequency = 1kHz, R_S = 1kΩ	1.8kΩ -85dB
Input Leakage	"On" Channel, at +25° C at +70° C "Off" Channel, at +25° C at +70° C	0.1nA 2.5nA 0.03nA 0.7nA
Power Requirements(2)	+15V Supply -15V Supply +5V Supply	20mA max 8mA max 215mA max
Size	Length x Height x Thickness	3.9" x 3.9" x 1.3" 9.9cm x 9.9cm x 3.3cm
Temperature Range	Module Temperature	0 to +70° C

NOTES: (1) For a single PCI-20005M-1 module without regard to "loads" connected through the I^3 Bus. However, in the single- ended mode it is assumed that all four mux outputs are connected together, and in the differential mode two mux outputs are connected together. (2) If a Module is powered from a PCI-20000 Carrier, the ±15V requirements are satisfied by the internal DC/DC converter and the equivalent load on the computer's +5V supply will be 385mA, maximum. This takes into account the efficiency of the DC/DC converter.

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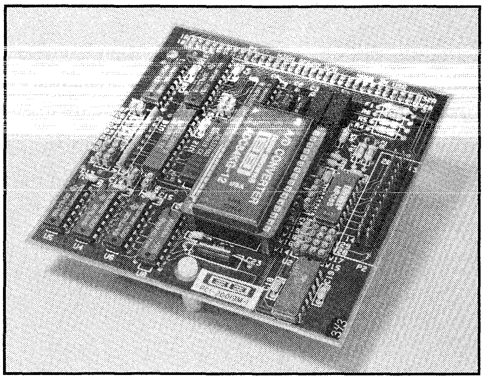


BURR-BROWN®

PCI-20019M-1

High Speed Analog Input Module

FEATURES

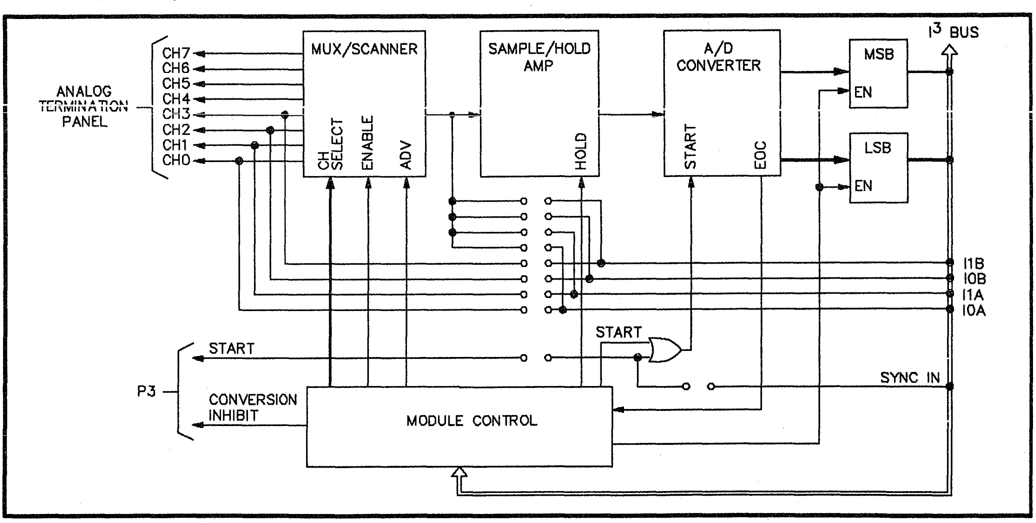
- 89kHz throughput rate
- Eight-channel input
- Hardware and software trigger capability
- Automatic channel advance
- Suitable as an OEM component
- Directly plugs into PCI-20000 Series Carriers

DESCRIPTION

The PCI-20019M-1 is a high-speed, 12-bit data acquisition module. Eight single-ended input channels are provided. This module is intended for high-level signals and does not contain an input amplifier which could reduce its speed. The combination of a high-speed sample/hold and A/D converter provides for input sampling at up to 89,000 channels/second.

The full-scale input range can be jumper-selected for 0 to +5V, 0 to +10V, ±2.5V, ±5V or ±10V. Internal hardware can configure the module to automatically increment channels after each "start convert". This feature greatly reduces the computer's software burden and results in increased speed. Conversions may be started from either an internal or external signal, upon reading the previous conversion, or by software command.

Additional input channels can be obtained by using the optional PCI-20031M-1 Expansion Module. Each expander adds 32 channels. The PCI-20019M-1 is also compatible with the PCI-20017M-1 Simultaneous Sample/Hold Module and with the PCI-20020M-1 Trigger/Alarm Module.



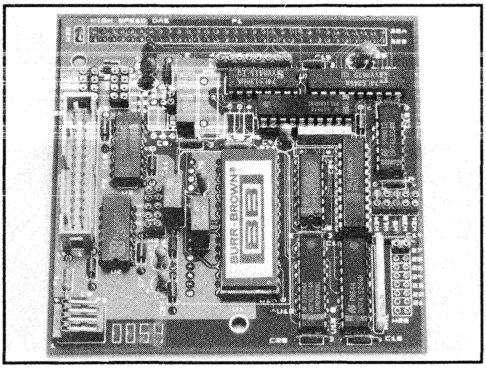
PCI-20019M-1 Module Block Diagram.

SPECIFICATIONS —PCI-20019M-1

All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility		All PCI-20000 Carriers
I/O Configuration		Analog Input
Number of Channels	Single-ended	Eight
Input		
Offset Voltage		Trimmable to zero
Offset Drift	Unipolar	3ppm/°C
	Bipolar	15ppm/°C
Impedance		1MΩ at 35pf
Voltage Range	Linear	±10V
	Without Damage	20V above supplies
Bias Current		100nA
Noise		±1LSB
A/D Converter		
Resolution		12 bits
Code	Uniplar	Complementary Binary
	Bipolar	Complementary Offset Binary
Linearity Error		±0.5LSB
Drift		±3ppm/°C
Gain Accuracy		Trimmable to zero
Drift		±30ppm/°C
Ranges		±2.5V, ±5V, ±10V, 0-5V, 0-10V
Dynamic Response		
Mux Settling Time	Within 0.01%, Maximum	3.5μ s(1)
Conversion Time	A/D, Maximum	10μ s
Aperture Jitter	Sample to hold time Uncertainty	.3ns
Acquisition Time	S/H, Maximum	1.5μ s
Total Convert Time		11.25μ s
Throughput Rate		89k channels/second(2)
Power Requirements(3)	+15V Supply	65mA max
	-15V Supply	50mAmax
	+5V Supply	385mA max
Physical	Length x Height x Thickness	3.9" x 3.9" x 1.3" 9.9cm x 9.9cm x 3.3cm
Temperature Range	Module Temperature	0 to+70°C

NOTES: (1) Normally, mux settling time need not be added to the other components of "total convert time". The software can be arranged so that channel selection (mux transfer) takes place during the A/D conversion cycle (after the S/H captures the signal). The PCI-20046S/47S software drivers perform this task automatically. (2) This speed represents the limits of a single PCI-20019M-1 Module. Please refer to the Speed Summary Table in the Configuration section of this Handbook for further information about throughput under representative conditions. (3) If a Module is powered from a PCI-20000 Carrier, the ±15V requirements are satisfied by the internal DC/DC converter and the equivalent load on the computer's +5V supply will be 1075mA, maximum. This takes into account the efficiency of the DC/DC converter.



BURR-BROWN®

PCI-20023M-1

High Speed Analog Input Module

FEATURES

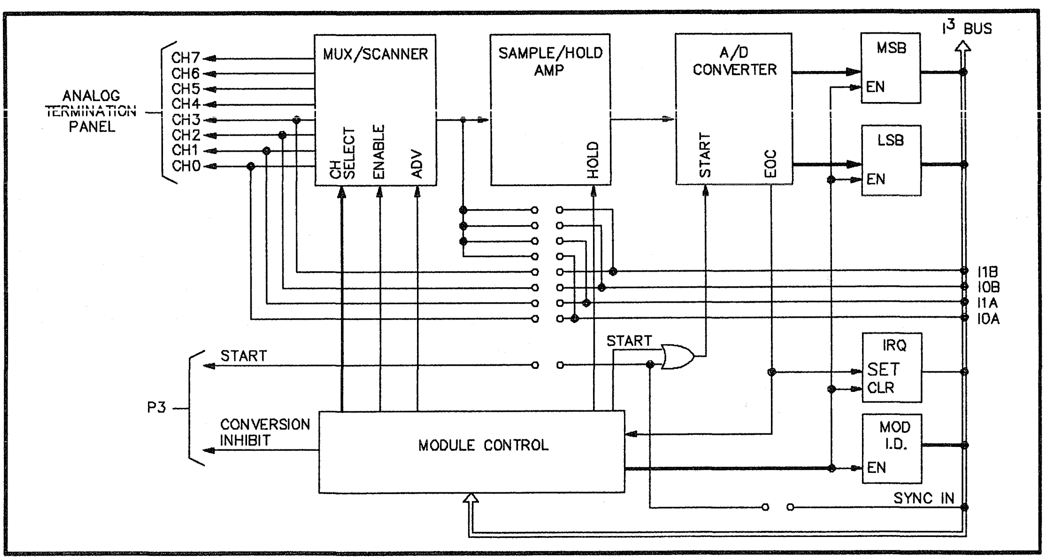
- 180kHz throughout rate in a PC/XT using DMA
- Eight-channel input
- Hardware and software trigger capability
- Automatic channel advance
- Suitable as an OEM component
- Directly plugs into PCI-20000 Series Carriers

DESCRIPTION

The PCI-20023M-1 is a high-speed, 12-bit data acquisition module. Eight single-ended input channels are provided. This module is intended for high-level signals and does not contain an input amplifier which could reduce its speed. The combination of a high-speed sample/hold ad A/D converter provides for input sampling at about 180,000 channels/second.

The full-scale input range can be jumper-selected for 0 to +10V, ±5V, or ±10V. Internal hardware can configure the module to automatically increment channels after each "start convert". This feature greatly reduces the computer's software burden and results in increased speed. Conversions may be started from either an internal or external signal, upon reading the previous conversion, or by software command.

Additional input channels can be obtained by using the optional PCI-20031M-1 Expansion Module. Each expander adds 32 channels. The PCI-20023M-1 is also compatible with the PCI-20017M-1 Simultaneous Sample/Hold Module and with the PCI-20020M-1 Trigger/Alarm Module.



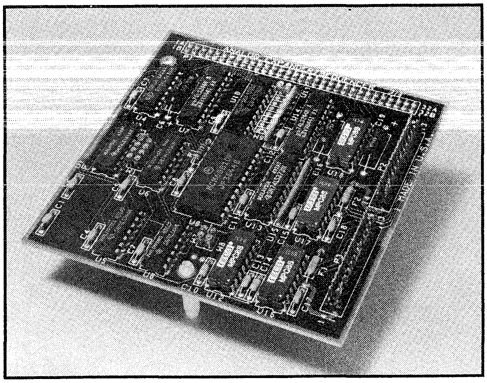
Block Diagram of PCI-20023M-1 Module.

SPECIFICATIONS —PCI-20023M-1

All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility		All PCI-20000 Carriers
I/O Configuration		Analog Input
Number of Channels	Single-ended	Eight
Input		
Offset Voltage		Trimmable to zero
Offset Drift	Unipolar	3ppm/ °C
	Bipolar	15ppm/° C
Impedance		1MΩ @ 35PF
Voltage Range	Linear	± 10V
	Without damage	20V above supplies
Bias Current		100nA typ, 300nA max
Noise		± 1LSB on 5V range
A/D Converter		
Resolution		12 bits
Code	Unipolar	Binary
	Bipolar	Offset binary
Linearity Error		± 0.5LSB
Drift		± 3ppm/ °C
Gain Accuracy		Trimmable to zero ± 1/2LSB
Drift		± 30ppm/° C
Ranges		± 5V, ± 10V, 0-10V
Dynamic Response		
Mux Settling Time	Within 0.01%, max	3.5μ s(1)
Conversion Time	A/D, max	4 μs
Aperture Jitter	Sample to hold time uncertainty	0.3ns
Acquisition Time	S/H, max	1.5μ s
Total Convert Time		5.5μ s
Throughput Rate	In an IBM PC/XT using DMA	180k channels/second
Power Requirements(2)	+15V Supply	42mA max
	-15V Supply	52mA max
	+5V Supply	685mA max
Physical	Length x Height x Thickness	3.9" x 3.9" x 1.3"
		9.9cm x 9.9cm x 3.3cm
Temperature Range	Module temperature	0 to +70° C

NOTES: (1) Normally, mux settling time need not be added to the other components of "total convert time". The software can be arranged so that channel selection (mux transfer) takes place during the A/D conversion cycle (after the S/H captures the signal). The PCI-20046S/47S software drivers perform this task automatically. (2) If a Module is powered from a PCI-20000 Carrier, the ± 15V requirements are satisfied by the internal DC/DC converter and the equivalent load on the computer's +5V supply will be 1250mA, maximum. This takes into account the efficiency of the DC/DC converter.



BURR-BROWN®

PCI-20031M-1

Analog Expander/ Sequencer Module

FEATURES

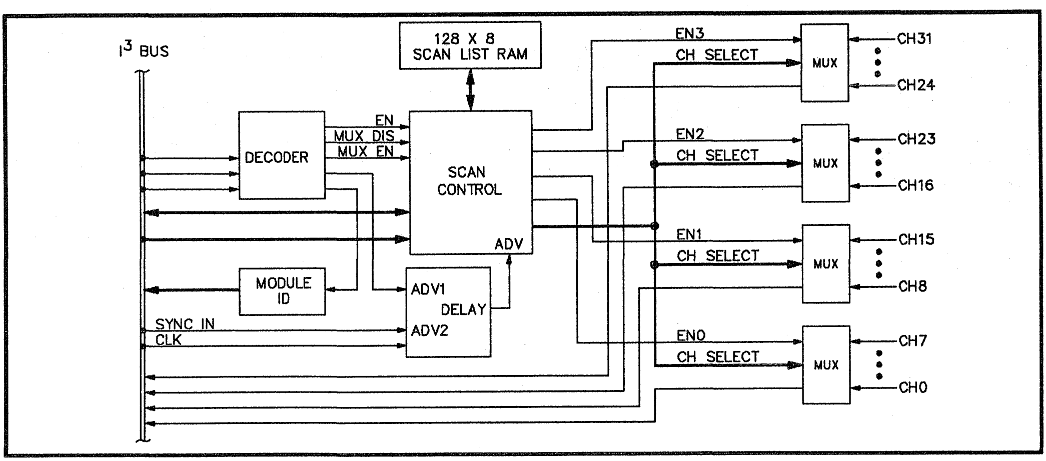
- Adds 32 channels to existing analog input count
- High speed - up to 180kHz scan rate
- Scan list held in on-board memory
- Scan list can contain up to 128 elements
- Inputs protected to ±20V
- Suitable as an OEM component
- Compatible with I^3 bus
- Directly plugs into PCI-20000 Series Carriers

APPLICATIONS

- Digital oscilloscope
- High-speed data logger
- Fast digital voltmeter
- Waveform recording
- Vibration analysis

DESCRIPTION

The Analog Expander/Sequencer Module was designed to complement the PCI-20019M-1 High-Speed Analog Data Acquisition Module in the PCI-20000 System by providing 32 additional multiplexed input channels. The throughput speed is determined by the Data Acquisition Module used. Analog input modules for speeds up to 180 kHz are now available. Please see the Speed Summary Tables earier in Section 10 for more information. The PCI-20031M-1 can also be used with the PCI-20002M-1 to add 32 single- ended or 16 differential input channels.



PCI-20031M-1 Module Block Diagram.

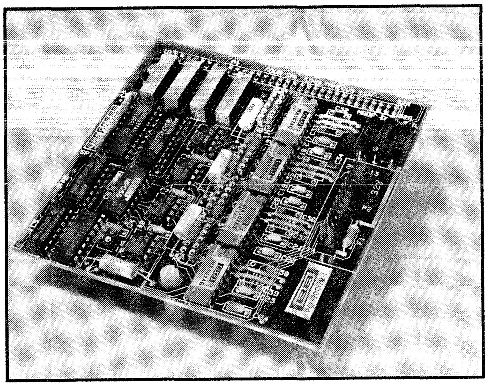
In this respect, the PCI-20031M-1 is similar to the PCI-20005M-1. When used with the PCI-20019M-1, high-speed performance is enhanced by the use of on-board memory to store the desired scan list and hardware to automatically advance through the scan list. This can be accomplished via a software, internal hardware, or external hardware signal (for example, each time an A/D conversion is initiated). This allows scanning to be accomplished without intervention from the host computer. The scan list can store up to 128 elements. The channel sequence specified in the scan list can be in any order desired, and can include duplicate channels. Duplicate channels are extremely useful in cases where a given channel must be sampled at a higher frequency than others.

SPECIFICATIONS—PCI-20031M-1

All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility	Primarily designed as Input Multiplexers for the PCI-20002M/19M/23M A/D Modules	All PCI-20000 Carriers
I/O Configuration		Analog Expander
Number of Channels	Single-ended	32
	Differential (with PCI-20002M)	16
Analog Signal Range	Linear operation	±10V
	Without Damage	20V above supply
Input Capacitance(1)	Channel "On": Single-ended	100pF
	Differential	50pF
	Channel "Off"	5pF
"On" Resistance	Maximum	1.8kΩ
"Off" Isolation	Frequency = 1kHz, R_S = 1kΩ	85dB
Input Leakage	"On"Channel: at 25°C	0.1nA
	at 70°C	2.5nA
	"Off" Channel: at 25°C	.03nA
	at 70°C	0.7nA
Channel List	On-Board RAM, advanced with Sync input or S/W command	
Length		128 Channels
Power Requirements(2)	+15V Supply	8mA max
	-15V Supply	4mA max
	+5V Supply	345mA max
Size	Length x Height x Thickness	3.9" x 3.9" x 1.3" 9.9cm x 9.9cm x 3.3cm
Temperature Range	Module Temperature	0 to +70°C

NOTES: (1) For a single 31M module without regard to "loads" connected through the I^3 Bus. However, in the single-ended mode, it is assumed that all four mux outputs are connected together. In the differential mode, two mux outputs are connected together. (2) If a Module is powered from a PCI-20000 Carrier, the ±15V requirements are satisfied by the internal DC/DC converter and the equivalent load on the computer's +5V supply will be 417mA, maximum. This takes into account the efficiency of the DC/DC converter.



BURR-BROWN®

PCI-20017M-1

Simultaneous Sample/Hold Module

FEATURES

- Measures 4 channels at the same time
- Eliminates time skew between channels
- Individual programmable gain amplifiers on each input
- Provisions for passive signal conditioning
- Compatible with I^3 Bus
- Directly plugs into PCI-20000 Series Carriers
- Suitable as an OEM component

DESCRIPTION

The PCI-20017M-1 is a 4-channel simultaneous sample and hold amplifier module with provisions for passive signal conditioning built-in. A block diagram of the PCI-20017M-1 is shown below. Each of the four simultaneous channels contain a differential programmable-gain amplifier. The S/H outputs are multiplexed to the I^3 bus where connections to an A/D converter are made.

The simultaneous sample/hold module is useful in applications where time-skew among channels must be minimized. Since the module has individual amplifiers for each channel, all 4 inputs can be captured at the same time.

The module actually has 8 inputs. The 4 other channels feed directly into the multiplexer without any signal processing. Thus, these additional inputs can be used to supplement the analog input channels on the A/D converter module.

SPECIFICATIONS—PCI-20017M-1

All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility		All PCI-20000 Carriers
I/O Configuration		Analog Input
Number of Channels	Single-ended, Straight Thru	4
	Differential, Simultaneous	4
Input Stage(1)	Jumper-Programmable Amplifier	G=1, 10, 100, 1K
Offset Voltage		Trimmable to zero
Offset Drift	RT1	($\pm 5\mu V \pm 10\mu V/G$)/°C
Common-Mode Rejection	60Hz, 100Ω unbalanced	
	G = 1	70dB
	G = 10	80dB
	G = 100, 1K	90dB
Common-Mode Range	Linear Response	10V (DC + peak AC)
	Without Damage	15V
Bias Current		±50nA
	vs Temperature	±0.1nA/ C
Nonlinearity	G = 1, 10	±0.03%
	G = 100	±0.05%
	G = 1000	0.1%
Gain Error	G = 1, 10	0.1%
	G = 100	0.25%
	G = 1000	0.75%
Drift	G = 1, 10	10ppm/°C
	G = 100	20ppm/° C
	G = 1000	30ppm/°C
Input Impedance		10GΩ at 20pF
Dynamic Response		
Slew Rate	G = 1 - 10	0.2V/μs
Frequency Response	Small Signal	
	G = 1, ±1%	30kHz
	G = 10, ±1%	3kHz
	G = 100, ±1%	300kHz
	G = 1k, ±1%	30Hz
Settling Time	10V Step, Error<0.01%	
	G = 1	100μs
	G = 10, 100	130μs
	G = 1k	350μs
Sample/Holds		
Acquisition TIme	Error< 0.01%	6μs
Aperture Delay	Maximum	275ns
Aperture Jitter		20ns
Droop Rate		0.03mV/μs
	At 70°C	0.8mV/μs
Hold Step		10mV
Scan Time(2)	Channel to Channel, to 0.01%	
	PCI-20002M-1	35μs
	PCI-20019M-1	15μs
Read Rate(3)	Four-Channel Read including A/D	See Speed Summary Table
Scatter(4)	Channel to Channel	20ns
Power Requirements(5)	+15V Supply	35mA Max
	-15V Supply	35mA Max
	+5V Supply	130mA Max
Size	Length x Height x Thickness	3.9" x 3.9" x 1.3"
		9.9cm x 9.9cm x 3.3cm
Temperature Range	Module Temperature	0 to+70°C

See following page for notes.

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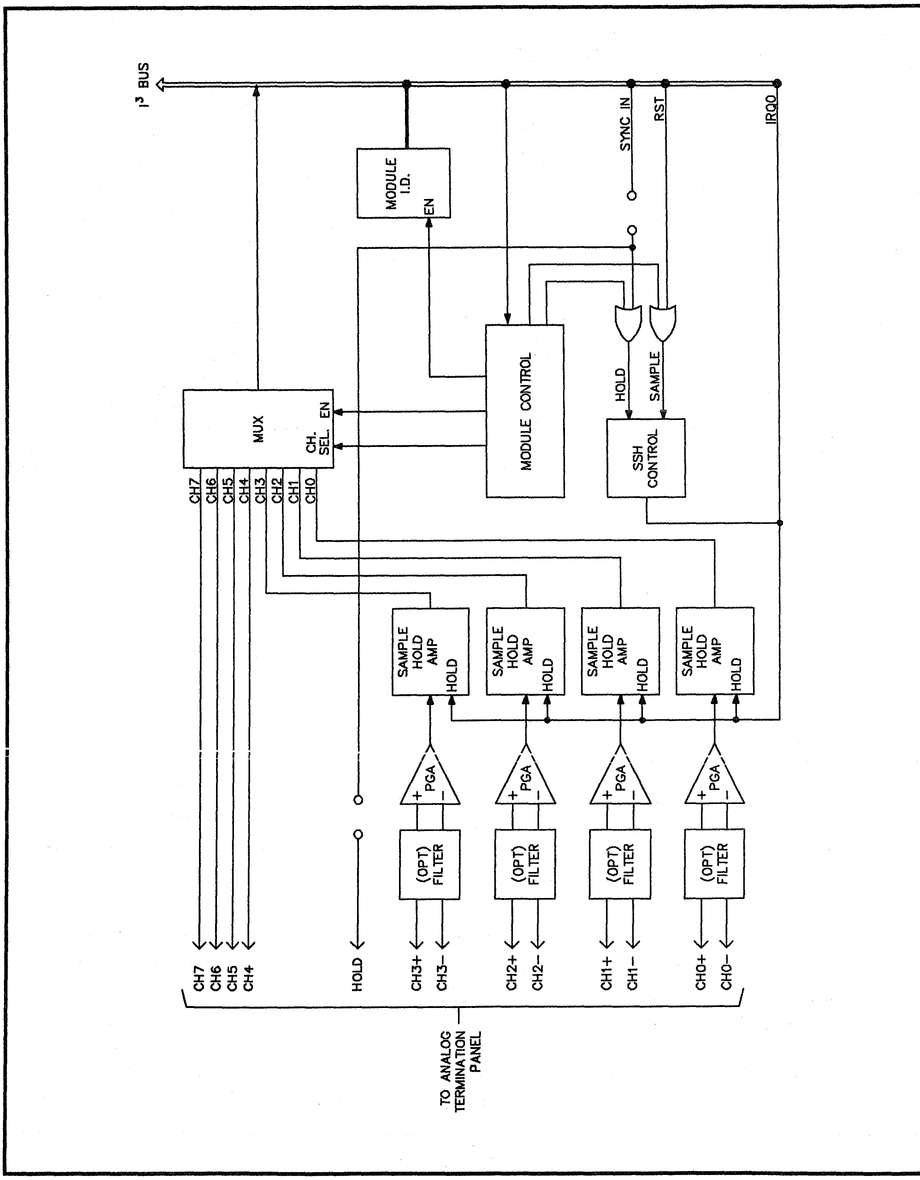
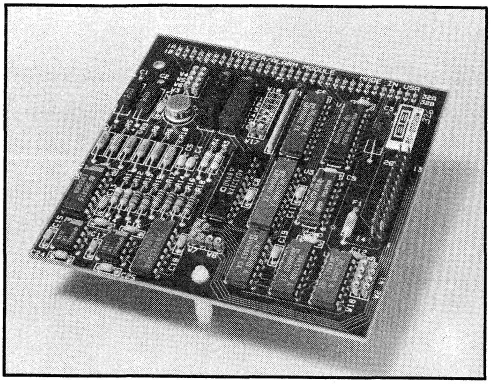
NOTES: (1) This applies to the differential channels only. (2) "Scan time" is defined as the time required to select one of the four S/H channels and to read it with a given A/D converter. (3) "Read Rate" is defined as the rate at which S/H channels can be read using the PCI-20026S/27S High Speed Read, expressed on a per-channel basis. It is assumed that all four channels hold desired data. (4) "Scatter" is defined as the maximum **difference** in time required to capture all S/H channels. It is a measure of the system's "simultaneity". This is the key specification of a simultaneous S/H system. (5) If a Module is powered from a PCI- 20000 Carrier, the ± 15V requirements are satisfied by the internal DC/DC converter and the equivalent load on the computer's +5V supply will be 550mA, maximum. This takes into account the efficiency of the DC/DC converter.



PCI-20017M-1 Four-Channel Simultaneous Sample/Hold Module Block Diagram.



BURR-BROWN®

PCI-20020M-1 Trigger/Alarm Module

FEATURES

- Software programmable limits
- Dual channel
- High, low or window comparisons
- 3.5μsec response time (MAX)
- Directly plugs into PCI-20000 series carriers
- Compatible with I^3 bus
- Suitable as an OEM component

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DESCRIPTION

The PCI-20020M-1 Trigger/Alarm module can monitor 1 or 2 analog channels, and will generate a digital output when pre-programmed conditions are satisfied. A block diagram is shown below. Thresholds in the range of ±10V can be programmed with 8-bit resolution. A trigger can be initiated on one of the following conditions:

Input BELOW limit,
Input ABOVE limit,
Input BETWEEN limits, or
Input OUTSIDE limits.

A pair of D/A converters and comparators are provided to perform the above functions. In the window modes (inputs Between or Outside), both comparators are connected to a single input. In all modes of operation the comparator outputs are combined with logic to produce a single output. The module can be programmed to trigger on true or false conditions. To minimize any oscillations or erroneous triggering, the comparators are designed with approximately 25mV or 1/2LSB of hysteresis. Both of the individual DAC and comparator outputs are available for external use.

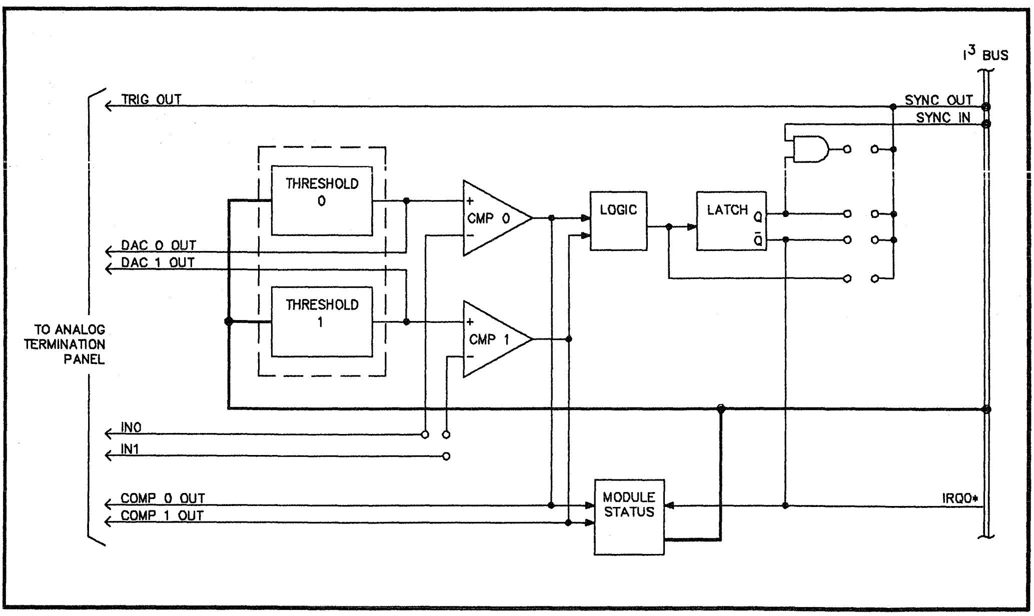
Jumper options select the mode of operation, gating of the digital output and whether or not the output is latched. Once latched, the alarm indication will remain until cleared by software.

SPECIFICATIONS —PCI-20020M-1

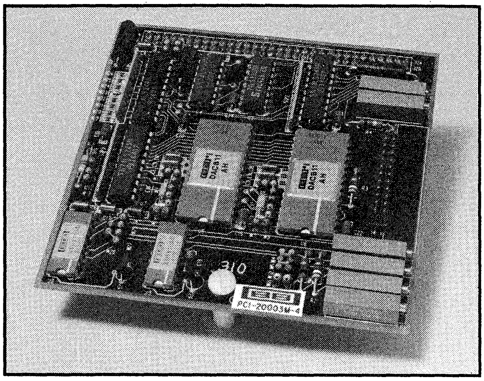
All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility		All PCI-20000 Carriers
I/O Configuration	Analog or Digital Inputs	Trigger/Alarm
Number of Channels	Level Compare	2
	Window Compare	1
Sync Output(1)	Jumper Programmable	Follow/Latched, Gated Sync In
Analog Outputs(1)		Both References and Comparators
Comparators		2
Input Range	Linear	±10V
	Without Damage	±15V
Bias Current		300na
Offset Voltage	Maximum	± 7.5mV
Hysteresis	±10%	25mV
References	D/A Converters	2
Resolution		8 Bits
Step Size	Minimum Increment	78.1mV
Code		Offset Binary
Input Range	Maximum	+9.92V, -10V
Linearity		±1/2LSB
Response Time	Input to Sync Output, Max	3.5µs
Power Requirements(2)	+15V Supply	35mA Max
	-15V Supply	25mA Max
	+5V Supply	265mA Max
Size	Length x Height x Thickness	3.9" x 3.9" x 1.3" 9.9cm x 9.9cm x 3.3cm
Temperature Range	Module Temperature	0 to +70°C

NOTE: (1) When the system is first powered up, the outputs of this module are NOT in determined states until initialized by software. That is, the analog outputs could be any value between ±10V and the digital outputs could be either "high" or "low". (2) If a Module is powered from a PCI-20000 Carrier, the ±15V requirements are satisfied by the internal DC/DC converter and the equivalent load on the computer's +5V supply will be 625mA, maximum. This takes into account the efficiency of the DC/DC converter.



PCI-20020M-1 Module Block Diagram.



BURR-BROWN®

PCI-20003M-2
PCI-20003M-4

12-Bit Analog Output Modules

FEATURES

- 12-bit resolution
- ±1/2LSB linearity error
- 3μs settling time
- Voltage and current outputs available
- Compatible with I^3 Bus
- Directly plugs into PCI-20000 Series Carriers
- Suitable as an OEM component

DESCRIPTION

The PCI-20003M-2 Module accepts digital code from the PC and generates analog output voltages in the range of ±10V. In addition to voltage outputs, the PCI-20003M-4 also has 4 to 20mA current outputs available. Below is a functional block diagram of the PCI-20003M-4. Both the PCI-20003M-2 and -4 modules contain 2 output channels with separate digital-to-analog converters (DACs).

All DACs have 12-bit resolution and can be jumper-programmed for ±5V, 0 to 10V and ±10V full-scale output. In addition, the current output models can be jumper-programmed for either 4 to 20mA or 5 to 25mA.

As is the case with all I/O modules, the I^3 bus can be used to chain the output of these modules to the next module.

Output signals are usually connected to an external termination panel via shielded ribbon cable, where field connections can be easily accommodated. Please see the termination data sheets for further information.

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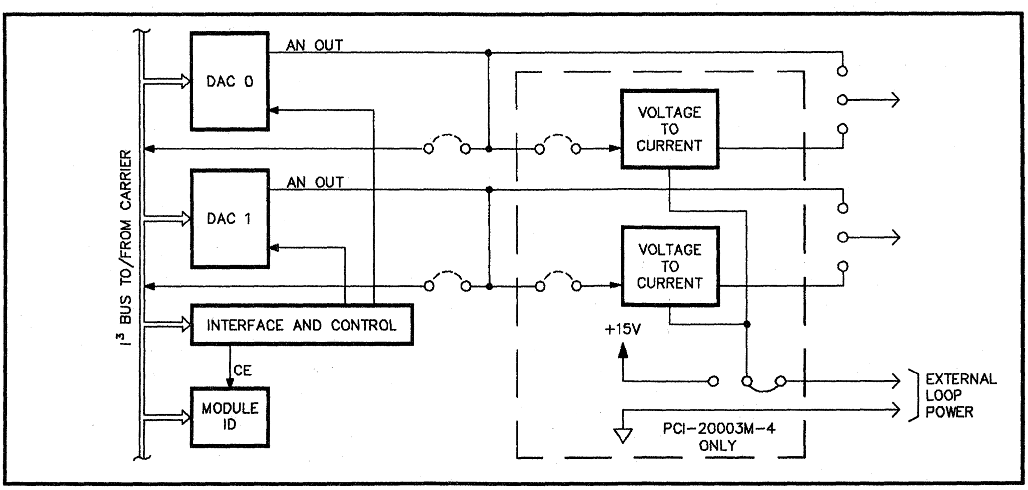


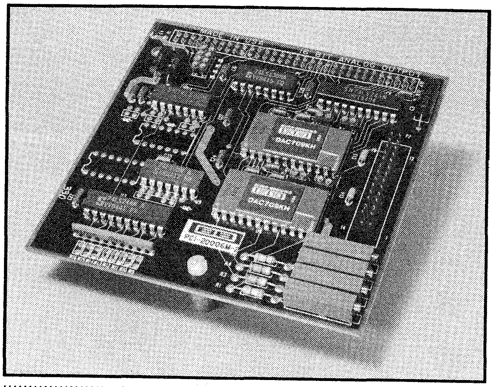
PCI-20003M Module Block Diagram.

SPECIFICATIONS -- PCI-20003M-2, PCI20003M-4

All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility		All PCI-20000 Carriers
Configuration		Analog Output
	PCI-20003M-2	Voltage Only
	PCI-20003M-4	Current or Voltage
Range	Voltage Output	±5V, ±10V, 0-10V
	Current Output	4-20mA, 5-25mA
Number of Channels		2
Resolution		12-Bits
Code	Unipolar	Binary
	Bipolar	Offset Binary
Linearity Error	Voltage Output, Maximum	±0.5LSB
	Current Output	±1.5LSB
Differential	Voltage Output, Maximum	±0.75LSB
Drift	0 to 50°C, Maximum	±0.75LSB
Monotonicity	0 to +50°C	Fully monotonic
Gain Accuracy	Voltage Output	Trimmable to zero
	Current Output	0.6%FSR
Drift	Voltage Output	±30ppm/°C
	Current Output	±80ppm/°C
Output Stage		
Current	Voltage Output	±5mA
Impedance	Voltage Output at DC	0.2Ω
Compliance	Current Output	15V or Loop supply
Settling Time	Voltage Output, with 0.01%	
	20V step	4µs
	10V step	3µs
	Current Output, within 0.1%	18µs
Slew Rate	Voltage Output	8V/µs
	Current Output	1mA/µs
Conversion Rate	See Speed Summary Table	
Power Requirements	Voltage Out or Current Out with External Loop Power	
	+15V Supply	50mA Max
	-15V Supply	70mA(1) Max
	+5V Supply	180mA(2) Max
	Current Out with Internal Loop Supply	
	+15V Supply	100mA(1) Max
	-15V Supply	70mA(1) Max
	+5V Supply	180mA(3) Max
External Loop Power	Two-Channel Current Output	+13.5 to 35V at 60mA
Size	Length x Height x Thickness	3.9" x 3.9" x 1.3" 9.9cm x 9.9cm x 3.3cm
Temperature Range	Module Temperature	0 to +70°C

NOTES: (1) When more than two PCI-20003M Modules are installed on a single Carrier, the required ±15V current may exceed that available. Typically, three modules operating in the Voltage or Externally powered Current Mode will work, but three modules are not guaranteed. (2) If a Module is powered from a PCI-20000 Carrier, the ±15V requirements are satisfied by the internal DC/DC converter and the equivalent load on the computer's +5V supply will be 900mA, maximum. This takes into account the efficiency of the DC/DC converter. (3) If a Module is powered from a PCI-20000 Carrier, the ±15V requirements are satisfied by the internal DC/DC converter and the equivalent load on the computer's +5V supply will be 1200mA, maximum. This takes into account the efficiency of the DC/DC converter.



BURR-BROWN®

PCI-20006M-1
PCI-20006M-2
16-Bit Analog Output Modules

FEATURES

- Compatible with I^3 Bus
- Directly plugs into PCI-20000 Series Carriers
- Suitable as an OEM component
- 16-bit resolution
- ±0.003% linearity error
- 10V/μs slew rate

DESCRIPTION

The PCI-20006M-1 and -2 modules accept digital code from the PC and generate analog output voltages in the range of ±10V. Below is a functional block diagram of the PCI-20006M-2. The PCI-20006M-2 module contains two digital-to-analog converters (DACs). The PCI-20006M-1 has one DAC.

Both DACs have 16-bit resolution and can be jumper-programmed for ±5V, 0 to 10V and ±10V full-scale output.

As is the case with all I/O modules, the I^3 bus can be used to chain the output of these modules to the next module.

Output signals are usually connected to an external termination panel via shielded ribbon cable, where field connections can be easily accommodated. Please see the termination data sheets for more information.

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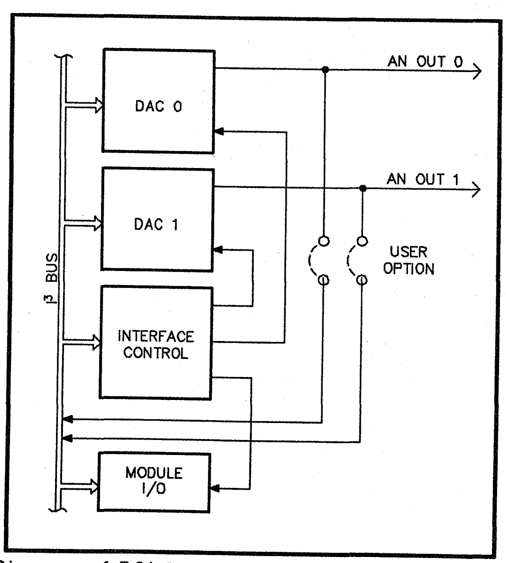


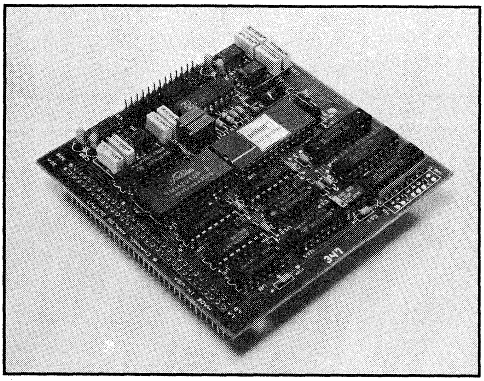
Block Diagram of PCI-20006M 16-Bit Analog Output Module.

SPECIFICATIONS — PCI-20006M-1, PCI-20006M-2

All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility		All PCI-20000 Carriers
Configuration		Analog Output
Range	Voltage Output(1)	±5V, ±10V, 0-10V
Number of Channels	PCI-20006M-1	One
	PCI-20006M-2	Two
Resolution		16-Bits
Code	Unipolar	Binary
	Bipolar	Two's Complement
Linearity Error	At +25° C	±0.002%FSR
	Over Temp. Range	±0.004%FSR
Differential	At +25° C	±0.003%FSR
	Over Temp. Range	±0.006%FSR
Monotonicity	Over Temp. Range	14-Bits
Gain Accuracy		Adjustable to Zero
Drift		±25ppm/°C
Offset		Adjustable to Zero
Drift	Unipolar	±3ppm/°C
	Bipolar	±10ppm/°C
Output Stage:		
Current		±5mA
Impedance	At DC	0.15Ω
Settling Time	To 0.003%FSR, 20kΩ Load Full Scale Step	8μs
Slew Rate		10V/μs
Conversion Rate	See Speed Summary Table	
Power Requirements	Single Channel:	
	+15V Supply	10mA Max
	-15V Supply	30mA max
	+5V Supply	210mA(2) max
	Two Channel:	
	+15V Supply	20mA Max
	-15V Supply	60mA(3) max
	+5V Supply	240mA(4) max
Size	Length x Height x Thickness	3.9" x 3.9" x 1.3" 9.9cm x 9.9cm x 3.3cm
Temperature Range	Module Temperature	0 to + 70° C

NOTES; (1) When the system is first powered up, the outputs of this module are NOT in determined states until initialized by software. That is, the analog outputs could be any value consistent with the hardware jumpers installed. (2) If a single channel module is powered from a PCI-20000 Carrier, the ±15V requirements are satisfied by the internal DC/DC converter and the equivalent load on the computer's +5V supply will be 450mA, maximum. This takes into account the efficiency of the DC/DC converter. (3) When more than two PCI-20006M-2 Modules are installed on a single Carrier, the required ±15V current may exceed that available. Typically, three modules will work, but this is not guaranteed. (4) If a dual-channel module is powered from a PCI-20000 Carrier, the ±15V requirements are satisfied by the internal DC/DC converter and the equivalent load on the computer's +5V supply will be 720mA, maximum. This takes into account the efficiency of the DC/DC converter.



BURR-BROWN®

PCI-20021M-1
8-CHANNEL ANALOG OUTPUT MODULE

FEATURES

- 12-bit resolution
- 1/2LSB linearity
- 500us settling time
- On-board data memory
- Compatible with I^3 bus
- Directly plugs into PCI-20000 series carriers
- Suitable as an OEM component

DESCRIPTION

The PCI-20021M-1 Analog Output Module for the PCI-20000 System generates eight 12-bit voltage outputs. Either a ±5V or a ±10V full-scale range can be selected by the user.

A multiplexed, dynamic refreshing technique is utilized. On-board memory holds the digital equivalents of the desired output voltages, which are consecutively read by a single digital-to- analog converter (DAC). The eight resulting analog signals are then multiplexed into separate sample/hold amplifiers. On-board circuitry automatically scans and converts the data to refresh the output channel values. Each channel can be addressed as if the module contained separate DACs.

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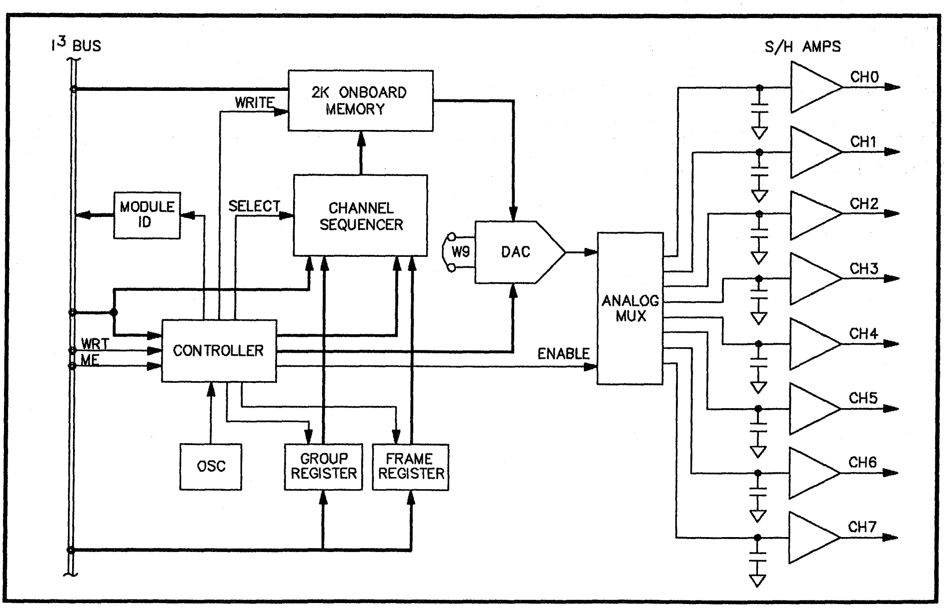
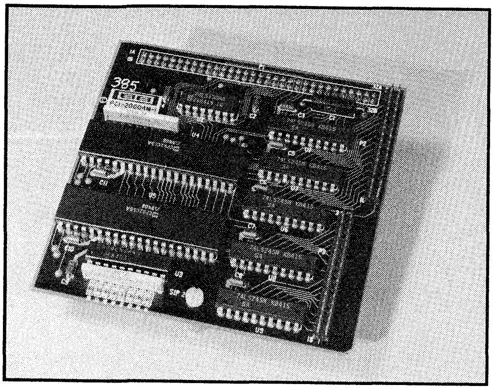


SPECIFICATIONS —PCI-20021M-1

All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility		All PCI-20000 Carriers
Configuration		Analog output
Range	Jumper selectable	±5V, ±10V
Number of Channels		Eight
Resolution		12-bits
Code		Offset binary
RAM Data Buffer	Eight Channels Each Frame	128 frames
Linearity		±1/2LSB
Gain Accuracy		±1/2LSB
Drift		±30ppm/°C
Offset		±2mV
Drift		±15ppm/°C
Output Stage:		
Current		±1mA
Impedance	At 2kHz	1Ω
Settling Time		500μs
Refresh Time	8-Channel Cycle	128μs
Conversion Rate		2kHz
Noise	DC to 10kHz, Maximum	±1LSB
Feedthrough	Channel to Channel	±1LSB
Power Requirements(1)	+15V Supply -15V Supply +5V Supply	43mA max 50mA max 569mA max
Size	Length x Height x Thickness	3.9" x 3.9" x 1.3" 9.9cm x 9.9cm x 3.3cm
Temperature Range	Module Temperature	0 to +70°C

NOTES: (1) If a Module is powered from a PCI-20000 Carrier, the ±15V requirements are satisfied by the internal DC/DC converter and the equivalent load on the computer's +5V supply will be 1127mA, maximum. This takes into account the efficiency of the DC/DC converter.



BURR-BROWN®

PCI-20004M-1
Digital Input/Output Module

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FEATURES

- 32 digital input/output points
- TTL-compatible levels
- Buffered outputs both source and sink current
- Directly compatible with industry standard opto-isolators
- Compatible with I^3 Bus
- Directly plugs into PCI-20000 Series Carriers
- Suitable as an OEM component

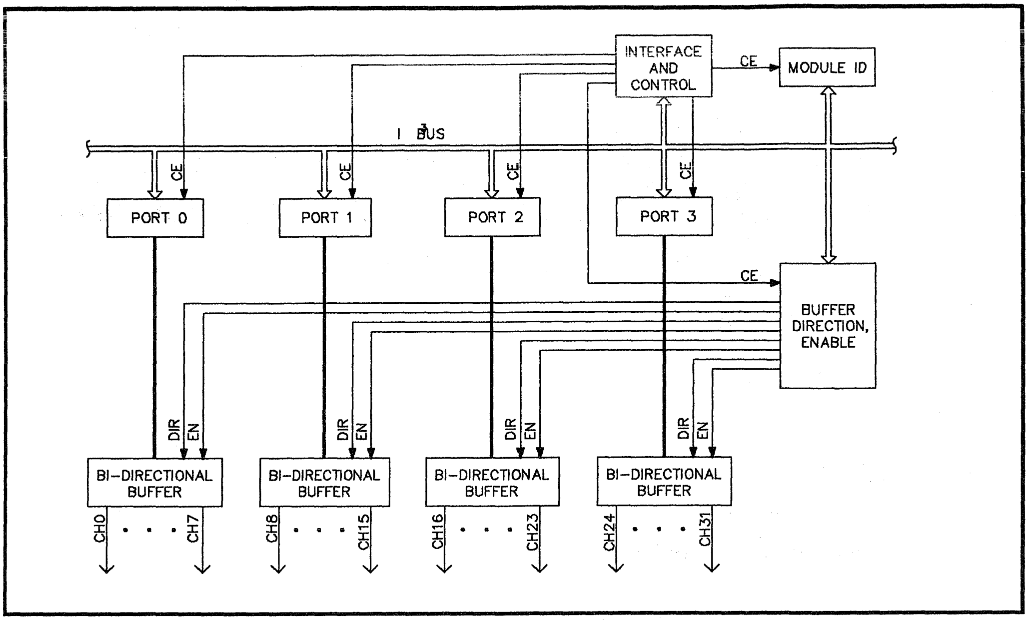
DESCRIPTION

This 32-point module functions with TTL-compatible digital signals. The 32 points are arranged in 4 bytes of 8 bits each. Each byte can, under software control, be selected for either input or output use. All lines are buffered to give full, bipolar, TTL drive capability. A block diagram is shown below.

The module can monitor or control devices having discrete on/off states such as relays, switches, lamps, etc. Through the use of opto-isolators couples (PCI-1100 series), non TTL-signals can also be interfaced. For example, loads such as AC or DC motors can be readily switched and AC line voltage can be detected.

In addition to reading (or writing) bytes, software can extract individual bits or assemble words. In this way, logical combinations can be tested to determine alarm or control conditions.

The field I/O signals are usually connected to external termination panels, and brought to the module via ground-plane ribbon cable. Both conventional and opto-isolated termination panels are suitable for use with all PCI-20000 digital signals. Please see the termination data sheets for more information.



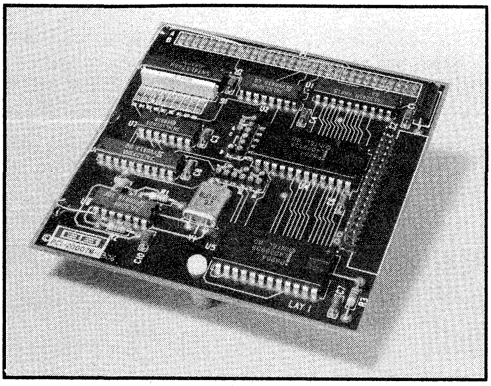
PCI-20004M-1--Digital I/O, Functional Block Diagram.

SPECIFICATIONS —PCI-20004M-1

All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility		All PCI-20000 Carriers
I/O Configuration	Software programmable as Inputs or Outputs by bytes	32 D I/O channels
Digital Inputs:		
High-Level Voltage	Minimum	2V
Low-Level Voltage	Maximum	0.8V
I_{IN}, High-Level	Maximum	20µs
I_{IN}, Low-Level	Maximum	-0.2mA
Input Clamp Level		-1.5V
Digital Outputs:(1)		
High-Level Voltage	I_{out} = Max	2V
Low-Level Voltage	I_{out} = Max	0.5V
Current Source	V_{out} = Low	-15µA
Current Sink	V_{out} = High	24µA
Tri-State Current	V_{out} = 2.7V	10µA
	V_{out} = 0.4V	200µA
Power Requirements	+5V Supply	350mA max
Size	Length x Height x Thickness	3.9" x 3.9" x 1.3" 9.9cm x 9.9cm x 3.3cm
Temperature Range	Module Temperature	0 to 70° C

NOTES: (1) All digital I/O ports are "inputs" at power-up.



BURR-BROWN®

PCI-20007M-1

Counter/Timer/Pulse Generator Module

FEATURES

- Multi-functions
  - Time base generator
  - Pulse generator
  - Event counting, accumulating and decrementing
  - Frequency measurement
- 125ns Resolution
- 0.01% Stability
- Suitable as an OEM component
- Directly plugs into PCI-20000 Series Carriers
- Compatible with I^3 Bus

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DESCRIPTION

This multi-function module can perform a number of important time domain operations. A block diagram of the PCI-20007M-1 is shown below. Software control of the module provides an array of pulse-counting and generation capabilities. Based upon an accurate 8MHz crystal-controlled oscillator, the module is useful in many precision applications. These include time base generation, event counting, accumulation and frequency measurement. The rate generator output can be linked to any other module through the I^3 bus to perform sync or other functions.

In addition to a rate generator, the module has four independent counter/timer blocks. This allows several simultaneous tasks, including multiple input and pulse-generation functions.

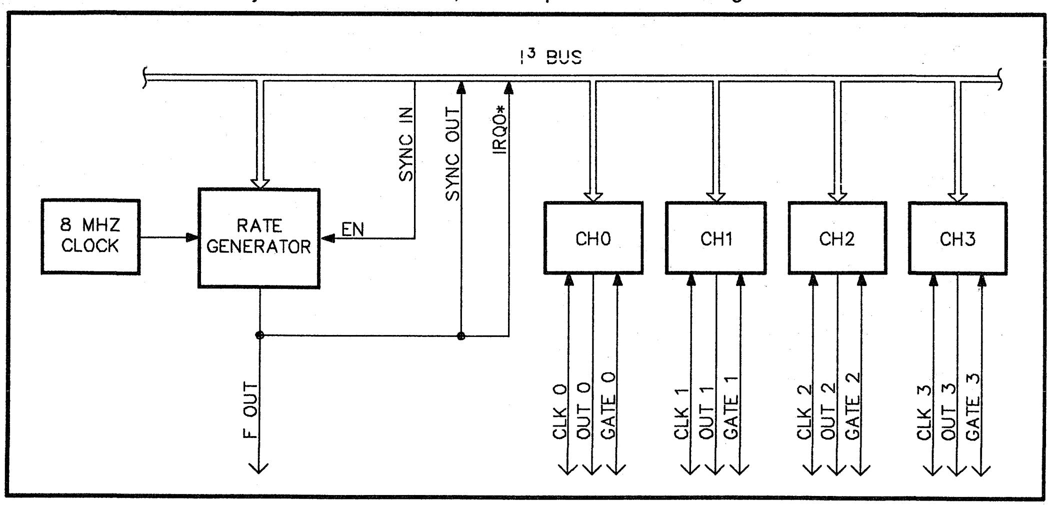
All direct input and output signals are TTL compatible. Where other levels are encountered, some applications can utilize the PCI-1100 series opto-isolators to provide logic-level conversion —for example: AC line voltage switching, or remote I/O situations where ground loop connections must be broken. Field I/O connections are usually made to external termination panels, and brought to the module through ground-plane ribbon cable. The family of standard digital termination panels can be used for counter/timer applications.

SPECIFICATIONS—PCI-20007M-1

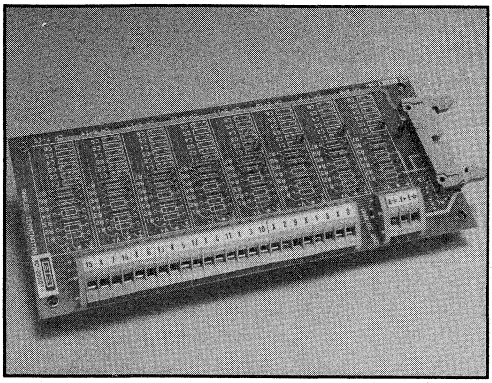
All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility		All PCI-20000 Carriers
I/O Configuration		4 Counters and 1 Rate Generator
Functions	Counters can be preset with start value and reset when read	Count, Accumulate, Divide Measure Frequency
Rate Generator	Pulse and square-wave outputs	
Counter Inputs		
High-Level Voltage	Minimum/Maximum	2V/5.5V
Low-Level Voltage	Minimum/Maximum	-0.5V/0.8V
I_{IN}, High-Level		200μA
I_{IN}, Low-Level		200μA
Range	16-bit counters	1 to 65,535
Sense	Pulse Input	Low-High-Low
Counter Outputs(1)		
High-Level Voltage	I_{out} = MAX, Minimum	2.4V
Low-Level Voltage	I_{out} = MAX, Maximum	0.45V
Current Source	V_{out} = Low	2mA
Current Sink	V_{out} = High	-400μA
Rate Generator(1)		
High-Level Voltage	I_{out} = MAX, Minimum	3.4V
Low-Level Voltage	I_{out} = MAX, Maximum	0.5V
Current Source	V_{out} = Low	8mA
Current Sink	V_{out} = High	-400μA
Frequency	Basic Frequency	8MHz
Range	N_1 and N_2 are 16-bit integers	8MHz/($N_1 \cdot N_2$)
Accuracy	At +25° C	±0.008%
	Over Temp Range	±0.015%
Power Requirements	+5V Supply	470mA Max
Size	Length x Height x Thickness	3.9" x 3.9" x 1.3" 9.9cm x 9.9cm x 3.3cm
Temperature Range	Module Temperature	0 to 70°C

NOTE: (1) When the system is first powered up, the outputs of this module are NOT in determined states until initialized by software. That is, the outputs could be "high" or "low".



PCI-20007M-1 Module Block Diagram



BURR-BROWN®

PCI-20010T Series
PCI-20024T Series
PCI-20057T-1
PCI-20008A-1
PCI-20012A Series
PCI-20015A-1
PCI-20032A-1

Analog Termination Panels and Cables--Passive Units

FEATURES

- Clamp type screw terminals for field wiring connections
- Extensive, passive signal conditioning capabilities
- Thermocouple, cold-junction monitor (except PCI-20010T-1)
- Panels can be used for either input or output functions
- Compatible with all analog PCI and selected VME products
- Cables are flat ribbon with connectors on both ends
- Cables can be used for either input or output (except PCI-20032A-1)
- Suitable as OEM components

DESCRIPTION

The PCI family of analog signal termination components includes both "passive" and "active" units. Passive products are general purpose panels that are not shipped from the factory with amplifiers or isolators installed. However, it is possible, in some cases, for the user to install active circuits on passive panels. Passive panels and their complementary cables are described in this data sheet. Active units are found in the PCI- 20042T-1 data sheet, later in this section. The passive panels include three basic types: **standard, high density,** and **customizer.**

The **standard**, PCI-20010T series termination panels can accommodate up to 16 channels of single-ended analog inputs or outputs, with signal conditioning available on each channel. Differential inputs may be connected by using the single-ended channels in pairs, thus allowing up to eight differential inputs per panel. One ribbon cable connector provides the interface for all 8/16 channels to the DA&C system. The PCI-20010T-2 is intended primarily for thermocouple applications. However, the function of all channels can be intermixed. This panel is factory configured for seven differential connections. Circuitry to monitor the ambient temperature of the screw terminals, for cold-junction compensation purposes, is included. This sensor is wired to channel four. Bias current return resistors for all seven thermocouple channels are installed.

The **high-density**, PCI-20057T-1 termination panel can accommodate up to 48 channels of single-ended analog inputs or outputs, with signal conditioning available on each channel. Differential inputs may be connected by using single-ended channels in pairs, thus allowing up to 24 differential inputs per panel. Each group of 16 single-ended channels is interfaced to the DA&C system with a separate ribbon cable connector (a total of three connectors). The PCI-20057T-1 also has a cold-junction compensation monitor and thus is useful for thermocouple applications. Up to 23 thermocouples can be supported on one PCI-20057T-1 panel. Bias current return resistors are installed on all channels. When input filtering or other types of thermocouple signal conditioning are anticipated, the PCI-20010T-2 or the PCI-20024T series is recommended.

The **standard** and **high-density** termination panel layouts are divided into groups of printed circuit patterns to support user installed passive signal conditioning networks. The layout on the PCI-20010T series accommodates current-to-voltage conversion, voltage dividers, filters, surge and transient suppression, and open thermocouple detection, etc. The PCI-20057T-1 has simpler provisions allowing for single-ended filters and voltage dividers. There are 16 network groups on the PCI-20010T-1 and 48 on the PCI-20057T-1. Each circuit is associated with a set of screw-terminal blocks at the edge of the panel. Field connections are made to the panels via the screw-terminal blocks. There are three screw terminals per pair of I/O channels. The center terminal on the PCI-20057T-1 is ground. On the PCI-20010Ts, the terminal between each I/O pair is jumper-programmable as either a ground or "+V" connection. The ground terminals greatly facilitate single-ended connections, while the +V option eases connections in two-wire transmitter applications (a separate block is provided on the PCI-20010Ts for the connection of an external-excitation or current-loop power supply). The PCI-20010T series and PCI-20057T-1 panels are compatible with PCI-20012A series cables.

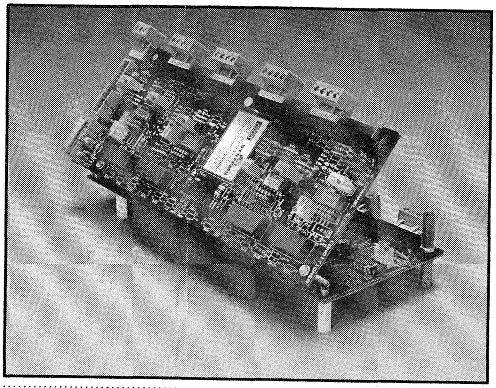
The **customizer**, PCI-20024T series termination panels can accommodate up to 32 channels of single-ended analog inputs or outputs, with signal conditioning available on each channel. Differential inputs may be connected by using single-ended channels in pairs, thus allowing up to 16 differential inputs per panel. A cold-junction compensation (CJC) monitor is included on channel four for thermocouple applications. Up to 15 thermocouples can be supported on one PCI-20024T panel. Bias current return resistors are installed on all channels. Field connections are made to the panels via screw-terminal blocks. There are three screw terminals per pair of I/O channels. The center terminal is ground. In contrast to the other analog panels, the **customizers** have a completely general layout pattern. Virtually any kind of passive or active network can be added to each individual channel . Each group of 16 single-ended channels is interfaced to the DA&C system with a separate ribbon cable connector (a total of two connectors). The PCI-20024T-1 and PCI-20024T-2 have different connector configurations. The -1 model has two dissimilar connectors and is intended for use with the PCI-20098C-1 carrier. One connector is a "high-density" type that mates with the PCI-20008A-1 cable, and plugs into the carrier. The other is a standard 26-pin type that is intended for use with any other analog PCI board or module when mated with the PCI-20015A-1 cable. The -2 model has two identical standard connectors and can be used with any analog I/O module or board except the "on-board" channels of the PCI-20098C-1. Please note that the standard connectors on the PCI-20024T mate only with the PCI-20015A-1.

The CJC network on each of the panels described in this data sheet generates 1mV/°K, ±1°K. The physical size of each panel is 9" X 3.5" X 1.6" (22.9cm X 8.9cm X 4.1cm). Each panel type can be mounted in the PCI-20029A-1 enclosure. An enclosure has room for four panels in a table-top or rack mount configuration. Additional information can be found in the PCI-20029A-1 data sheet.

The PCI-20008A-1, PCI-20012A-1,-2, and the PCI-20015A-1 are fully shielded flat ribbon cables. The PCI-20008A-1 is intended for use with the PCI-20098C-1's analog inputs. The PCI-20012A series and the PCI-20015A-1 cables can be used for either analog inputs or outputs. PCI-20012A cables can be used with the PCI-20010T series or the PCI-20057T-1. PCI-20015A-1 is for use with the standard connectors on the PCI-20024T series only. Shields are important to minimizes both noise pickup and emission. The cables contain 26 wires and are terminated with T&B Ansley (or equivalent) female connectors. PCI-20012A-1 is 6 ft (2m) long, while PCI-20012A-2 is 12 ft (4m) long. Both the PCI-20008A-1 and the PCI-20015A-1 are 4 ft (1.2m) long. All shielded cables have the shield connected at one end only to avoid ground loops. The grounded end is clearly marked. The PCI-20032A-1 is a special-purpose, multi-connector cable intended for analog output use only. It is 6 ft (2m) long and is built with non-shielded flat ribbon cable. One end of the cable is intended to connect to the PCI-20010T-1 or PCI-20057T-1 termination panels ONLY. The other end actually has three connectors that are intended to plug onto three different, one- or two-channel, analog output modules (PCI-20003M-2, PCI-20003M-4, PCI-20006M-1, or PCI-20006M-2). This has the effect of saving space and reducing cost by connecting up to six analog outputs to one termination panel instead of to three.

Various cable and connector manufacturers place marks or codes to indicate the location of wire or pin number 1. When using ANY PCI system, these codes or marks should be IGNORED. The correct wire and pin designations are described in the PCI user manuals. For those who wish to make their own cables, here are the correct matting connectors for the termination panels:

PCI-20010T Series	T&B Ansley #609-2630
PCI-20024T-1, High Density	Amphenol # 845-C026S-ALA00
PCI-20024T-1, Standard	T&B Ansley #609-2630
PCI-20024T-2	T&B Ansley #609-2630
PCI-20057T-1	T&B Ansley #609-2630



BURR-BROWN®

PCI-20042T-1
PCI-20043T-1
PCI-20044T-1
PCI-20045T-1

Active Signal Conditioners Termination Panels

FEATURES

- Isolated models rated for 750V (2500 test)
  - Input-to-Output signal isolation
  - Channel-to-Channel isolation
- Four channels per unit, or eight channels per pair
- Provisions for RTDs, strain gages, etc.
- Current source excitation for bridge type transducers
- Cold-junction compensation for thermocouples
- Selectable gains of 1, 10, 100, 1K or user defined
- Differential, high impedance, instrumentation amplifier inputs
- Stand-alone capability (can be used with other DA&C systems)
- Suitable as OEM components

APPLICATIONS

- Signal Isolation (Isolated Models)
  - Measurement of signals riding on large common-mode potentials
  - Protection against power line contacts
  - Ground loop interruption
- Accurate measurement of low-level voltages in noisy environments
- Transducer signal conditioning
- Biological and physiological measurements

DESCRIPTION

The PCI-20042T-1 thru PCI-20045T-1 series are each four-channel active signal conditioners. On the PCI-20042T-1 and PCI-20043T-1 all input channels are completely isolated from each other and from the main power supply ground. The PCI-20044T-1 and the PCI- 20045T-1 correspond to the former units except that they are NOT isolated. The PCI-20042T-1 and the PCI-20044T-1 are "base" units, while the PCI-20043T-1 and the PCI-20045T-1 are designed to add channels. They are known as "expanders". If needed, one expansion unit can be stacked below one base unit to provide an additional four channels. It is permissible to mix isolated and non-isolated units. Signals (after isolation, if available) from the lower panel connect to the upper panel through a short ribbon cable (included with the expansion unit). All eight signals are then available at a ribbon cable connector on the upper assembly (single-ended, referenced to output ground). The conditioned signals can be connected to the PCI-20000 system through the PCI-20012A series cables. PCI-20042T-1 thru PCI-20045T-1 can also be used with other, independent, measurement systems.

Each input channel is independently amplified by a true differential-input instrumentation amplifier. The low noise, excellent DC stability, and low nonlinearity preserve the integrity of low-level signals. The differential input of this amplifier provides excellent rejection of extraneous common-mode voltages that may exist with respect to the input reference (ground) points. These features can be critical in many applications. On the isolated panels, the individually amplified input signals are passed to separate high-performance isolation amplifiers which translate the input signals so that they are referenced to the output ground. Any input common-mode voltages that exist with respect to output ground are rejected by the isolation barrier. This allows the interruption of ground loops that would otherwise lead to serious system errors. Isolation permits the measurement of small signals in the presence of large common-mode voltages, while protecting other connected instrumentation from such voltages.

of small signals in the presence of large common-mode voltages, while protecting other connected instrumentation from such voltages.

These panels can accommodate input signals from transducers such as thermocouples, RTDs, and strain gages. In addition to amplification and isolation (on PCI-20042T-1 and PCI-20043T-1), the panels have provisions for specialized types of signal conditioning. An on-board cold-junction compensation network allows any mixture of thermocouple types. For bridge configurations, each channel includes a constant current source for bridge excitation and mounting locations for user-installed bridge completion resistors. Other locations allow for user-installed components that permit the incorporation of one or two poles of filtering, voltage dividers, input protection, etc.

On-board calibration potentiometers allow the user to null input offsets and adjust gain and excitation currents if required.

Input power for each of the signal conditioning panels comes from an external ±15VDC supply. Both the PCI-20042T-1 and the PCI- 20043T-1 include a DC-to-DC Converter (power supply) which provides isolated DC power for the four channels of amplification and signal conditioning on each panel.

The PCI-20038A series power supply is recommended for powering the panels. Up to eight each of the PCI-20042T and PCI-20043T (64 isolated channels), or up to 24 each of the PCI-20044T-1 and PCI-20045T-1 (192 channels) can be powered by one supply.

Each panel measures 9" X 3.5" X 1.4" (22.9cm X 8.9cm X 3.6cm). The PCI-20029A-1 enclosure is available to house these panels in a table-top or rack-mount environment. Each enclosure will house up to 32 conditioned channels provided by four pairs of panels.

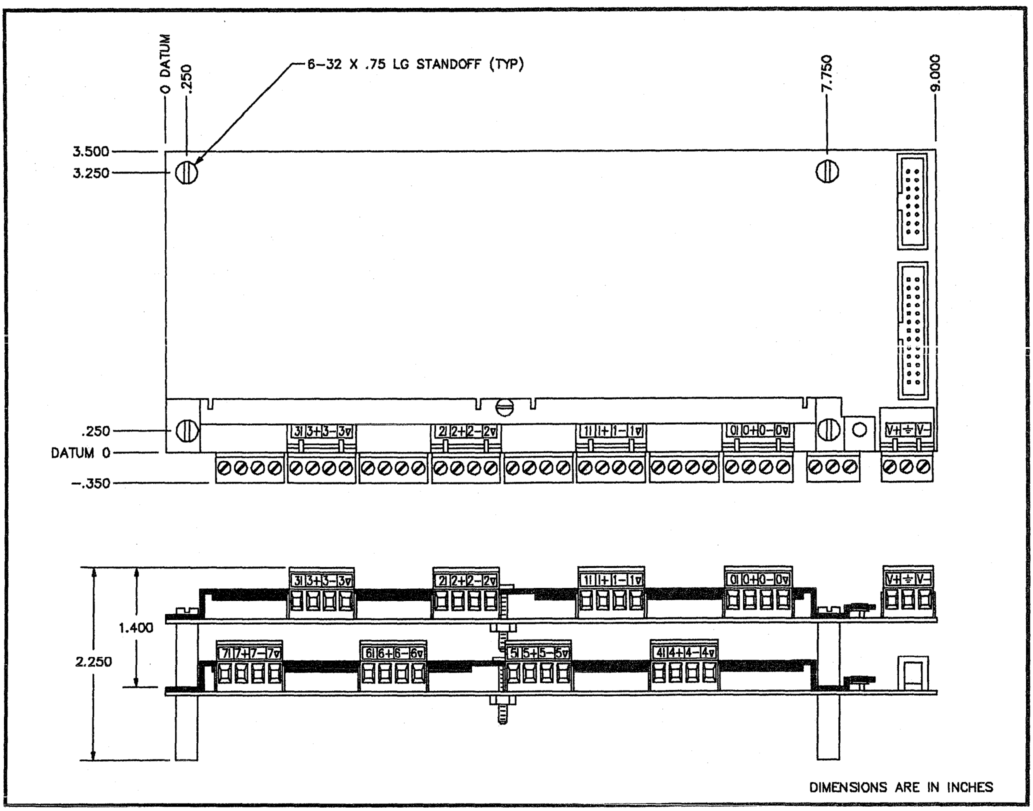


FIGURE 1. Base and expander unit dimensions and mounting details.

SPECIFICATIONS--PCI20042T-1, PCI-20043T-1, PCI-20044T-1, PCI-20045T-1

All specifications are typical at +25°C unless otherwise noted.

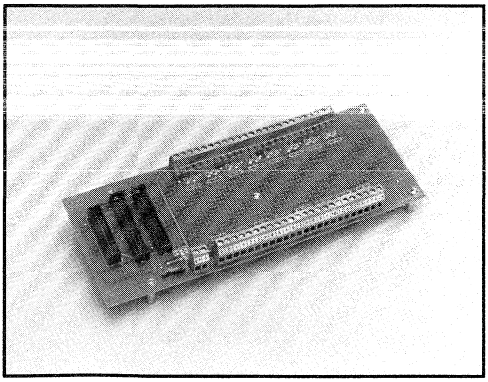
PARAMETER	CONDITIONS	SPECIFICATION
Number of Channels	Base or Expansion Unit	4
	Base plus Expansion Unit	8
Input Stage		
Gain	Jumper Programmable[1]	G=1,10,100,1K
User,	Defined via R_G, G_A=1 or 10	G=1 to 1K
Equation[2]	Isolated	$1+[40K/(R_G+40)]G_A$
	Non-Isolated	$1+[40K/(R_G+40)]$
Accuracy	Equation	±20%
Accuracy	Fixed Gains	±.05%
Linearity, Isolated	G = 1, 10	±0.083% FS
	G = 100	±0.083% FS
	G = 1000	±0.96% FS
Non-Isolated	G = 1, 10	±0.05% FS
	G = 100	±0.15% FS
	G = 1000	±0.05% FS
Offset Voltage		±1mV
Drift, Isolated	RTI	1mV/°C max
Non-Isolated		7uV/°C
Common-Mode, Rejection	60Hz, 1K unbalanced	
	G = 1	80dB
	G = 10 to 1000	96dB
Range	DC + Peak AC	10V
Bias Current		6nA
Input Impedance		100Meg @ 15pF
Crosstalk	Channel-to-channel	-100dB
Output Stage		
Offset Voltage	RTO, Isolated Models Only	±1mV
Drift	RTO, Isolated Models Only	±.5mV/°C
Current		1mA
Frequency Response	Full Scale, 1% Flatness	
Bandwidth		
Isolated	G = 1, 10, 100	100Hz
	G = 1000	30Hz
Non-Isolated	G = 1	30kHz
	G = 10	3kHz
	G = 100	300Hz
	G = 1000	30Hz
Slew Rate		.15V/us
Settling Time		
Isolated	All Gains	.002S
Non-Isolated	G = 1, 10	60uS
	G = 100	500uS
	G = 1000	4500uS
Isolation Ratings		
Voltage	Continuous, DC+Peak AC	750V
	Test, 10 Seconds	2500V
Leakage Current	240Vrms, 60Hz	1uA
Isolation Mode Rejection	60Hz, G=1000	127dB
Excitation Current	For Resistive Loads	
Adjustment Range		1.1mA to 2mA
Factory Setting		1.4mA ±2uA
Compliance		14V
Cold-Junction Sensor	Thermocouple Compensation	
Scale Factor		10mV/°K, ±1°K
Power Requirements	±15V	
Isolated	Base Unit	+110mA
	Expander Unit	-110mA
	Base plus Expander (Total)	±110mA
Non-Isolated	Each Unit	±20mA
Temperature Range	Board Temperature	0 to 70°C

NOTES: (1) Overall gains of 1 to 1K are produced by combinations of first- and second-stage gains of 1, 10, 100 and 1 and 10 respectively. (2) G_A is the second-stage gain (isolation amplifier).

BURR-BROWN®

PCI-20011T-1
PCI-20025T Series
PCI-20058T-1
PCI-20009A-1
PCI-20013A Series
PCI-20036A-1
PCI-20061A-1

Digital Termination Panels and Cables--Passive Units



FEATURES

- Clamp-type screw terminals for field wiring connections
- Passive signal conditioning capabilities
- Can be used for either input or output functions
- Compatible with all digital PCI products
- Cables are shielded, ground-plane type
- Suitable as an OEM component

DESCRIPTION

The PCI family of digital signal termination components includes both "passive" and "active" panels. Passive products are general purpose units that are not shipped from the factory with isolators, relays, or logic circuits installed. However, it is possible, in some cases, for the user to install active circuits on passive panels. Passive panels and their complementary cables are described in this data sheet. Active units providing optical isolation and power handling capability are found in the PCI-20018T-1 data sheet, later in this section. The passive panels include three basic types: **standard, high density, and customizer.**

The **standard,** PCI-20011T-1 termination panel can accommodate up to 16 channels (or points) of digital I/O with signal conditioning available on each channel. One ribbon cable connector provides the interface for all 16 channels to the DA&C system.

The **high-density,** PCI-20058T-1 termination panel can accommodate up to 48 channels of digital I/O, with signal conditioning available on each channel. Each group of 16 channels is interfaced to the DA&C system with a separate ribbon cable connector (a total of three connectors).

The **standard** and **high-density** termination panel layouts are divided into groups of printed circuit patterns to support user installed passive signal conditioning networks. The layout on the PCI-20011T-1 accommodates current-to-voltage conversion, voltage dividers, filters, surge and transient suppression, contact wetting, and LED indicators. The PCI-20058T-1 has simpler provisions allowing for logic pull-up and contact wetting. There are 16 network groups on the PCI-20011T-1 and 48 on the PCI-20058T-1. In addition, the PCI-20058T-1 has space for the user to install components to create one input contact debounce circuit. Each network/circuit is associated with a set of screw-terminal blocks at the edge of the panel. Field connections are made to the panels via the screw-terminal blocks. There is a "ground" terminal adjacent each pair of inputs. The PCI-20011T-1 is compatible with the PCI-20013A series cables. The PCI-20058T-1 panel is compatible with both the PCI-20036A-1 and PCI-20061A-1 cables.

The **customizer,** PCI-20025T series termination panels can accommodate up to 32 channels of digital I/O, with signal conditioning available on each channel. Field connections are made to the panels via screw-terminal blocks. There is a "ground" terminal adjacent to each pair of inputs. In contrast to the other digital panels, the customizers have a completely general layout pattern. Virtually any kind of passive or active network can be added to each individual channel. The PCI-20025T-1 and PCI-20025T-2 have different connector configurations. The -1 model has a "high-density" connector and is intended for use with the PCI-20098C-1's digital I/O, counter/timers, and sync/control lines. This connector mates with the PCI-20009A-1 cable. The -2 model has two standard connectors and can be used with any digital I/O modules or boards except the "on-board" channels of the PCI-20098C-1.

When used with a PCI board, carrier, or module, the interconnecting cable brings +5V to the termination panel. In most cases up to 240mA is available to power on-board functions (LEDs, pull-ups, etc.). A separate terminal block is also provided for the connection of an external power supply, if additional current or another voltage is required.

The physical size of each panel is 9" X 3.5" X 1.6" (22.9cm X 8.9cm X 4.1cm). Each panel type can be mounted in the PCI- 20029A-1 enclosure. An enclosure has room for four panels in a table-top or rack mount configuration. Additional information can be found in the PCI-20029A-1 data sheet.

The PCI-20009A-1, PCI-20013A series, and the PCI-20061A-1 are built with "ground-plane" type flat ribbon cable. They are intended for both digital input and output use. Included in this category are the counter/timer applications. The PCI-20009A-1 contains 50 wires and is intended for use only with the PCI- 20098C-1 and the PCI-20025T-1. The PCI-20013A series and the PCI-20061A-1 contain 34 wires. The PCI-20013A series is used to connect the PCI-20011T-1 (and the opto-isolation panels described in the PCI-20018T-1 data sheet) to any other digital board, carrier, or module. PCI-20061A-1 mates with the PCI-20025T-2 and PCI-20058T-1 and connects to any PCI digital board, carrier, or module (except PCI-20098C-1). The ground-plane minimizes cable inductance while reducing electrostatic and electromagnetic emissions. The PCI- 20009A-1 is 4 ft (1.2m) long while PCI-20013A-1 and the PCI- 20061A-1 are 6 ft (2m) long. The PCI-20013A-2 is 12 ft (4m) long. All ground-plane cables have the ground plane connected at one end only to avoid ground loops. The grounded end is clearly marked.

The PCI-20036A-1 is NOT shielded, but can be used for many digital I/O applications. It is a lower cost cable intended for applications where it is not critical to minimize noise or to preserve pulse shape. The PCI-20036A-1 is 4 ft (1.2m) long and has 34 wires. It mates with both the PCI-20025T-2 and the PCI-20058T-1 panels.

Various cable and connector manufacturers place marks or codes to indicate the location of wire or pin number 1. When using ANY PCI system, these codes or marks should be IGNORED. The correct wire and pin designations are described in the PCI user manuals. For those who wish to make their own cables, here are the correct matting connectors for the termination panels:

For PCI-20011T Series:
..... T&B Ansley #609-3430 and #609-5015M

For PCI-20025T-1:
........2 each Amphenol #845-C050-ALA00

For PCI-20025T-2 or PCI-20058T-1:
........................T&B Ansley #609-3430

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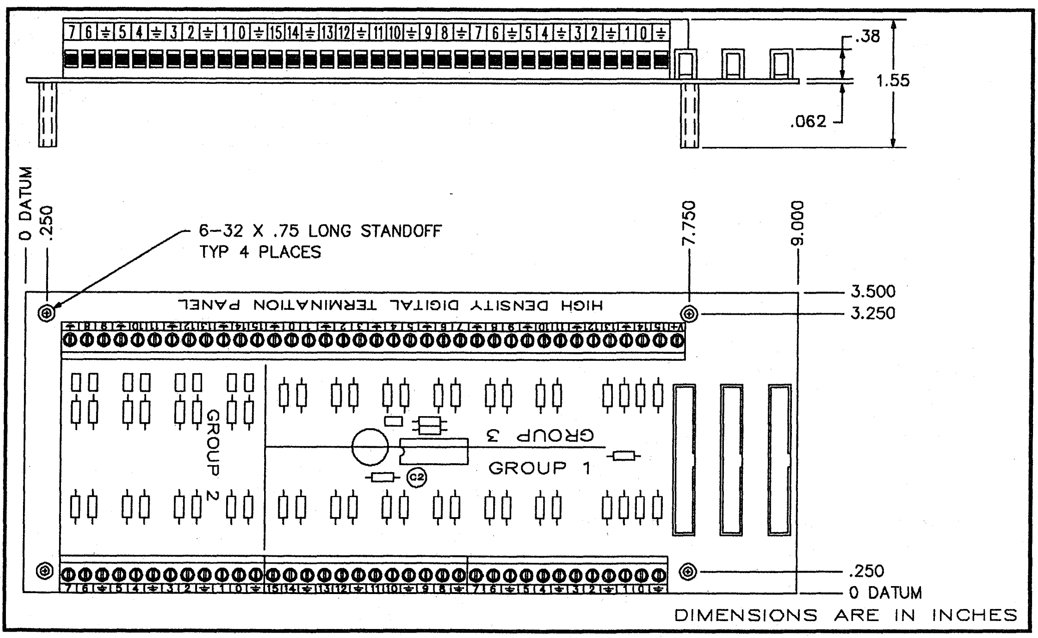
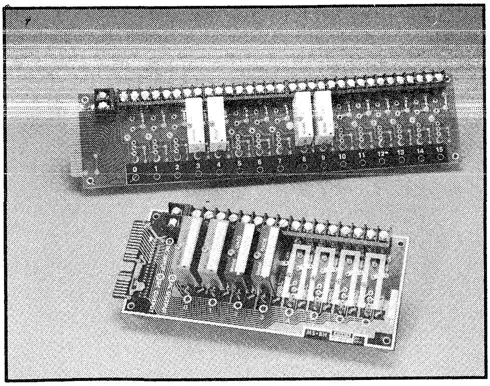


FIGURE 1. PCI-20058T Termination Panel Layout and Dimensions (inches).



BURR-BROWN®

PCI-20018T-1
PCI-20048T-1
PCI-20013A Series
PCI-1100 Series

Optically Isolated Digital Termination Panels

FEATURES

- Panels
  - Screw terminals provide for easy field wiring connections
  - Can be used for either input or output functions
  - Provides isolation and power handling capabilities
  - LEDs indicate channel status
- Modules
  - Converts a wide range of voltages to TTL levels
  - Switches up to 60VDC and 240VAC at 3A
- Suitable as an OEM components

DESCRIPTION

The PCI-20018T-1 and PCI-20048T-1 are digital signal termination panels that accommodate a separate PCI-1100 series, optically isolated I/O module for each channel. Various combinations of the different opto-modules can be intermixed on one panel. However, each contiguous group of eight channels (starting with channel 0) must contain only input or output modules. The PCI- 20018T-1 supports eight channels, therefore, inputs and outputs can not be mixed on this panel. The PCI-20048T-1 supports up to 16 channels. Six different types of PCI-1100 series modules are now available.

The termination panels are divided into identical circuit patterns, each being associated with a plug-in module and a set of two screw-terminal blocks at the edge of the panel. Figure 1 shows a schematic diagram of the PCI-20018T-1 panel which is representative of the PCI-20048T-1 as well.

Field connections are made to the panel via the screw-terminal blocks. When used with a PCI board, carrier or module, the interconnecting cable brings +5V to the termination panel. Up to 250mA is available to power on-board functions, including LED channel status indicators. A separate block is provided for the connection of an external power supply if this is desired. A 50-pin card-edge connector allows connection to other parts of the DA&C system. The panels are compatible with the PCI-20013A series cables.

The PCI-20013A series is built with "ground-plane" type flat ribbon cable and is intended for either digital input or output use. Included in this category are the counter/timer applications. The ground-plane minimizes cable inductance while reducing electrostatic and electromagnetic emissions. The cables contain 34 wires and are terminated with female connectors. The PCI-20013A-1 is 6 ft (2m) long, while the PCI-20013A-2 is 12 ft (4m) long. All ground-plane cables have the ground-plane connected at one end only to avoid ground loops.

Each digital I/O port in the PCI-20000 system supports 16 channels. Therefore, when a cable such as the PCI-20013A series is connected to a PCI-20018T-1, which accommodates eight channels, the other eight channels in that cable are not available for use.

The physical size of the PCI-20018T-1 panel is 8" X 3.5" X 2.1" (20.3cm X 8.9cm X 5.3cm). This height includes the height of the PCI-1100 series modules. The board itself is 1.4" (3.6cm) high. Up to four panels can be mounted in a PCI-20029A-1 enclosure. This enclosure can accommodate most combinations of both analog and digital panels (except the PCI-20048T-1) in a table-top or rack mount configuration. Additional information can be found in the PCI-20029A-1 data sheet. The PCI-20048T-1 is 14" X 3.5" X 2.1" (35.6cm X 8.9cm X 5.3cm), including the module's height. One panel fits into a PCI-20051A-1 enclosure, which has an optional PCI-20052A-1 cover.

Please see the PCI-20051A-1 data sheet for more information.

Various cable and connector manufacturers place marks or codes to indicate the location of wire or pin number 1. When using ANY PCI system, these codes or marks should be IGNORED. The correct wire and pin designations are described in the PCI user manuals. For those who wish to make their own cables, here are the matting connectors:
For Termination Panel: T&B Ansley #609-5015M
For Board, Carrier, or Module:
..................................T&B Ansley #609-3430
The PCI-1100 Series digital opto-isolators are modules that plug into the PCI-20018T and PCI-20048T termination Panels. One module is required for each channel. Input and output types are available in six different models for a wide range of applications. All input models accept both AC and DC voltages. Each provides a TTL output to drive a standard PCI digital input. Different models are provided for AC and DC outputs. These units convert TTL outputs from the PCI system to switch higher voltage (and current) loads. The DC output device (PCI-1103) presents an open collector NPN transistor to the load. The AC output units (PCI-1104 and PCI-1106) contain zero crossing circuitry and switch their loads with triacs. When an opto-module senses a valid input, it lights an LED on the termination panel as an indicator.

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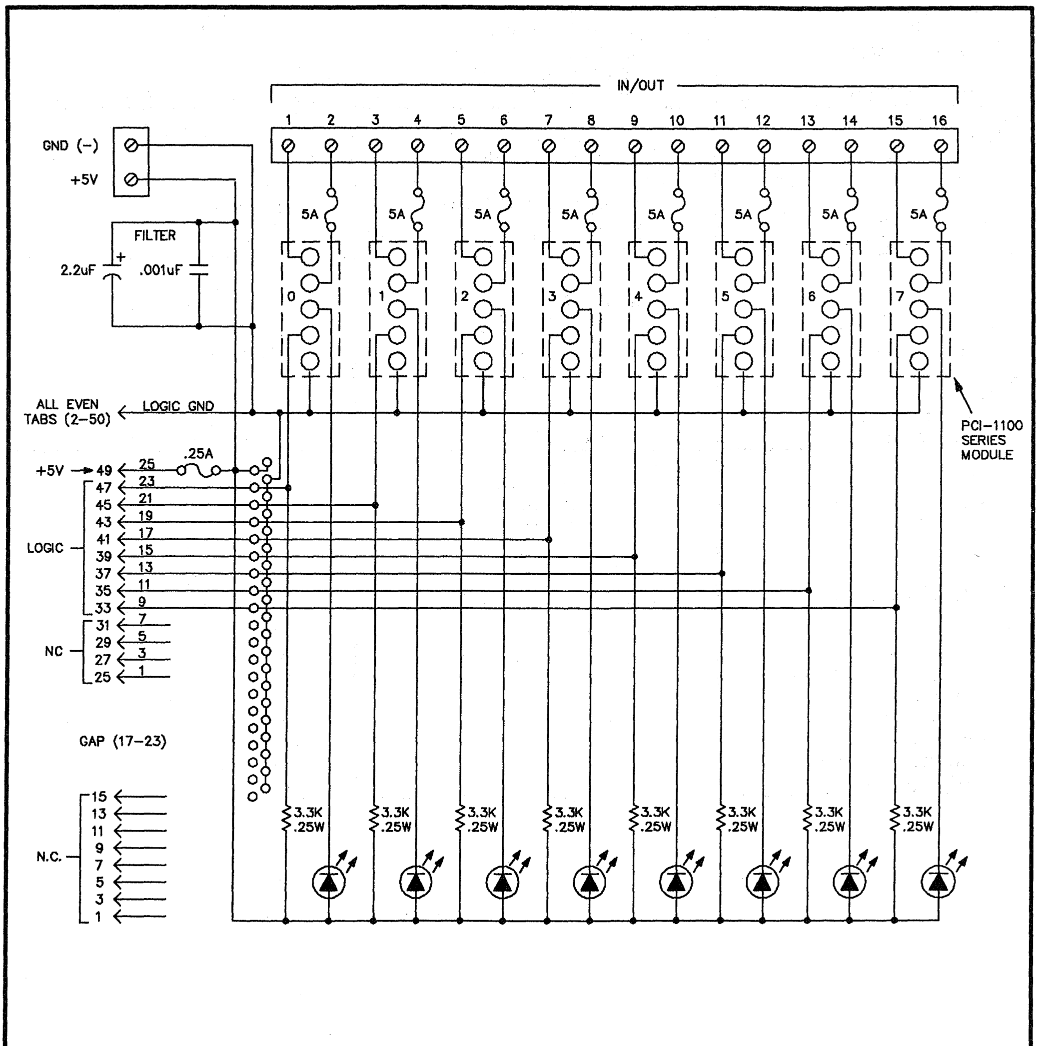
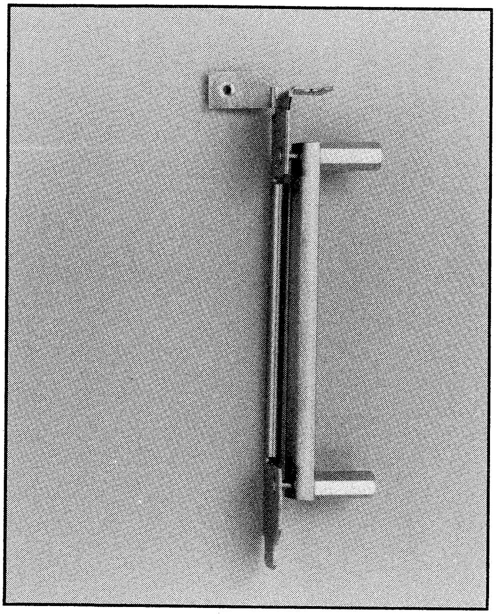


FIGURE 1. Circuit Diagram of the PCI-20018T-1 Panel.

SPECIFICATIONS -- PCI-1100 Series Opto-Isolation Modules

All specifications are typical at +25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Isolation	Input to Output	4000V
Temperature Range	Case Temperature	-30 to 70°C
PCI-1101	AC or DC Input	1 Channel
Input, On	AC Input	15-32V / 12-30mA
	DC Input	10-32V / 8-30mA
Off	AC or DC Input	3V / 1mA
Output Levels	3.3K pull-up, 50mA pull-down	TTL
Switching Time	Turn-on / Turn-off	5mS / 5mS Max
PCI-1102	AC or DC Input	1 Channel
Input, On	AC or DC Input	90-140V / 6-10mA
Off	AC or DC Input	45V / 3mA
Output Levels	3.3K pull-up, 50mA pull-down	TTL
Switching Time	Turn-on / Turn-off	20mS / 20mS Max
PCI-1103	DC Output	1 Channel
Load Range	@ 45°C (@ 70°C)	5-60V / 3A (2A)
Minimum Load Current		20mA
Voltage Drop	Across output transistor	1.6V Max
Off Leakage	@ 60V	1mA
Switching Time	Turn-on / Turn-off	100uS / 750uS
PCI-1104	AC Output	1 Channel
Load Range	@ 45°C (@ 70°C)	12-140V / 3A (2A)
Minimum Load Current		20mA
Voltage Drop	Across output triac	1.6V Max
Off Leakage	@ 120V, 60Hz	5mA
Input Levels		TTL
Frequency Range		25-65Hz
Switching Time	Turn-on/off	1/2 cycle Max
PCI-1105	AC or DC Input	1 Channel
Input, On	AC or DC Input	180-280V / 4-7mA
Off	AC or DC Input	80V / 1mA
Output Levels	3.3K pull-up, 50mA pull-down	TTL
Switching Time	Turn-on / Turn-off	20mS / 20mS Max
PCI-1106	AC Output	1 Channel
Load Range	@ 45°C (@ 70°C)	24-280V / 3A (2A)
Minimum Load Current		20mA
Voltage Drop	Across output triac	1.6V Max
Off Leakage	@ 120V, 60Hz	5mA
Input Levels		TTL
Frequency Range		25-65Hz
Switching Time	Turn-on/off	1/2 cycle Max



BURR-BROWN®

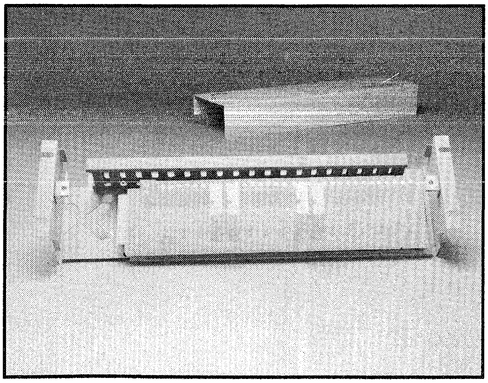
PCI-20028A-3
Strain-relief Bracket

FEATURES

- Supports cables as they exit from the PC
- Compatible with all PCI series ribbon cables
- Works with IBM PC, XT, AT and other hardware-compatible PCs

DESCRIPTION

The PCI-20028A-3 is a metal bracket designed to support flat ribbon cables as they exit from the personal computer. The bracket fits into the rear of an expansion board slot, where a board hold-down device would otherwise go. An adjustable clamp allows from one to five cables to be accommodated. Use of this bracket helps prevent damage to the PC or installed boards if the cables are accidentally pulled on. The PCI-20028A-3 is installed adjacent to either a PCI-20001C, PCI-20041C, PCI-20098C, or PCI- 20202C series carriers in an unused slot of the computer. In most cases one PCI-20028A-3 bracket is recommended for each carrier (in addition to the combination clamp that is included with each carrier) if one or more modules will be plugged into the carrier.



BURR-BROWN®

PCI-20029A-1
PCI-20051A-1
PCI-20052A-1
Termination Panel Enclosures

FEATURES

- Mounts in a standard 19-inch (48cm) rack
- Provides both mechanical and electrical protection
- Suitable as an OEM component

DESCRIPTION

The PCI-20029A-1 is a metal enclosure designed to support up to four standard-size analog and/or digital termination panels. All PCI-20000 models are accommodated except the PCI-20048T-1. PCI- 20048T-1 fits into the PCI-20051A-1 enclosure. Because of the larger size of the PCI-20048T-1, the PCI-20051A-1 holds only one panel.

All enclosures mount into standard 19-inch (48cm) relay racks, but can also be used in a table-top configuration. A cover is included with the PCI-20029A-1. An optional cover, the PCI- 20052A-1, is available for the PCI-20051A-1.

These enclosures help prevent mechanical damage to the termination panels while restricting accidental human contact with internal circuits. A plastic cable tray in the PCI-20051A-1 keeps the field wiring neat. Figures 1 and 2 suggest the mechanical configurations and give the major dimensions.

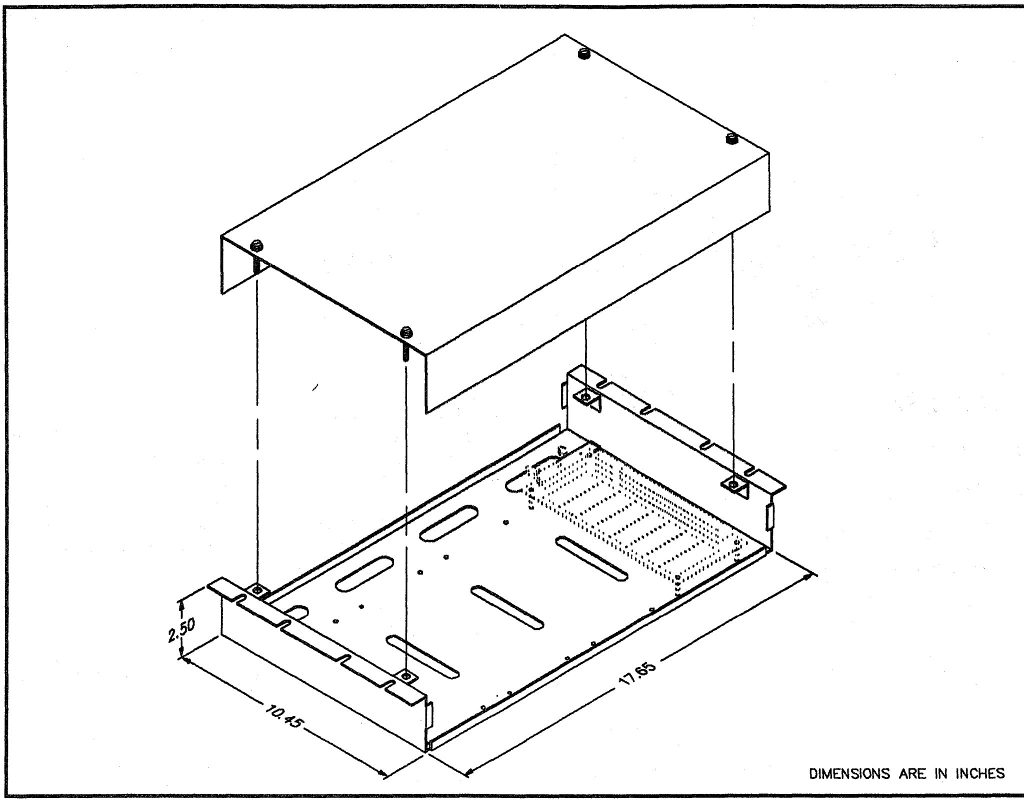


FIGURE 1. PCI-20029A-1 Enclosure.

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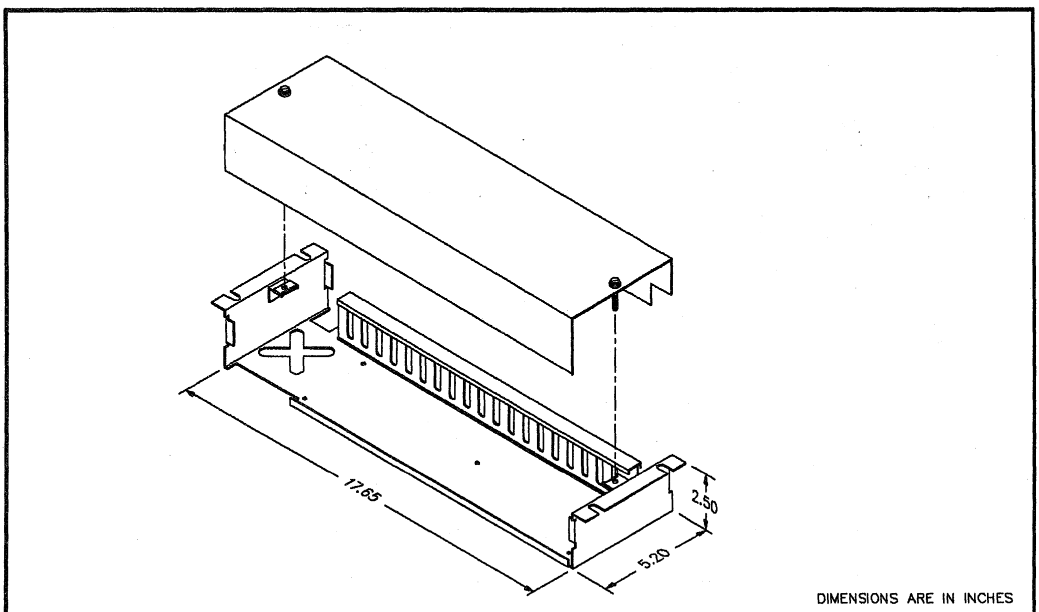
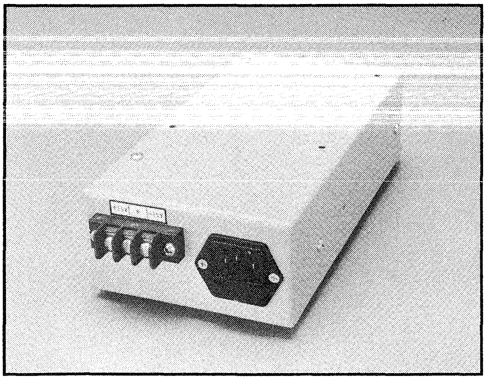


FIGURE 2. PCI-20051A-1 Enclosure and PCI-20052A-1 Cover.

BURR-BROWN®



PCI-20038A-1 (115VAC)
PCI-20038A-3 (240VAC)

±15 Volt DC Power Supply

FEATURES

- ±15VDC at 0.8A
- ±0.05% line and load regulation
- Short-circuit protected
- Convenient plug and terminal connections

DESCRIPTION

The PCI-20038A series consists of general-purpose ±15VDC power supplies. They are available in both 115 and 240 AC line voltage models. Each has adjustable outputs (±5%) and is capable of delivering 800mA to its loads. Current limit/foldback protection is included.

PCI-20038A-1 operates from 105 to 132VAC, while PCI-20038A-3 requires 209 to 264VAC. Both accept line frequencies between 47 and 63Hz. A continuous output current of 800mA is supported with less than 5mV peak-to-peak ripple and ±.05% load regulation. Line regulation is ±.05% for a 10% line change. The ambient operating temperature range is 0 to 50°C.

The supplies are completely enclosed in a metal case, offering both mechanical and electrical contact protection. While they can be used for almost any purpose, the PCI-20038A is primarily intended to power the PCI-20042T thru PCI-20045T series of Active Signal Conditioners. If desired, the supplies can be mounted either inside or on the rear of the PCI-20029A-1 Termination Panel Enclosure. Figure 1 shows the physical dimensions of the power supplies, and the input and output connectors.

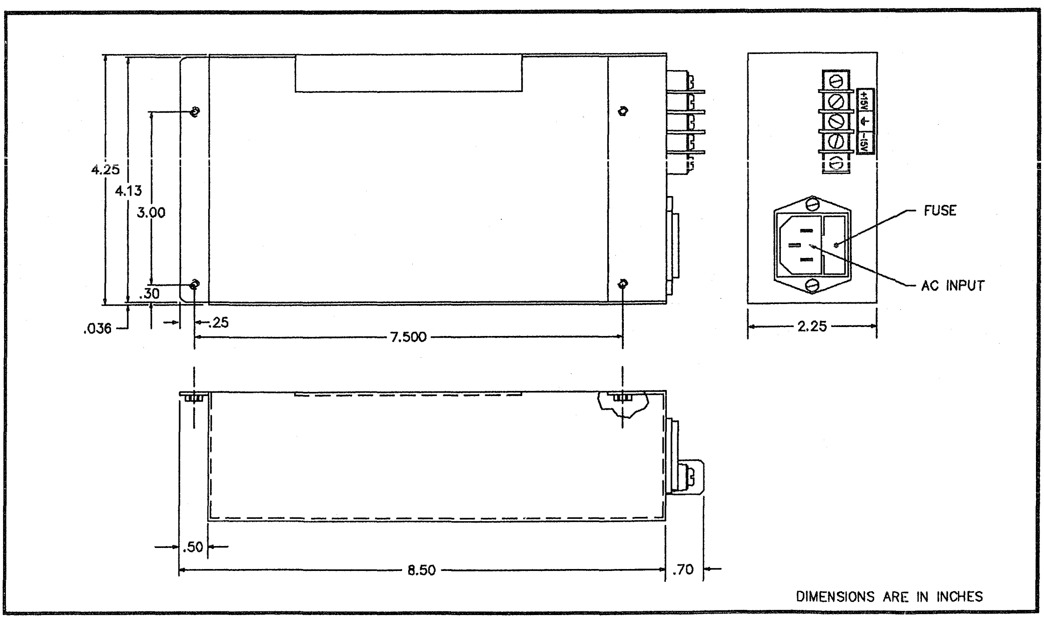


FIGURE 1. PCI-20038A ±15VDC Power Supply.

Section 11

PCI WORK STATIONS and SYSTEMS

TABLE OF CONTENTS

INTRODUCTION

Three major types of products are included in this section: Stand-alone Systems, Expansion Enclosures, and Paks. In general, the products are "vertically integrated" systems based upon standard PCI-20000 components (boards, carriers, modules, etc.) and software. An exception is the PCI-20055H series of PC Bus Expansion Enclosures. These boxes are designed to add expansion space to an existing PC or Work Station. Added space can be used for any combination of PCI I/O boards and carriers. This can be useful in constructing large systems or when it is desirable to have the data acquisition hardware outside the PC. It is often appropriate to share a single "measurement setup" (PCI-20055H plus other PCI-20000 I/O products) among several PCs. This is readily accomplished with the companion interconnecting cable with high quality connectors.

Paks are logical combinations of hardware and software, assembled for user convenience, and intended for a given class of applications. Upon installing the Pak in his computer, the user is ready to apply the system. PCI ControLOGraph is tailored for traditional data logging operations. No previous skills are required to conduct monitoring, data collection, and graphics display tasks. Sophisticated data interpretation facilities are built-in. DSP Paks are intended for high speed acquisition and signal processing applications, including vibration analysis. The included menu-driven software automatically captures an analog input at rates up to 180kHz, computes the power spectrum, and presents the result in a choice of display formats.

Stand-alone systems are <u>complete</u> in all respects. They internally include all necessary computer, I/O hardware, and software facilities. Nothing else is required. The system is built upon an industrial quality, PC compatible, computer platform with a high resolution color display. The PCI input/output section supports analog input, analog output, and digital I/O. Data acquisition, test, measurement, analysis, display, data logging, and control applications are ready to implement with the easy-to-use menu-driven software.

Product Summary

PCI Work Stations

PCI Work Station (PCI-501H-1). Complete, industrial quality data acquisition, test, measurement, and control system. Includes 48 analog inputs, 8 analog outputs, and 32 digital I/O. Menu-driven LABTECH NOTEBOOK software. Rack-mount PC/AT compatible platform with EGA monitor, floppy and hard disks. For 120VAC operation.

PCI Work Station (PCI-501H-2). Complete, industrial quality data acquisition, test, measurement, and control system. Includes 48 analog inputs, 8 analog outputs, and 32 digital I/O. Menu-driven LABTECH NOTEBOOK software. Rack-mount PC/AT compatible platform with EGA monitor, floppy and hard disks. For 240VAC operation.

PC Bus Expansion Enclosures

PC Expander (PCI-20055H-3). Adds 7 slots to an existing PC or Work Station. 120VAC input, 200W power supply. Flip-top lid. Designed for all PCI boards and carriers. Requires the PCI-20063A-1 interface to the PC.

PC Expander (PCI-20055H-4). Adds 7 slots to an existing PC or Work Station. 240VAC input, 200W power supply. Flip-top lid. Designed for all PCI boards and carriers. Requires the PCI-20063A-1 interface to the PC.

PC Interface Board (PCI-20063A-1). Couples host PC to PCI-20055H series PC Expanders.

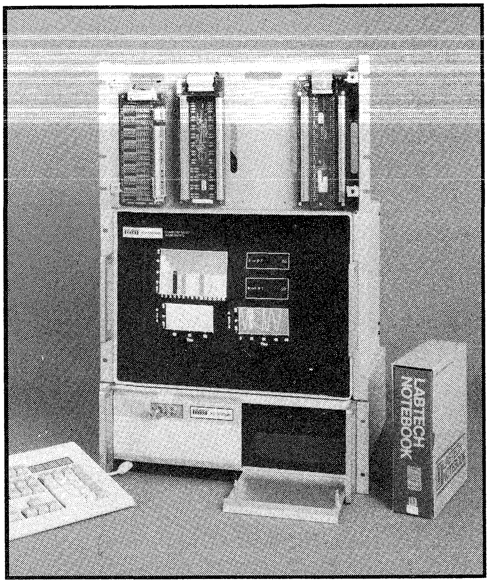
System Paks

PCI ControLOGraph (PCI-20056K-1). Hardware/software system for data-logger type applications. Completely menu-driven. No computer skills required. Complete with all necessary hardware and software (except PC).

Digital Signal Processing Pak (PCI-20207K-1). Combines the PCI-20202C-1 *Smart* carrier with the PCI-20019M-1 high speed analog input module and the PCI-20205S-1 DSPview software package. 89kHz maximum sample rate.

Digital Signal Processing Pak (PCI-20207K-2). Combines the PCI-20202C-1 *Smart* carrier with the PCI-20023M-1 very high speed analog input module and the PCI-20205S-1 DSPview software package. 150kHz maximum sample rate.

Digital Signal Processing Pak (PCI-20207K-3). Combines the PCI-20202C-2 *Smart* carrier with the PCI-20023M-1 very high speed analog input module and the PCI-20205S-1 DSPview software package. 180kHz maximum sample rate.



BURR-BROWN®

PCI-501H Series

PCI WORK STATION For Data Acquisition, Test, Measurement, and Control

INDUSTRIAL QUALITY

DESCRIPTION

The *PCI WORK STATION* is an integrated system, optimized for data acquisition and process control functions. Unique tasks or experiments are set up and run by making selections from menus, with just a few keystrokes. Setting up channel assignments, triggering, real-time calculations, and graphic presentations can all be accomplished without prior training. The user interface consists of a high performance color display and a familiar "typewriter" keyboard. Acquired data may be directed to disk for permanent storage upon command. In addition, stored data can be replayed for further analysis. Any setup can be saved with a user defined name for future use.

APPLICATION AREAS

- Materials Testing
- Burn-In
- Product Design
- Life Test
- Machine and Robotics Control
- Production Test
- Product Evaluation
- Quality Assurance
- Incoming Inspection
- Simulators
- *Real-Time* Process Control
- Laboratory Automation

KEY FEATURES

- Easy to Use, No Programming Required
- Shipped Complete, Ready to Run
- Ideal for Monitoring, Test and Control Applications
- Rugged, Rack-Mount Enclosure
- Interface to Real-World Signals Included Supports:
  - Analog Inputs - 48 Single-Ended or 24 Differential Channels
  - Analog Outputs - 8 Channels
  - Digital Input/Outputs - 32 Channels
- Input/Output Interface Channels are Easily Expandable
- *Real-Time,* High Resolution, Color Graphics Display
- *Real-Time* Analysis and Data Reduction Supported by Extensive Math and Statistical Functions
- Alarm Capabilities
- Very Large Data Storage Capability
- IBM PC/XT/AT Compatible Architecture. Supports Other Computer Functions

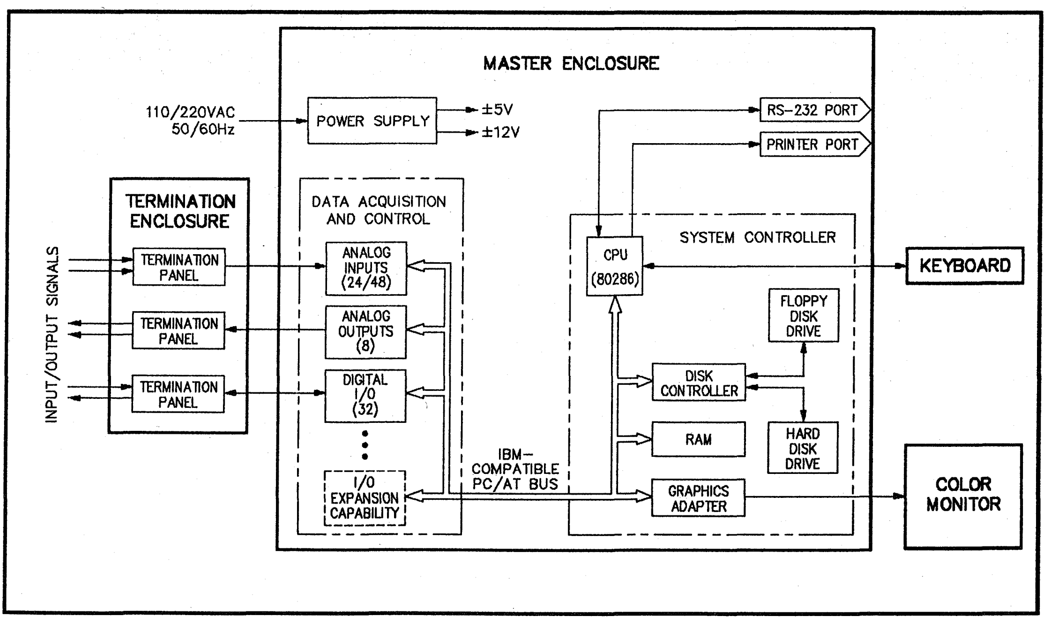
The *PCI WORK STATION* is a member of Burr-Brown's comprehensive data acquisition and control family. These products include the PCI-20000 Boards, Carriers, Modules and Termination components for measuring, analyzing and generating analog, digital and pulse signals. These electrical signals can represent temperature, distance, speed, time, flow, pressure, force, open/closed, and on/off, etc. The *PCI WORK STATION* consists of industrial-grade hardware components based upon the popular personal computer (PC) architecture. The accompanying software utilizes the best characteristics of today's powerful PCs while emphasizing productivity with its clear and consistent user interface. No programming skills are required to define a wide range of sophisticated laboratory and industrial applications.

Based upon the industry-standard LABTECH NOTEBOOK software, the *PCI WORK STATION* brings real-time data acquisition, process monitoring and control within easy reach of everyone. All functions are reduced to menu-driven choices, minimizing the need for previous measurement or computer skills. The user interface is optimized to support a wide range of laboratory, factory and test applications. Reading voltages, currents, resistances, frequencies, thermocouples, and digital signals is easy to accomplish. Outputs including voltage, current, pulse, frequency and digital (on/off) are also menu controlled. Even complex control operations, utilizing the popular PID algorithm, are simple to construct. Options allow for the automation and customization of advanced analysis, presentation, and report-generation features.

The capabilities of LABTECH NOTEBOOK permit expansion of the *PCI WORK STATION's* factory configuration to include additional input/output types and hundreds of total channels. Each channel can be individually configured for a unique function with user-defined rates for sampling, data logging and display. Additional information and specifications for the LABTECH NOTEBOOK portion of the *PCI WORK STATION* can be found in the PCI-20040S-1 Product Data Sheet.

Mechanically the system consists of four major components: the Master Enclosure, the Signal Conditioning/Termination Enclosure, the Monitor/Display and the Operator Keyboard. While all are rack-mountable, the brackets can be removed for desk or bench-top use. The master enclosure and monitor are cooled by fan-forced, filtered air. A positive internal pressure is maintained to inhibit dirt and dust from entering the cabinets. A key-activated safety lock prevents unauthorized changes to the system's operation. The two versions of the PCI-501H are configured at the factory for different AC line voltage ranges. The PCI-501H-1 is set for 120VAC while the PCI-501H-2 is set for 240VAC. Instructions are included so that either unit can be switched for the other range.

The master enclosure houses the 16-bit 80286-based central processing unit (CPU), external communications ports (RS-232C serial port & Centronics printer port), and the graphics and disk controllers. Also included is 512 KBytes of RAM, a 1.2 MByte floppy drive, a 20 MByte hard drive, the analog and digital input/output interface boards (88 total channels), and a 200 watt



PCI-501H Series Block Diagram.

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power supply. All electronic components are located on plug-in boards to simplify maintenance, repair and I/O configuration changes. The floppy disk drive is located behind a hinged access door to enhance resistance to spills, splashes and dust. A real-time clock, with battery backup, provides for the accurate time stamping of data. CPU integrity is checked by automatic diagnostic tests at power-on. The user can periodically invoke more extensive built-in test sequences if desired.

Four expansion slots are provided to support future system requirements which can include up to 3.5 MBytes of RAM and up to 256 I/O channels. For very large installations, the PCI-20055H series Expansion Enclosures can each add up to 512 additional channels. The number of channels that can be added is dependent upon the I/O types selected. Please consult your local Burr-Brown systems sales representative or the factory applications engineers for additional information.

The input/output interface is accomplished with highly reliable PCI-20000 series modular components. Signal termination panels, cables and a rack mount enclosure are also included. All cables are shielded to minimize noise pickup and radiation.

The signal conditioning/termination enclosure contains separate screw terminal panels for each I/O type. Besides providing convenient connection points for the external signal wires, the panels support user-installable signal-conditioning functions that can include: scaling, filtering, over-voltage protection, cold-junction compensation (for thermocouples), pullups, pulldowns, diode clamps, etc. Additional signal-conditioning capabilities are accessible with other PCI termination components available from Burr-Brown.

A high-resolution color graphics monitor supports the setup and display of the test, acquisition and control functions. A protective low-glare face plate prevents damage to the 13-inch screen. Controls are located behind a hinged access door to enhance resistance to spills, splashes and dust. The monitor can display 64 colors with 640 by 350 dot resolution.

The sturdy keyboard conforms to the DIN standard and has 101 keys, including function keys and a numeric keypad. Similar to the other enclosures, the keyboard unit is sealed to resist liquid splashes, spills, and dusty environments. As an added system security measure, the keyboard can be disconnected after setup. If required, it is also possible to reconnect the keyboard without disturbing the functioning system.

It is important to note that the hardware and operating system portions of the *PCI WORK STATION* are fully IBM PC compatible. This insures that the large base of applications related software for the PC is available to extend the usefulness of the system. These include word processors, spreadsheets, analysis, graphics, and communications packages.

"Disk management" software is an integral part of the *PCI WORK STATION*. This allows first time computer users to utilize the advanced features of the operating system without learning special terminology.

Comprehensive documentation covers all aspects of installation, operation, and calibration. Each system is shipped, at no extra charge, with Burr-Brown's innovative SYSCHECK, the System Assurance Utilities and Diagnostics Software Package. This menu-driven product easily verifies proper installation and utilization of all PCI system components. Not only does SYSCHECK greatly reduce the time required to confirm appropriate operation but it provides a permanent resource for test and calibration.

SPECIFICATIONS - PCI-501H Series

All specifications are typical at 25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Input/Output Functions		
Analog Inputs	Single-Ended / Differential	48/24 Chs
Resolution		12-Bits
Speed, Throughput	Single Channel	25kHz Max
	Multiple Channels	800 Hz Max
Analog Outputs	Voltage Output	8 Chs
Resolution		12-Bits
Speed		800 Chs/Sec
Digital I/O		32 Chs
I/O Levels	Buffered Outputs	TTL Compatible
Speed	Inputs	800 Chs/Sec
	Outputs, Open Loop	1500 Chs/Sec
Control Loops	Analog or Digital	
Speed		70 Hz
Signal Terminations	Enclosure Included	
	Analog Inputs	Screw Terminals & 3 Shielded Cables
	Analog Outputs	Screw Terminals & Shielded Cable
	Digital I/O	Screw Terminals & 2 Shielded Cables
Software		
Operating System		MS DOS 3.21
Hard Disk Management System	Menu-Driven DOS "Shell"	PathMinder
Data Acquistion and Control	Completely Menu-Driven	LABTECH NOTEBOOK
Master Enclosure	IBM Compatible PC/AT	Rack Mountable
CPU Speed	Intel 80286 (80287 Socket)	8MHz, 0 wait state
RAM Memory	(Expandable to 3.5 MBytes)	512 KBytes
Mass Storage	Floppy Disk Drive	1.2 MByte
	Hard Disk, 40 mSec Access	20 MByte
Communications Ports	Serial	RS-232C
	Parallel Printer	Centronics
Expansion Slots	Available, Full size	4
Power Supply		
DC Output Power	Total	200 Watts
Output Current	+5V Supply	21A
	-5V Supply	0.3A
	+12V Supply	7.5A
	-12V Supply	0.3A
AC Input Power	Master Enclosure & Monitor	400 Watts Max
	PCI-501H-1	98-132 V, 50/60Hz
	PCI-501H-2	208-262 V, 50/60Hz
Monitor	Industrial Face Plate	Rack Mountable
Compatibility	64 Colors	Enhanced Color Graphics (EGA)
Screen Size	Diagonal Measure	13" (33cm)
Resolution	Horizontal/Vertical	640 by 350
Keyboard	DIN Standard, Detachable	101 Key, AT Format
Physical Size		
Master Enclosure	Width, Depth, Height (inch)	17.5 x 19.5 x 6
	(cm)	44.5 x 49.5 x 15.2
Monitor	Width, Depth, Height (inch)	18.5 x 16.8 x 12.5
	(cm)	47 x 42.5 x 31.8
Signal Terminations	Width, Depth, Height (inch)	17.7 x 2.5 x 10.5
	(cm)	45 x 6.4 x 26.7
Weight		
Master Enclosure		39 lbs (17.7 kg)
Monitor		42 lbs (19 kg)
Signal Terminations		9 lbs (4.1 kg)
Environmental	Industrial Grade	Dust & Splash Resistant
Temperature Range	Internal, operating	0 to 45°C
Humidity	Relative, non-condensing	8-80%

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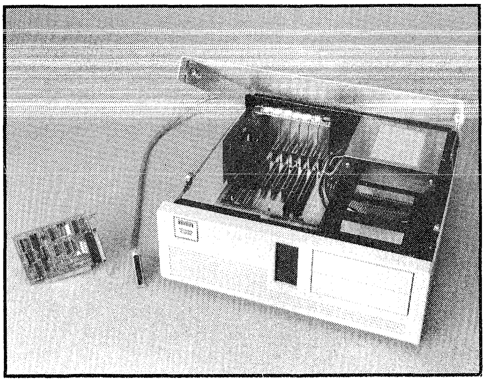


PCI-20055H Series
PC Bus Expansion Enclosure
PCI-20063A-1
PC Bus Host Interface Board

The PC Expander

Expansion Enclosures for the IBM PC Bus

FEATURES

- 7 Slot Capacity
- 200 Watt Internal Power Supply
- Bench-Top or Rack-Mount Installation
- Easy-Access Flip-Top Lid
- 3 ft. (.9M) Interconnecting Cable
- Quality Connectors At Both Ends Of Cable
- Compatible With All PCI-20000 System Components
- Provisions for Additional Mass Storage Media Installation

DESCRIPTION

The PCI-20055H Series of Expansion Enclosures is designed to enhance the capabilities of any IBM compatible Personal Computer (PC) in data acquisition, test, measurement and control applications. As a system is expanded, it is possible to run out of expansion slots. Even with slots available, sufficent power for the add-in features may not be available. Most PC's have just a few available expansion slots for the installation of important add-in boards. The "PC Expander" extends the capability of the computer by adding up to 7 additional expansion slots. This permits the construction of medium to large-scale installations. Systems containing 300 to 600 channels are easily accommodated. In addition, multiple PC Expanders can be used when even larger configurations are required. As a general rule, up to four PC Expansion boxes can be connected to one host computer. However, if DMA is to be used, we recommend that only two expanders be directly connected to a given computer. Here are three examples of tested configuration options:

1) Non-DMA Modes of Operation. Four Interface Boards installed in one host computer, with one PC Expander connected to each (four total PC Expanders). Up to 2048 DI/O, or 1280 Analog Input channels can be accommodated.

2) All Modes of Operation Including DMA. Two Interface Boards installed in one host computer, with one PC Expander connected to each (two total PC Expanders). Up to 1024 DI/O, or 640 Analog Input channels can be accommodated.

3) All Modes of Operation Including DMA. One Interface Board is installed in the host computer. Three PC Expanders are "daisy-chained" together to the one computer. Up to 1152 DI/O, or 720 Analog Input channels can be accommodated.

The convenient, flip-top lid provides easy access to the test and measurement system without disturbing the host computer. Both desktop and rack installations are supported by the attractive housing. The width of the enclosure is 17.4 inches (44 cm) allowing convenient tray mounting in a standard 19 inch rack. Only a half-size interface driver board (PCI-20063A-1) plugs into the host PC. While available separately, this board is required for operation of the PC Expander. Interface boards are sold individually so that one PC Expander-based system can be shared (only one is connected at a given time) by several computers (each with a PCI-20063A-1 installed). The PC Expander is easily connected and disconnected from the PC with a high quality, round, shielded cable. The provided 3 foot (.91M) cable has D-connectors on both ends. This length allows positioning the PC Expander on either side or above/below the host computer.

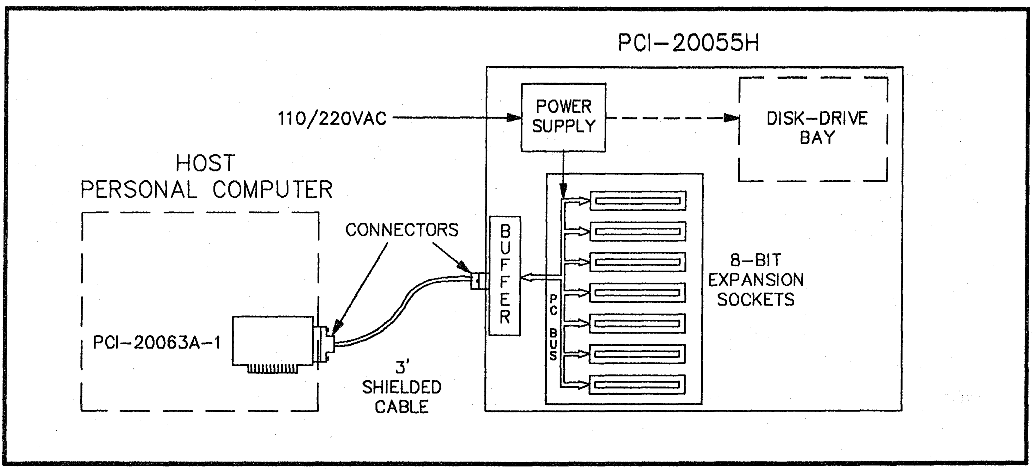
While designed specifically to support the Burr-Brown PCI-20000 series of data acquisition and control components, the PC Expander will also accept many other PC/XT type plug-in boards. This includes floppy and hard disk controllers as well as RAM expansion boards. The umbilical cable that interconnects the host PC and the PC Expander supports standard 8-bit transfers and is intended primarily for PC/XT type computers. However, the unit is compatible with PC/AT type machines when only PC/XT type boards are installed in the PC Expander.

The PCI-20063A-1 PC Bus Host Interface Board plugs directly into an expansion slot in any IBM PC/XT/AT or compatible Computer. Compatibles are available from IBM, AT&T, Olivetti, Zenith, Siemens, Compaq, and PC's Limited, to name just a few. These include the 386-type machines. In addition, the IBM PS/2 model 30 also supports this and all other PCI-20000 products. No jumpers or switches need to be set on the interface board, further simplifying installation.

The high speed of the interconnection hardware allows the PC Expander to be used with virtually all PC compatible machines with bus speeds up to 10MHz. It is important to note that most compatible computers with CPU speeds in excess of 8MHz divide the clock speed to 8MHz (or less) before connection to the expansion bus. This is done to maintain compatibility with the wide range of add-in boards available. Thus, most 80286 and 80386 computers running at 12, 16 and even 20MHz are compatible with the PC Expander.

A separate, internal power supply is included to energize all boards installed within the PC Expander. The AC input is switch selectable for use in most parts of the world. The PCI-20055H-3 is shipped with the switch set for 120VAC operation, while the PCI-20055H-4 is shipped in the 240VAC configuration. 200 watts of output power are available to satisfy all known applications. A fan assures adequate air flow for proper cooling. Mounting provisions for up to three half-height disk drives is also included.

A functional block diagram of the product is shown below.



Block Diagram of the PCI-20055H Series.

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SPECIFICATIONS - PCI-20055H-3, -4

All specifications are typical at 25°C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility	See text above	IBM PC/XT/AT and compatibles
PC Bus Speed	Max Recommended, See Text	10 MHz
Available Slots	PC/XT, 8-bit, full size	7
Slot Spacing		0.8" (2.03 cm)
Power Supply	DC Output, 200 Watts Total	
Output Current	+5V	20A
	-5V	0.5A
	+12V	8A
	-12V	0.5A
AC Power Input	Switchable	
	120/240 VAC ±15%, 47-400Hz	300 Watts max
Factory Setting	PCI-20055H-3	120VAC
	PCI-20055H-4	240VAC
Physical Size	Width	17.4" (44 cm)
Cover Closed	Depth, Excluding Cables	17" (43.2 cm)
	Height, Including Feet,	6.5" (16.5 cm)
Enclosure Weight		28 lbs (12.7 Kg)
Temperature Range	Internal	0 to 50°C

BURR-BROWN®

PCI-20056K-1

PCI ControLOGraph An Integrated Data-Logging System

FEATURES

- Integrated data-logging, real-time display, alarm, control and graphic analysis package
- Data recorded in hours, minutes, seconds, and tenth seconds along with day, month and year
- Completely menu driven, NO programming required, NO previous computer skills required
- 48 inputs —
  - 21 differential analog inputs, including thermocouples
  - 24 digital inputs
  - 3 counter/frequency inputs
- 8 digital alarm and control outputs controlled by analog, digital, and/or counter channels
- Trigger options (analog, digital and/or counter) allow both pre- and post-trigger data to be viewed
- Auto-restart allows an unattended system to resume taking data after recovery from a power failure
- Graphics analysis incorporates "active cursors" to display a given data point or the difference between data points
- ASCII data files are compatible with Lotus, ASYST, BASIC, etc., providing for additional post-acquisition analysis
- System includes a PC plug-in carrier board, modules, termination panels, cables, software, and operations manual

APPLICATIONS

- General data-logging functions, replaces chart recorders and printers while providing extensive analysis capabilities
- Time studies
- Laboratory data collection and control
- Life test and burn-in operations
- Utilities monitoring

DESCRIPTION

The PCI ControLOGraph System is a integrated, IBM PC-compatible system of hardware and software for data logging, real-time display, alarm annunciation, digital control, and graphics analysis. The system is completely menu-driven and requires no programming or previous experience in the use of personal computers. The system includes all necessary PCI hardware and software. The hardware is factory configured for immediate use after installation in the PC. Any IBM PC, PC/XT, PC/AT or compatible computer is suitable. Provisions for the easy connection of the user's sensing and control devices are provided through screw terminal panels.

Sensor inputs can include 21 analog channels, 24 discrete levels and 3 frequency/pulse sources. All 48 channels constitute a "frame" of data which is recorded, as a group, upon command. Each channel can be labeled and referred to by any unique, user- defined name. On each analog channel, one of four input ranges, covering ±10mV to ±10V, can be menu-selected. When using thermocouples, any of the channels can be designated as J, K, or T type devices. Each of the counter inputs can be used to measure frequency or count events. Data can be recorded and displayed in any units desired. The user can define both linear and arbitrary nonlinear relationships between input signals and recorded/displayed data. The digital channels can monitor the state of individual bits or any combination of all 24.

The data collection process is safeguarded by two unique features that help insure that available data cannot be lost. All channels can be recorded directly to non-volatile disk media. This means that in the event of an AC power interruption, all data is permanently saved. In addition, the system's auto-restart feature automatically "reboots" the computer and resumes the data-logging function when power is restored. In conjunction with the computer's real-time clock, the ControLOGraph provides accurate time stamping of the data—both before power interruption and after power restoration. Acquired data is continuously stored to disk in a circular buffer. The size and characteristics of the buffer can be tailored to fit the job's requirements. The circular buffer architecture provides several important features, including the capture of pre-trigger data. Up to 30,000 frames (48 input channels each) of data can be stored.

SOFTWARE

The user controls the acquisition of analog, digital, and counter data from clearly described menu options. Arbitrary functions can be defined to linearize or translate the input data into desired engineering units. Digital alarms or control outputs can be keyed to any combination of input signals. Outputs can be generated when the inputs are below, above, within a window or outside a window as defined by preset limits. Comprehensive triggering capabilities allow unique events (including fault conditions) to capture data both before and after the trigger. Numerous options allow the ControLOGraph to be customized for specific uses. System setups can be saved for later recall, enabling the users to develop a library of applications.

The data acquisition rate can be set in two ways —internal and external. The internal mode establishes a fixed time-base that can be set in 1/10-second increments, with intervals up to almost 100 hours. Each time "tick" causes a frame of data to be read. The external mode acquires a frame of data for each TTL input pulse.

In both cases the data is time stamped and saved under a user-defined file name. After the acquisition is complete, the data can be recalled from disk for display and/or analysis. Built-in graphical and tabular displays are included. In the graphics mode any one, four, or as many as eight channels (digital only) can be viewed at the same time. "Zoom" capabilities allow detailed inspection of any region of the overall data set.

Also included are "find" functions. The find functions can be used to search for specific data values, the maxima or minima or the data set, and digital events or patterns. Auto-scaling provides maximum visual resolution, while the digital display of the cursor's position yields precise time and amplitude readings. Data corresponding to the cursor position can be presented in several modes: real-time, date, trigger relative, and origin relative. The real-time and date modes yield the actual time of the data recording in an hh:mm:ss and day/month/year format, respectively. Data can also be presented relative to the system trigger or any selected point. This last mode provides precise "delta" readings.

A special file-building function generates ASCII format files that can be read by Lotus, ASYST, or DADiSP to provide additional data reduction, analysis, or presentation capabilities.

SPECIFICATIONS - PCI-20056K-1

All specifications are typical at +25°C unless otherwise noted.

PARAMETER	SECIFICATION
INPUT FRAME (total channels)	48 channels
Analog (differential input, 12-bit resolution)	21 channels
Voltage ranges	±10mV to ±10V
Thermocouple types	J,K,T
Digital (TTL)	24 channels
Counter/Frequency	3 channels
Maximum count	65,535
Maximum frequency	650kHz
OUTPUT CHANNELS	
Digital Alarm/Control	8 channels
Output levels	TTL
Sink/source current	24mA/15mA
Control stimulus	Analog, digital, counter
SAMPLE RATE AND PERIOD (IBM PC/AT)	
To RAM Disk (channels/second and seconds/frame)	480 and 0.1
To Hard Disk (channels/second and seconds/frame)	80 and 0.6
To Floppy Disk (channels/second and seconds/frame)	12 and 4
FRAME ACQUISITION TIME (max)	0.1s
DATA BUFFER, Type	Circular
Max Size (frames)	30,000
Max Delay (see trigger types)	30,000
TRIGGER INPUT TYPES	Analog, Digital and Counter/ Frequency
Stops acquistion after delay	
REAL-TIME DISPLAY, 16 equal-sized windows	
Can be modified during run without interruption	Any 16 Channels
GRAPHICS DISPLAY, choice of any 1 or 4 channels	
(8 if digital) Cursor-controlled read-out of data	1, 4 or 8
OUTPUT FILE COMPATIBILITY	
Can be read by Lotus, ASYST, BASIC, etc.	ASCII Real

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BURR-BROWN®

PCI-20207K Series

Digital Signal Processing System for the IBM PC Bus -- DSP Paks

FEATURES

- DSP Paks Include:
  - *Smart* Carrier
  - Analog Input Module
  - Menu-Driven FFT Analyzer Software
- Plugs Directly Inside IBM PC/XT/AT and Compatible PCs
- Based upon the Industry Standard TMS320C25 Processor, offering:
  - Both 28MHz and 40MHz Versions Available
  - Up to 10 MIPS (100nS Instruction Cycle)
  - Comprehensive Software Support
- Up to 96KWords of On-Board High Speed Memory, Zero Wait State
- Continuous Data Conversions to/from ALL Available Host Memory
- Internal Timebase / Rate Generator
- Programmable from High-Level Languages
- Extensive Subroutine Libraries and Hardware Drivers Available
- Multi-Channel, High Speed Analog Input and Output Capabilities, via the PCI-20000 Family of I/O Modules

HARDWARE APPLICATIONS

- Fast Fourier Transforms
- Transient Analysis
- Biomedical Signal Analysis
- Spectral Analysis
- Vibration Analysis
- Digital Filtering
- Data Acquisition
- TMS320C25 Software Development

DESCRIPTION

The PCI-20207K series are high performance Digital Signal Processing packages (DSP Paks). They contain the PCI-20202C series *Smart* Carriers and selected PCI analog input modules. The PCI-20207K series is summarized in Table 1. DSP Paks are designed for the IBM Personal Computer (PC) bus. With these products it is now possible, at low-cost, to utilize real-time DSP techniques in a wide variety of applications. Optional termination panels and ribbon cables are available to help facilitate external connections.

The *Smart* Carrier board is based upon the highly regarded Texas Instruments TMS320C25 processor. TMS320s are the most widely used, tested and supported processors available. By using this high performance signal processor, you are able to process data from 20 to 200 times faster than the PC could when used alone.

Also included in each DSP Pak is DSPview. DSPview (PCI-20205S-1) is an FFT analyzer software package. It provides an introduction to typical applications and capabilities. Because it is menu-driven, DSPview brings a working demonstration of the system's key components to all users. Useful Instruments include:

- Display of a Time Signal and its Spectrum
- Display of a Power Spectrum in a One-shot Waterfall format
- Display of a Power Spectrum in a Running Waterfall format

Comprehensive documentation is provided for both the *Smart* carrier and the I/O modules covering all aspects of installation and programming. A special menu-driven software package automatically tests the key functions of the carrier.

For additional information, please refer to the detailed *Smart* Carrier and Module data sheets found in this Handbook.

Table 1. The PCI-20207K series -- DSP Paks

DSP Pak	Carrier	Clock Rate	Analog Module	Max Sample Rate	Software Included
PCI-20207K-1	PCI-20202C-1	28MHz	PCI-20019M-1	89kHz	PCI-20205S-1
PCI-20207K-2	PCI-20202C-1	28MHz	PCI-20023M-1	150kHz	PCI-20205S-1
PCI-20207K-3	PCI-20202C-2	40MHz	PCI-20023M-1	180kHz	PCI-20205S-1

SPECIFICATIONS PCI-20207K Series -- DSP Paks

All specifications are typical at 25C unless otherwise noted.

PARAMETER	CONDITIONS	SPECIFICATION
Board Level		
Compatibility		IBM compatible
Functions		I/O and DSP
Addressing	I/O Mapped, Switchable	8 Bytes
Physical Size	*Smart* Carrier Without Modules	One Slot
	Smart Carrier With Modules	Two Slots
Temperature Range	Board Temperature	0 to 55C
Power Requirements	From PC supply, +5V	3.8 Amps
DSP Processor	Texas Instruments	TMS320C25
Speed	PCI-20207K-1/-2	
	Clock Speed	28MHz
	Time/Instruction Cycle	142nSec
	Instructions/Sec	7 million
	PCI-20207K-3	
	Clock Speed	40MHz
	Time/Instruction Cycle	100nSec
	Instructions/Sec	10 million
Memory, On-Board	Zero Wait State	
	On Carrier, Program Space	16KWords
	Data Space	16KWords
	Optional Expansion Module	
	PCI-20207K-1/-2	PCI-20201M-1
	Program Space	32KWords
	Data Space	64KWords
	PCI-20207K-3	PCI-20201M-2
	Program Space	32KWords
	Data Space	64KWords
DMA, Speed	To/From Host PC RAM	400KBytes/Sec
Size	PC/XT, Available RAM	1MByte
	PC/AT, Available RAM	16MByte
Analog Inputs		
Number of Channels		8
Resolution		12-Bits
Acquisition Speed	Using DSPview	
	PCI-20207K-1 (PCI-20019M-1)	Up to 89kHz
	PCI-20207K-2 (PCI-20023M-1)	Up to 150kHz
	PCI-20207K-3 (PCI-20023M-1)	Up to 180kHz
Rate Generator	(Timebase Generator)	1 Channel
Output Frequency	Software Programmable	TTL Pulse Output
Equation	$2 \leq n_1, n_2 \leq 65535$	
	PCI-20207K-1/-2	$3.5MHz/(n_1 \cdot n_2)$
	PCI-20207K-3	$5MHz/(n_1 \cdot n_2)$
Frequency Range	PCI-20207K-1/-2	.001Hz to 875kHz
	PCI-20207K-3	.001Hz to 1.2MHz
Output Voltage Levels	Digital High, I_{oh} = max	2.7V min
	Digital Low, I_{ol} = max	0.5V max
Output Current	Capability, Sink	24 mA
	Source	3 mA
PC Interrupts	PC Levels 2 thru 7	High/Low Edge
Serial I/O Port	Buffered TMS320C25 Port	
Speed	PCI-20207K-1/-2	3.5Mbaud
	PCI-20207K-3	5Mbaud
External Inputs	Interrupt to TMS	TTL, Deglitched
	Clock Input	To Any Module
Menu-Driven Analysis	Software	
DSPview	FFT Analyzer Software	PCI-20205S-1

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Section 12

PCI-20000 SOFTWARE SUPPORT
TABLE OF CONTENTS

*** NOTE: The PCI-20026S Series and PCI-20027S Series of software supersede the original PCI-20014S Series, PCI-20046S Series and PCI-20047S-1.**

POWERFUL SOFTWARE FOR PCI SYSTEMS

THE PCI-20000 SYSTEM

The PCI-20000 hardware system for data acquisition, test, measurement and control includes "Boards" and "Carriers" which plug into any IBM PC/XT/AT or compatible computer expansion slots (or into slots in an expansion chassis). Carriers in turn can accommodate two or three "Modules" each, that plug "piggy back" into the carrier. This combination provides the user with a modular system of real-world I/O that is extremely flexible.

Any combination of boards and modules can be selected to meet specific application requirements. This is a powerful approach that allows standard components to be specified and configured by the user into a system optimized for his individual requirements. This maximizes performance and minimizes cost, since the user needs to buy only those components required to get his job done satisfactorily.

As requirements change, different modules can be substituted to solve a new problem. As new modules are added to the product line, performance can be upgraded easily. More modules and boards can be added if requirements expand.

PCI-20000 SOFTWARE

A wide range of software packages are available for the PCI-20000. They are summarized below. More detailed data sheets appear later, after this summary. The PCI-20000 family of software supports all analog I/O, digital I/O, and counter-timer functions. Five major categories exist:

- System Assurance and Diagnostics Software
- Demonstration diskettes for selected software and hardware
- Programming Tools & Drivers
  - General-purpose
  - High-performance
  - Digital signal processing (DSP)
  - Scientific
- Applications Packages
- Additional Software, third-party products offered by other companies

SYSTEM ASSURANCE and DIAGNOSTICS SOFTWARE

- **SYSCHECK (PCI-20074S-1).** This completely menu-driven software is included with every PCI hardware system. It helps the user insure that the system has been installed successfully and that it is performing properly. Diagnostic tools are included.

DEMONSTRATION SOFTWARE DISKETTES

We offer several demonstration diskettes that provide a clear and concise overview of selected PCI-20000 products. All diskettes run on IBM (and compatible) personal computers that contain a Color Graphics Adapter (CGA) card, except where noted. For your demonstration diskettes, please contact your local sales office listed at the back of this handbook.

- **PCI-20000 System Demo (PCI-20034S-1).** This diskette presents an overview showing system capabilities, specifications, and applications. Two levels of demonstration are provided: Basic Concepts and Advanced Features.
- **PCI ControLOGraph Intelligent Data Logger Demo (PCI-20054S-1).** This demonstration presents an overview of the PCI ControLOGraph showing how it is configured and what its capabilities are.
- **LABTECH Notebook Demo (PCI-20065S-1).** This demo presents the major features of the menu-driven data acquisition and control package.
- **SNAPSHOT STORAGE SCOPE Demo (PCI-20069S-1).** This diskette shows how SNAPSHOT emulates a digital storage oscilloscope. The demo diskette simulates real-product operations.
- **RELAY LADDER LOGIC RS1000/PC Demo (PCI-20070S-1).** This demo shows how a low cost personal computer, PCI hardware, and Relay Ladder Logic software can emulate and replace a high performance programmable controller.
- **DADiSP Demo (PCI-20072S-1).** This demo shows the capabilities of the DADiSP scientific spreadsheet analysis software.
- **LABTECH CONTROL Demo (PCI-20099S-1).** This demo presents the features and capabilities of LABTECH CONTROL. It interfaces PCI hardware to industrial process monitoring and control applications with completely menu-driven software. An enhanced color graphics adapter (EGA or VGA) and color monitor are required.

GENERAL-PURPOSE SOFTWARE

General-purpose software includes a family of memory-resident hardware drivers. Known as the PCI-20026S series, these drivers are optimized for BASIC, C, and Turbo Pascal programmers. Their function is to buffer the programmer from the electrical details of PCI hardware products. As a result, the capabilities for data acquisition and control are excellent, and programming has never been easier. For special applications, the extensive group of universal "calls" can be further enhanced by adding the "High- Performance" companion products described later in this section.

- **BASIC Language Interface (PCI-20026S-1).** BASIC is the most popular of all personal computer languages. It is easy to learn and easy to use.
- **C Language Interface (PCI-20026S-2).** C is an efficient high- level language that allows high-speed operations. The PCI- 20026S-2 supports Lattice or Microsoft C compilers (through compiler version 3.X).
- **Turbo Pascal Language Interface (PCI-20026S-3).** Pascal is a structured language for organized programming, and it also provides high efficiency. Turbo Pascal is a version of Pascal published by Borland International. It is fast and is very easy to learn.
- **Combination Software Package (PCI-20026S-4).** A combination of the three software packages listed above (one each: PCI-20026S-1, PCI-20026S-2, PCI-20026S -3). This package is for the user who wants to add multiple-language programming capability to his PCI-20000 system at a greatly reduced cost compared to buying each language package separately.

Each of the PCI-20026S series packages also include:

- **Thermocouple Interfacing.** Linearization and cold-junction compensation for J, K and T thermocouples are included in each interface package at no extra cost to the user! Analog readings may be returned directly in degrees, or the user may access the linearization and compensation routines to post-process his data.
- **Tutorial and Error Checking.** Each of the PCI-20026S language support packages provides tutorial and demonstration material to aid a new user in getting started with the PCI-20000 system. Error-checking capability is included in each package with appropriate error codes to describe difficulties encountered.

HIGH-PERFORMANCE SOFTWARE

High-performance software products include the PCI-20027S and PCI-20096S series of driver packages. Both series are designed to interface with the general-purpose PCI-20026S series to greatly increase the capabilities and speed of the PCI-20000 system. In use, the PCI-20026S, PCI-20027S and PCI-20096S can be coupled together. However, only the PCI-20026S can be used alone. To gain the high speed and DMA capabilities of the PCI-20027S requires that it be coupled to the PCI-20026S (both are required). Likewise, to add the direct to/from disk features of the PCI-20096S requires that it be coupled to the PCI-20027S and the PCI-20026S (all three are required). Additional information will be found in the complete data sheets, later in this section.

PCI-20027S Series

- **BASIC Language Interface (PCI-20027S-1).**
- **C Language Interface (PCI-20027S-2).**
- **Turbo Pascal Language Interface (PCI-20027S-3).**
- **Combination Software Package (PCI-20027S-4).** A combination of the three software packages listed above (one each: PCI-20027S-1, PCI-20027S-2, PCI-20027S -3). This package is for the user who wants to add multiple-language programming capability to his PCI-20000 system at a greatly reduced cost compared to buying each language package separately.

Each of the PCI-20027S Interface Packages includes these features:

- **Optimized I/O Routines.** Internal routines are written in assembly language to provide maximum speed. Special data acquisition routines allow high data rates independent of the programming language used.
- **Assembly Language.** Each package includes detailed instructions showing how to access the assembly language routines directly. This is for the user who prefers to work in assembly language to obtain increased speed and efficiency.
- **Tutorial and Error Checking.** Each of the PCI-20027S language support packages provides tutorial and demonstration material to aid a new user in getting started with the PCI-20000 system. Error-checking capability is included in each package with appropriate error codes to describe difficulties encountered.

PCI-20096S Series

- **BASIC Language Interface (PCI-20096S-1).**
- **C Language Interface (PCI-20096S-2).**
- **Turbo Pascal Language Interface (PCI-20096S-3).**

Each of the PCI-20096S interface packages includes these features:

- **Optimized Direct To/From Disk Routines.** Internal routines are written in assembly language to provide maximum speed. Special provisions to support all DOS recognized "disk drives", including floppy disk, hard disk, and RAM disk, etc. Routines allow high data rates independent of the programming language used.
- **Assembly Language.** Each package includes detailed instructions showing how to access the assembly language routines directly. This is for the user who prefers to work in assembly language to obtain increased speed and efficiency.
- **Tutorial and Error Checking.** Each of the PCI-20096S packages provides tutorial and demonstration material to aid a new user in getting started with the PCI-20000 system. Error-checking capability is included in each package with appropriate error codes to describe difficulties encountered.

DIGITAL SIGNAL PROCESSING

Digital signal processing (DSP) techniques have been in use for a long time. However, with the introduction of the *Data Professional* family of products, DSP takes on new capabilities and application opportunities. Now, data acquisition and control processes involving complex mathematical computations can take place at unprecedented speeds. Filters, vectors, and trigonometric, windowing, interpolation, and transform functions are performed in milliseconds instead of seconds or minutes. The key to this revolution is the PCI-20202C series of *Smart* carriers. This logical extension to the PCI-20000 family of modular data acquisition hardware products is armed with an on- board Texas Instruments TMS320C25 processor. These exceptional products accept the large array of PCI analog, digital and counter/timer modules.

To insure ease-of-use, the hardware is teamed with a full complement of software support programs. To satisfy most applications, high-level language interface drivers and function libraries are included. These programs eliminate the need for the user to write assembly language code for the TMS processor. For operations requiring custom algorithms, a complete "toolbox" of code generation, test and compilation programs are available. These programming support products are described below. Spectral analysis is so common that a specific, menu-driven package has been produced for this application area. More information on DSPview can be found in the Applications section. The PCI family contains still other software products that should be considered for DSP-type applications. These include DADiSP (in the Applications section) and ASYST (in the Scientific section).

- **DSP Library Plus (PCI-20203S-1).** BASIC language support subroutine library. Provides an uncomplicated, high-performance interface between the Data Professional hardware and the programmer.
- **DSP Library Plus (PCI-20203S-2).** C language support.
- **DSP Library Plus (PCI-20203S-3).** TurboPascal language support.
- **DSP Library Plus (PCI-20203S-4).** FORTRAN language support.
- **DSP Library Plus (PCI-20203S-5).** Combination software package. Includes: PCI-20203S-1, PCI-20203S-2, PCI-20203S-3, and PCI-20203S-4.
- **DSP Software Development Pak (PCI-20204S-1).** For custom Smart carrier code generation. Includes: crossassembler, program loader, disassembler, and monitor/debugger. Requires Microsoft Macro Assembler (PCI-20208S-1).
- **DSP Carrier Drivers (PCI-20206S-1).** BASIC language high-level interface between the Smart carrier and the user's PC resident program. A companion to PCI-20204S-1.
- **DSP Carrier Drivers (PCI-20206S-2).** C language interface.
- **DSP Carrier Drivers (PCI-20206S-3).** Turbo Pascal language interface.
- **DSP Carrier Drivers (PCI-20206S-4).** FORTRAN language interface.
- **Macro Assembler (PCI-20208S-1).** Standard Microsoft Macro Assembler. Used with PCI-20204S-1 to assemble and link custom TMS320 code.

SCIENTIFIC

This category contains a family of software modules that possess a unique combination of hardware interface, analysis and graphics capabilities. ASYST can be compared to BASIC, C, or Turbo Pascal in that they are all high-level programming languages. What is different is the way in which ASYST integrates the total acquisition, analysis, and presentation process. "Calls" for hardware control, signal collection, math manipulation, statistics, automatic plotting, curve fitting, integration, convolution, FFT, signal output, and many other functions are included. The data acquisition language for serious programmers with comprehensive or complex analysis and graphic presentation requirements.

- **ASYST Module 1/Module 2 (PCI-20301S-1).** Module 1 provides System/Graphics/Statistics. Establishes environment for scientific programming language. Provides data representation, storage, math functions, text editor, file manipulation, plotting, and graphics display. Module 2 is the Analysis extension to Module 1. Reduces data with an extensive selection of analytic functions, including: integration, filtering, FFT, and curve fitting.
- **ASYST Module 3 (PCI-20301S-3).** Data Acquisition. Integrated interface couples Module 1 to PCI-20000 data acquisition and control hardware. Supports analog input, analog output, digital I/O, and counter/timer functions
- **ASYST (PCI-20301S-4).** Combination software package. Includes PCI-20301S-1 and PCI-20301S-3.

APPLICATIONS PACKAGES

- **PCI ControLOGraph (PCI-20056K-1)** Intelligent Data Logger System. While not just a software package alone, the PCI ControLOGraph System contains powerful software that provides traditional data-logger functions, plus thermocouple cold-junction compensation and linearization, engineering units conversion, auto-zero correction, auto-restart after power failure, real-time data display, spreadsheet and language-interfaces. No programming expertise is required on the part of the user. Please see the PCI-20056K-1 data sheet in section 11.
- **LABTECH NOTEBOOK (PCI-20040S-1).** This is a menu-driven software package for real-time data acquisition, process control,

and/or data analysis. LABTECH Notebook offers curve-fitting and Fast-Fourier-Transform (FFT) routines, on-line help and tutorials, graphic data display, and automatic interfacing to spreadsheet packages such as Lotus 1-2-3 and Symphony. It is excellent for users wanting a software package that requires minimum computer programming skills.

- **REAL TIME ACCESS (PCI-20065S-1).** An extension to LABTECH Notebook that supports real-time data transfers to spreadsheets or other analysis programs.
- **DADiSP (PCI-20067S-1).** A menu-driven, graphical, data analysis package that is often called a scientific spreadsheet. It performs post-acquisition signal analysis and display.
- **SNAPSHOT STORAGE SCOPE (PCI-20068S-1).** A menu-driven waveform-capture system. Useful for transient analysis and general digital oscilloscope applications.
- **SNAP-CALC (PCI-20068S-2).** An extension to SNAPSHOT that adds comprehensive math capabilities.
- **SNAP-FILTER (PCI-20068S-4).** An extension to SNAPSHOT and SNAP- CALC that adds comprehensive digital filtering capabilities.
- **SNAP-ACTION (PCI-20068S-5).** An extension to SNAPSHOT and SNAP- CALC that adds comprehensive decision making and control capabilities.
- **SNAP-GENERATOR (PCI-20068S-7).** An extension to SNAPSHOT and SNAP- CALC that adds comprehensive signal generation capabilities. Can be used in conjunction with data acquisition.
- **SNAP-STREAM (PCI-20068S-8).** An extension to SNAPSHOT that adds continuous, high speed, direct to disk storage capabilities.
- **RELAY LADDER LOGIC RS1000/PC (PCI-20073S-1).** Package for process monitoring and control. Integrates the industry standard, symbolic ladder logic language with PCI hardware to emulate a high performance programmable controller at reduced cost.
- **LABTECH CONTROL (PCI-20097S-1).** For integrated industrial monitoring and control. Menu-driven. Includes: real-world interface through PCI-20000 hardware, data logging, PID, analysis, and real-time color graphics display.
- **DSPview (PCI-20205S-1).** Menu-driven FFT analyzer software for use with Data Professional hardware. Automatically displays the time signal, and its spectrum (three formats). Provides introduction to DSP techniques.

ADDITIONAL SOFTWARE AVAILABLE FROM OTHERS

There is a large and growing body of high-performance software available for use with the PCI-20000 System. Much of this software has been developed by organizations who specialize in a particular type of software. The Additional Software Listings section features vendor-supplied information regarding selected software packages for your consideration. Each of these software packages interfaces to products within the Burr-Brown PCI-20000 product line, and each is optimized for a particular application area. We invite you to consider them for your applications.

For further information or for purchase of any of these software products, you should contact the vendor directly. Any product warranties will be provided by the vendor, not by Burr-Brown. The product information in this section is based on material supplied by the vendors. Burr-Brown assumes no responsibility for omissions or inaccuracies.

FEATURES

- Completely Menu-Driven
- Identifies Installed PCI Hardware
- Verifies Proper Operation
- Locates Possible Address Conflicts
- Input Signal Monitoring & Display
- Output Signal Generation
- Supports Periodic Calibration
- On-Line Help & Troubleshooting Hints

BURR-BROWN®

PCI-20074S-1 SYSCHECK

System Assurance and Diagnostics

DESCRIPTION

SYSCHECK is the System Assurance Utility and Diagnostics Software Package. This menu-driven product, shipped at no extra charge with each system, easily verifies proper installation and utilization of PCI system components. No computer or programming skills are required to fully utilize all of the built-in features. Not only does SYSCHECK greatly reduce the time required to confirm appropriate operation but it provides a permanent resource for periodic test and calibration. Non- programmers are provided with a fundamental way of exercising the input/output capabilities of their PCI system. This can be useful as both a product tutorial and in performing modest measurement and simulation functions. As a tutorial, SYSCHECK provides an overview of basic, PC-based, data acquisition and control hardware capabilities. Thus, SYSCHECK is well suited to technical training environments.

An automated memory map search identifies the address (location) of each PCI hardware components in the PC. Graphics are used to indicate how each device is configured and how standard software channel assignments are related to the hardware. This search also brings potential memory map conflicts to the attention of the user. If required, corrective actions are suggested. Each of the boards, carriers and modules found in the search can be exercised to confirm expected performance. The I/O functions of each product can be accessed individually.

SYSCHECK allows measurement of real-world analog, digital and counter Inputs. Conversely, the user can generate analog, digital and frequency outputs. In addition to general-purpose I/O, SYSCHECK also allows verification of the PCI-20000's direct memory access (DMA), trigger/alarm and simultaneous sample & hold capabilities.

In operation, a user can connect his signal source (thermocouple, strain gage, pressure transducer, etc.) through his actual interconnection components (termination panel, cable, etc.) to a selected channel on his analog input board or module. SYSCHECK reads and displays the result. This confirms whether the input signal is connected to the correct channel and if all sections are operational. If the input is a low-level signal, the software permits complete control of any available programmable gain amplifier (PGA) to produce an appropriate working voltage level. Noisy signals can be mathematically averaged to smooth the displayed reading.

In addition to being menu-driven, the software has easy-to-use, on-line, "help" to assist new users. Also provided are suggestions on how to take full advantage of the PCI-20000 system. A section on "diagnostic hints" provides useful troubleshooting guidelines.

PCI-20034S-1 PCI-20000 System Preview
PCI-20054S-1 ControLOGraph Demo
PCI-20064S-1 LABTECH Notebook Demo
PCI-20069S-1 SNAPSHOT Demo
PCI-20070S-1 Relay Ladder Logic Demo
PCI-20072S-1 DADiSP Demo
PCI-20099S-1 LABTECH CONTROL Preview

Preview and Demonstration Software Diskettes

FEATURES

- Provides a clear and concise overview of PCI-20000 products
- "Lifelike" PC environment promotes understanding
- No PCI hardware is required
- Works with IBM PC/XT/AT and other compatibles
- Normally supplied on 5-1/4" diskettes with easy-to-follow instructions. 3-1/2" diskettes are also available upon request.

DESCRIPTION

Each of the preview and demonstration diskettes described here are available, at no cost, from Burr-Brown sales offices and representatives worldwide. Each preview/demo is self-contained, requires no computer skills to operate, and does not require PCI hardware. Review of these disks will add valuable insight into the capabilities and specifications of the products they represent.

PCI-20034S-1 presents a general overview of the PCI-20000 System. Capabilities, specifications and applications are described. The presentation is in two levels: basic concepts and advanced features. Each level takes about 10 minutes to view. The user has complete control over presentation speed and can pause, go back, or skip ahead at will. This material can be a valuable aid in system configuration as well as an appropriate source of background information for management and engineering.

PCI-20054S-1 presents a general overview of the PCI ControLOGraph data acquisition and control system. The ControLOGraph is a menu-driven software package specifically designed for data logging applications. Capabilities, specifications and applications are described. The presentation includes two levels: basic concepts and advanced features. Each takes about 10 to 15 minutes to view. The user can control the speed of presentation by pausing if desired. This material is valuable for both the potential end user and as an appropriate source of background information for management and engineering.

PCI-20064S-1 provides a general overview of LABTECH NOTEBOOK. NOTEBOOK is a menu-driven software package for data acquisition and control. Capabilities and applications are suggested. Viewing takes about 10 minutes. The user can control the presentation rate. This material is valuable for both the potential end user and as an appropriate source of background information for management and engineering.

PCI-20069S-1 provides a general overview of SNAPSHOT STORAGE SCOPE. SNAPSHOT is a menu-driven data acquisition system that emulates a digital storage oscilloscope. Capabilities and applications are suggested. The user can simulate real product operations. This material is valuable for both the potential end user and as an appropriate source of background information for management and engineering.

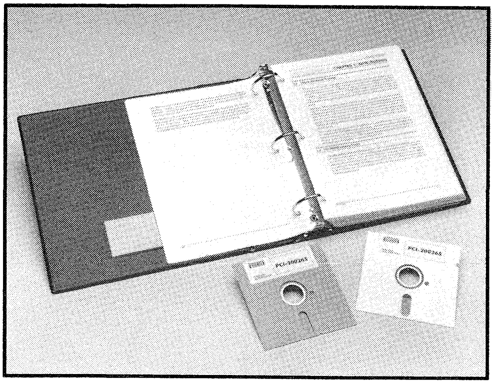
PCI-20070S-1 provides an overview of "Relay Ladder Logic". Relay Ladder Logic is a menu-driven data acquisition and control program which uses the relay ladder symbology common in programmable logic controllers. Features and capabilities are described in this 15 minute demonstration. This material is valuable for both the potential end user and as an appropriate source of background information for management and engineering.

PCI-20072S-1 provides a general overview of DADiSP. DADiSP is a menu-driven, post-acquisition, data analysis and display software package. It is a spreadsheet-type product that operates on entire waveforms. Capabilities and applications are suggested. This material is valuable for both the potential end user and as an appropriate source of background information for management.

PCI-20099S-1 provides both an overview and a realistic demonstration of LABTECH CONTROL's capabilities and applications. LABTECH CONTROL is a menu-driven integrated industrial monitoring and control package. It includes a "real-world" interface through PCI-20000 hardware, data logging, PID control, analysis, and user configurable real-time process oriented color graphics displays. The demo is also menu-driven and contains material that is valuable for the potential end user and also for management as a source of background information.

REQUIREMENTS

All demos require an IBM-compatible personal computer. Most with operate with any color graphics adapter (CGA, EGA, or VGA). A color monitor is recommended, however, a monochrome monitor will suffice in many cases. LABTECH CONTROL requires an extended graphics adapter (EGA or VGA) and a color EGA or VGA monitor.



BURR-BROWN®

PCI-20026S-1 BASIC Language Interface
PCI-20026S-2 C Language Interface
PCI-20026S-3 TURBO PASCAL Language Interface
PCI-20026S-4 Combination Software Package containing PCI-20026S-1, PCI-20026S-2, and PCI-20026S-3

Software Drivers Language Support Libraries

FEATURES

- Interfaces PCI Hardware to BASIC, C, TURBO PASCAL, and Assembly languages
- Compatible with PC/MS DOS, version 2.0 or higher
- Easy-to-use high-level commands
- Eliminates the need for the programmer to be familiar with the details of the hardware

DESCRIPTION

The PCI-20026S series of software support packages are members of a family of memory-resident drivers. Each is designed to provide an uncomplicated, consistent and useful interface between several of the most popular high-level languages and the PCI- 20000 hardware system. All goals are realized by buffering the programmer from the internal details by offering a set of commands to invoke the major hardware functions. Therefore, no detailed knowledge of the hardware is required. The PCI-20026S series contains many general purpose functions that operate in any IBM PC/XT/AT or compatible computer. The operating system can be PC or MS DOS, version 2.0 or greater. A summary of the available calls is found below. High speed, DMA, and direct to/from disk capabilities can be easily added by utilizing the families' companion products, the PCI-20027S and PCI-20096S series. Details on these products follow this data sheet.

BASIC, C, and TURBO PASCAL were selected because of their wide user base and general acceptance. However, all of the PCI-20026S packages can be used directly from Assembly language if desired. Error checking is provided to help eliminate potential difficulties. Tutorial material, including detailed sample programs in each language, offers assistance to new users.

Please refer to the Speed Summary Tables in the Configuration Section (Section 10) of this handbook for performance information and a comparison of language speeds.

NOTE: The PCI-20026S and PCI-20027S series of software drivers supersede the original PCI-20014S, PCI-20046S Series and PCI-20047S-1.

BASIC - BASIC has gained wide acceptance as a general-purpose language because it is easy to learn and utilize. Program development time is generally short. However, in comparison to other languages, its execution time is slow.

IBM BASIC A through version A3.10 is supported. Other true compatibles such as Compaq BASIC and GWBASIC, can also be used.

Microsoft QuickBASIC Compiler version 4.5 is supported. Compiling BASIC code increases its execution speed about five times.

IBM BASIC Compiler is also supported, with some limitations.

C - C is a versatile language that is respected by sophisticated programmers. Existing subroutines and libraries can be linked together to build a given application. Direct access to the computer is available. In contrast, however, C is considered cryptic and harder to learn than other languages. The execution speed of C is about seven times that of interpreted BASIC.

Microsoft C Compiler version 4.0, 5.0, and 5.1 and Lattice C Compiler thru version 3.0 are supported. Borland TURBO C version 2.0 is also supported.

TURBO PASCAL - TURBO PASCAL is considered very user friendly, with a host of built-in tools for I/O transactions. It is highly recommended for new programmers. Turbo offers all the power that a DA&C application requires, along with the speed of C, without much of the hassle. The relative execution speed of TURBO PASCAL is about seven times that of interpreted BASIC.

Borland TURBO PASCAL through version 5.0 is supported.

APPLICATIONS EXAMPLE FOR PCI-20026S SERIES

"Read an analog input channel."

BASIC

```
"
"     'Include the Driver Interface Header
"     'Initialize the Hardware & Software
"
120 CHN=5        'Define Channel 5
130 GAIN=10      'Define Gain=10(for Ch 5)
140 ZERO=0       'Autozero with respect to Ch 0
150 RANGE=2      'Define that A/D is on Bipolar range
"
"    'Possible other tasks
"
230 CALL CNF.AI (CHN, GAIN, ZERO, RANGE) 'Configure Input
240 CALL READ.CH (AI, CHN, DATA)         'Read Analog Input
"
"
"     '"Process/Manipulate/Display Data"
"     'etc....
"     'etc......
   END
```

C

```
cnf_ai (chn, gain, zero, range);
data=read_ch (ai, chn);
```

Turbo Pascal

```
Procedure CNfAI (CHn, Gain, Zero, Range);
Data=Read Ch (AI, Chn);
```

COMMAND SUMMARY -- PCI-20026S SERIES

Utility Calls

ERR.SYS	Return the last error code
INIT	Initialize the system hardware
SETVEC	Sets the dispatch vector
SYSINIT	Initialize the system hardware

Configuration Calls

CNF.AI	Configure an analog input channel
CNF.BG	Configure burst generator
CNF.CNTR	Configure a counter channel
CNF.DI	Configure a digital input
CNF.DO	Configure a digital output
CNF.HDI	Configure handshake digital input
CNF.HDO	Configure handshake digital output
CNF.JMPS	Configure software jumpers
CNF.LCT	Configure 32-bit counter
CNF.LD	Configure 32-bit divider
CNF.RG	Configure a rate generator
CNF.RTD	Configure an RTD input
CNF.SCT	Configure 16-bit counter
CNF.SD	Configure 16-bit divider
CNF.TCPL	Configure a thermocouple input
CNF.TRIG	Configure a trigger/alarm module
CNF.VDCG	Configure variable duty cycle generator

Read Calls

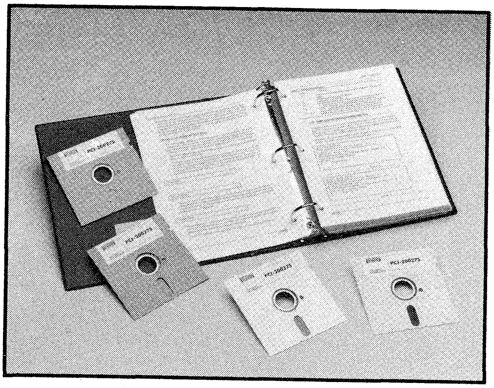
READ.CH	Read any input channel
READ.CTS	Read a group of three counters simultaneously
READ.FRQ	Read the frequency of a TTL input
READ.LCH	Read input channel in long value format
READ.LS	Read signal from 32-bit device
READ.SS	Read signal from 16-bit device
READ.SSH	Read simultaneous sample/hold inputs
STAT.CNT	Read a counter value and status
STAT.HD	Query status of a handshake DI/O port

Write Calls

WRITE.CH	Write a value to any output channel
WRITE.GR	Write a group of analog outputs simultaneously

Miscellaneous Calls

CVT.RTD	Linearize RTD data and return temperature
CVT.TCPL	Linearize and compensate thermocouple data
SOFT.INTR	Generate a software interrupt



BURR-BROWN®

PCI-20027S-1 BASIC Language Interface
PCI-20027S-2 C Language Interface
PCI-20027S-3 TURBO PASCAL Language Interface
PCI-20027S-4 Combination Software Package containing PCI-20027S-1, PCI-20027S-2, and PCI-20027S-3

High-Performance, High-Speed Software Driver Extension

FEATURES

- Supports Data Files Up to the Limit of Available 640k RAM
- Supports Direct Memory Access (DMA)
  - Up to 360k bytes/s I/O transfers
  - Analog, digital, and counter data can all be transferred simultaneously
- Supports High-Speed Analog Data Acquisition, up to 180kHz
- Provides for Pre-Trigger and Post-Trigger Data Recording
- Supports PCI-20000 Boards, Carriers, and Modules
- Has Easy-to-Use High-Level Commands. Programmer needs only limited familiarity with hardware details
- Choice of Language Interface: BASIC, C, and Turbo Pascal

DESCRIPTION

The PCI-20027S series are high-performance, memory-resident, software drivers. They provide easy-to-use direct memory access (DMA) and high-speed data acquisition capabilities. A list of the available commands is shown below in the Command Summary Table. The PCI-20027S series operates in conjunction with the PCI-20026S series drivers. PCI-20027S is an add-on or extension to the PCI-20026S. It can not be used alone. Both driver sets are designed for IBM PC/XT/AT and compatible personal computers running PC or MS DOS version 2.0 or greater. The drivers provide language interface support for PCI-20000 data acquisition, test, measurement and control hardware.

The PCI-20027S series is a collection of high-level calls which can be invoked from BASIC, C, or TURBO PASCAL languages. The programmer does not need to have a detailed knowledge of the hardware to use these calls. All routines are internally written in assembly language to insure the highest possible speed and performance.

The DMA calls offered by the PCI-20027S series allow analog, digital, and counter data transfers to occur simultaneously. The foreground/background feature allows the user to start a DMA process, and then while DMA is operating, to perform whatever other functions are desired in the user's programming language. For example, DMA can be used to collect analog input data and to store it in memory in the background. At the same time the foreground program (under user software program control) can be performing display, analysis, or control functions. DMA transfers allow data files greater than 64k bytes, up to the limit of the available 640K RAM (as recognized by DOS). Data files can be written to and read from simultaneously. Multiple buffers can be allocated.

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The PCI-20027S series supports the maximum DMA speed possible with the PCI-20000 system. Please note that in many cases the speed DMA transfers in the IBM PC is faster than the speed in the IBM AT because of the IBM AT's internal architecture. Please refer to the Language Independent Speed Summary Table in the configuration section (Section 10) of this handbook, for speed guidelines.

The PCI-20027S series also supports non-DMA high-speed data acquisition calls. They allow users to make "block-mode" readings, and to specify the channels to be read, the sampling frequency, and the number of samples to be acquired. The sampling frequency can be provided by an internal hardware pacer clock or it can come from an external source. Throughput rates are shown in the Speed Summary Table.

Other extremely important data acquisition, test, measurement, and control functions are supported. The multiple I/O function capability allows a user to input a variety of input types all at the same time, or output a variety of output types at the same time. For instance, the user can read analog inputs, digital inputs, and counter inputs with the same DMA setup. In the same manner, the user can write analog outputs and digital outputs with one DMA setup. Often it is highly desirable to examine the data acquired just before and just after a specified trigger event. The PCI-20027S series also provides for this important pre-trigger/post-trigger function.

PCI-20027S series COMMAND SUMMARY

Buffer Utilities

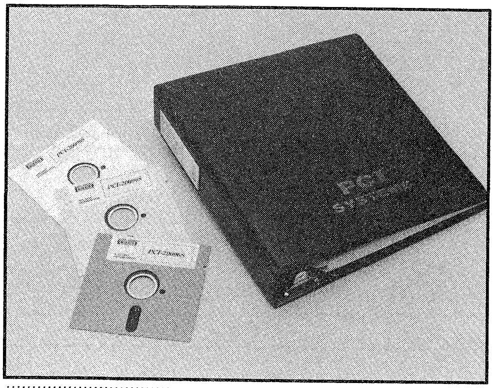
BUF.DEC	Decodes and returns data to a user's array
BUF.ENC	Encodes and writes data to a user's array
BUFLOC	Return address and pointers for a buffer
BUFSEEK	Moves location pointer within a data buffer
BUFSIZE	Sets up buffers and buffer sizes
CHGBUF	Changes active buffer

High Speed Analog Acquisition Calls

CNF.HS	Configure a high-speed data acquisition
HS.RUN	Execute a high-speed data acquisition

DMA Acquisition Calls

CNF.DMA	Configure a DMA channel list
DMA.BUF	Assign a DMA buffer
DMA.RUN	Start a DMA data acquisition
DMA.STAT	Returns the status of a DMA run
DMA.STOP	Stop a DMA operation
DMA.SWAP	Switches to a second buffer



BURR-BROWN®

PCI-20096S-1 Basic
PCI-20096S-2 C Language
PCI-20096S-3 Turbo Pascal

TURBO Stream Direct To/From Disk Software Drivers

FEATURES

- Up to 191 KBytes/Second Transfer Rate to Hard Disk
- Acquire Data to Disk Directly from Analog/Digital/Counter Hardware
- Writes Data directly to RAM, Floppy and Hard Disks
- Outputs Data from Disk directly to Analog/Digital Hardware
- Data Files can be as big as available Disk
- Interfaces to BASIC, C, TURBO PASCAL & ASSEMBLY LANGUAGES
- Compatible with PCI-20026S and PCI-20027S Series Software
- Easy to use High-Level Commands
- Eliminates the need for the programmer to be familiar with the details of the hardware

DESCRIPTION

TURBO Stream, the PCI-20096S series of direct-to/from-disk software products, is designed to provide an uncomplicated and useful interface between the PCI-20000 system and all forms of mass storage in your PC. These "Drivers" maintain high performance while avoiding the complexities of Assembly language. All goals are realized by offering the programmer a set of "commands" to invoke desired functions. This effectively "buffers" the user from the internal details of the hardware. Direct memory access (DMA) techniques are used to maximize speed. In addition to storing data to disk, data files can be read from disk to any PCI output device (analog or digital). Speeds up to 191KBytes/second are readily accomplished on some machines. A speed test utility call is provided to help predict performance for a specific configuration.

TURBO Stream is an addition to the PCI family of modular software products. This software module is intended to be used in conjunction with the PCI-20026S series and the PCI-20027S series of software products (both are required). In addition, TURBO Stream also supports the former PCI driver family, which included the PCI-20046S series and the PCI-20047S-1 software products. TURBO Stream gives the programmer the ability to conveniently utilize all available storage media. This includes hard disks, floppy disks and RAM disks. The size of a data file is limited only by the size of accessible media. IBM or Microsoft DOS, version 3.0 or greater, is also required.

The most widely used software language families are supported. These include BASIC, C and TURBO PASCAL. However, all of the PCI modular driver packages can be used directly from Assembly language if desired. Error checking is provided to help eliminate difficulties. Tutorial material, including detailed sample programs in each language, offers assistance to new users.

BASIC--IBM BASICA, thru version A3.10, is supported. Other compatibles, such as COMPAQ BASIC and GWBASIC, can also be used.

Microsoft QuickBASIC, compiler, version 4.5 is supported.

IBM BASIC COMPILER, thru version 2.00 is supported, with some limitations.

C--MICROSOFT and **LATTICE C COMPILER**s, thru version 3.00, are supported. Microsoft versions 4.xx, and 5.xx are also supported, as is **BORLAND TURBO C** version 2.0

TURBO PASCAL--BORLAND TURBO PASCAL, thru version 5.0, is supported.

COMMAND SUMMARY - PCI-20096S Series

CONFIGURATION CALLS

CNF.DTD--Configure Direct to Disk

READ/WRITE CALLS

DTD.RUN--Conducts the Disk Read/Write operation

UTILITY CALLS

DTD.SEEK--Locates a given data record

DTD.XFER--Moves Data Segments between files and memory

DTD.TIMER--Determines the approximate maximum throughput rate

SPECIFICATIONS - PCI-20096S Series Software Libraries

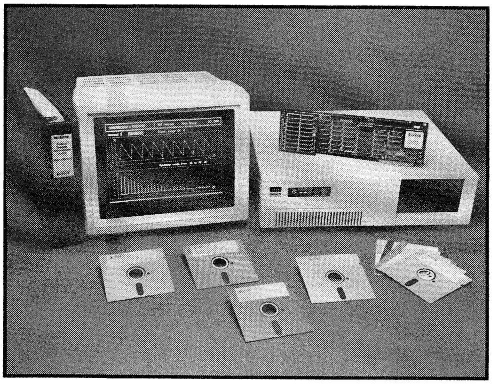
PARAMETER	CONDITIONS	SPECIFICATION
Distribution Media	360 KByte Format	5.25" Floppies
Language Interfaces	Microsoft BASIC Microsoft C Borland TURBO PASCAL	PCI-20096S-1 PCI-20096S-2 PCI-20096S-3
Compatible Hardware Carriers	Data Acquisition & Control DMA Required	Burr-Brown PCI-20041C-3 PCI-20098C-1
Boards		PCI-20091W-1
Modules	Analog Input, General Purpose Analog Input, High Speed Analog Input, Very High Speed Analog Input, Channel Expander Analog Output, 12-Bit Resolution Analog Output, 16-Bit Resolution Digital I/O Counter/Timer	PCI-20002M-1 PCI-20019M-1 PCI-20023M-1 PCI-20031M-1 PCI-20003M-2,4 PCI-20006M-1,2 PCI-20004M-1 PCI-20007M-1
Software Functions	Please see Data sheet text for additional details	DTD.SEEK DTD.XFER DTD.TIMER CNF.DTD DTD.RUN
Speed Benchmarks Inputs(1)	IBM PC, 4.77 MHz *Standard* 286, 6 MHz(2) *Standard* 286, 8 MHz(2) *Standard* 286, 8 MHz(3) *Standard* 286, 8 MHz(4) *Standard* 386, 16 MHz(2) IBM PC/AT, 8 MHz	60 KBytes/Sec 121 KBytes/Sec 132 KBytes/Sec 191 KBytes/Sec 180 KBytes/Sec 141 KBytes/Sec 162 KBytes/Sec
Outputs(1)	*Standard* 286, 8 MHz(2) *Standard* 286, 8 MHz(4)	136 KBytes/Sec 180 KBytes/Sec
Requirements Computer Operating System Related Software	IBM or Microsoft	IBM PC Compatible DOS 3.0 or Greater PCI-20026S Series PCI-20027S Series

Notes: 1) Performance is shown in Bytes/Second. Please note that analog data transfers require more than one byte. Analog inputs require two bytes while analog outputs require three bytes.

2) With Miniscribe 6053 43MByte hard disk.

3) With Miniscribe 3650 65MByte hard disk and ADAPTEK ACB 2372 controller.

4) To extended memory RAM disk.



BURR-BROWN®

PCI-20203S Series

DSP LIBRARY PLUS

High-Level Language Interface

FEATURES

- Supports:
  - Analog Inputs and Outputs
  - Vector Operations
  - Trigonometric Functions
  - Autocorrelation and Crosscorrelation
  - Filtering
  - Window Functions
  - Fourier Transforms
  - Interpolation and Decimation
  - Data Transfer
  - User-Defined Library Routines
- Optimized for High Speed, System is up to 200 times faster than PC alone
- High-Level Language Interface for BASIC, C, TURBO PASCAL, and FORTRAN
- Compatible with PCI-20202C *Smart* Carrier System
- No TMS320 Assembly Language. Programming Required

APPLICATIONS

- Data Acquisition
- Digital Filtering/Windowing
- Fourier Transforms
- Spectrum/Signal Analysis
- Automatic Test Equipment

DESCRIPTION

DSP Library Plus is an extensive collection of subroutines for data acquisition and digital signal processing applications. Designed to run on the PCI-20202C series *Smart* Carriers, this software offers unprecedented ease of use and speed of operation. DSP algorithms in this library will run from 20 to 200 times faster than conventional algorithms running on the PC alone.

The library consists of three major parts:

- TMS Assembly Code to operate the hardware
- A Language Dependent Header File
- A High-level language interface

The first part is a program that resides within RAM on the *Smart* Carrier. This code (written in TMS320 assembly language) is executed directly by the TMS320C25 processor. It performs all of the signal processing computations at very high speed. Control of the analog input and output operations (A/D and D/A) is also performed at this level. Table 1 lists the input/output modules currently supported by the library. The second portion of the library consists of a software module that is included at the beginning of the application program. This code allows users to communicate with the system from the familiar environment of their favorite high-level language. Interfaces for BASIC, C, TURBO PASCAL, and FORTRAN are now available. The third portion of the library resides within the host PC's RAM. It is this code that links the PC to the *Smart* Carrier. Running under the MS DOS operating system, this code insures compatibility for all IBM PCs and true compatibles. All data conversions and computations are invoked through standard subroutine calls. Communication between the application program and the memory resident functions are through a user-defined interrupt dispatch vector. The code to read this vector is included within the supplied header file. There is no TMS assembly code to write, and a detailed understanding of the hardware is not required. Library calls can be concatenated to avoid intermediate data transfers between the

Smart carrier and the host PC. This minimizes overhead and optimizes the speed of applications requiring multiple operations. A diagram illustrating the functional structure of DSP Library Plus is shown in Figure 1. DSP Library Plus includes the drivers found in PCI-20206S. Additional drivers are not required.

While a given library package can only support one language, it is acceptable to load several library versions simultaneously. This permits more than one language to be used at the same time.

Model Number	Description
PCI-20002M-1	Analog Input, 12-bit resolution, Single- Ended/Differential, Programmable Gain
PCI-20003M-2	Analog Output, 12-bit resolution, 2 channels (V_{out})
PCI-20003M-4	Analog Output, 12-bit resolution, 2 channels (V_{out} or I_{out})
PCI-20006M-1	Analog Output, 16-bit resolution, 1 channels (V_{out})
PCI-20006M-2	Analog Output, 16-bit resolution, 2 channels (V_{out})
PCI-20019M-1	High Speed Analog Input, 12-bit resolution, Single- Ended
PCI-20023M-1	Very High Speed Analog Input, 12-bit resolution, Single-Ended

Table 1. A Summary of PCI Input/Output Modules Supported by DSP Library Plus.

DSP Library Plus can fit within 12KWords of the Smart Carrier's program memory. An additional version, containing a very fast 256 point FFT routine, is also included, and requires 29K Words of program memory. Memory expansion is available using the PCI-20201M series modules.

The DSP Library Plus structure enables the user to add his own application-specific subroutines to be executed by the *Smart* Carrier. Complete software development tools are available in the DSP Software Development Package (PCI-20204S-1).

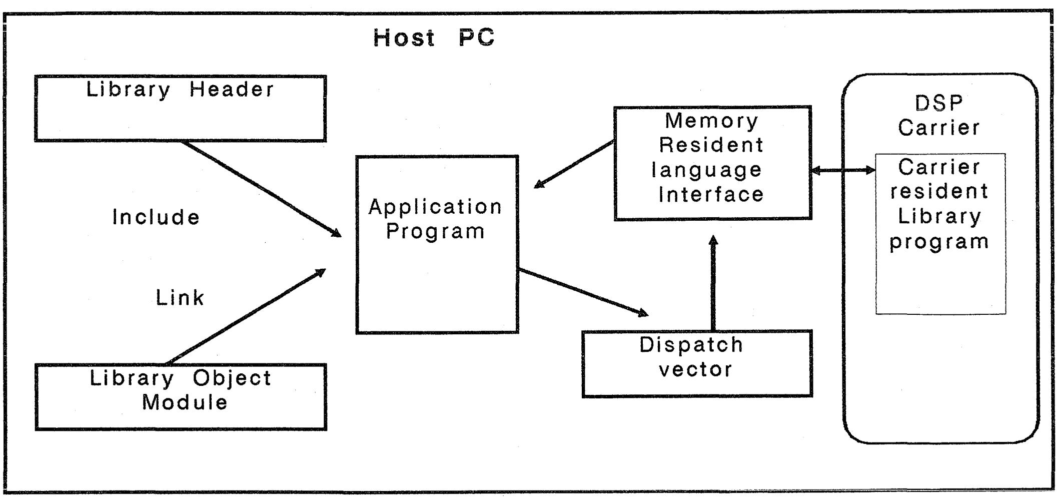


Figure 1. The structure of DSP Library Plus.

Table 2. DSP Library Plus Functions

A/D AND D/A CONVERSION FUNCTIONS SUPPORTED:

SETAD	Initialize and A/D Module	**STPCLK**	Stop the Pacer Clock
SETDA	Initialize a D/A Conversion	**CHKDA**	Status of Background D/A
SETFRQ	Initialize the Pacer Clock	**ADIN**	Wait Mode A/D Conversion
DAOUT	Wait Mode D/A Conversion	**STRTAD**	Background A/D Conversion
SRTCLK	Start the Pacer Clock	**CHKAD**	Status of Background A/D Conversion
STRTDA	Background D/A Conversion		

DATA TRANSFER FUNCTIONS SUPPORTED:

SDMADR	Sets DMA Buffer Pointer	**PCDMAW**	Data Transfer to the Smart Carrier
GDMADR	Gets DMA Buffer Pointer	**PCDMAR**	Data Transfer from the Smart Carrier
DSPCOP	Copies Buffers and Shifts Data		

VECTOR OPERATIONS SUPPORTED:

VMOV	Vector Move	**VICLP**	Vector Inverse Clipping
VSSUB	Vector Scalar Subtraction	**VSUB**	Vector Subtraction
VNEG	Vector Negation	**VBNB**	Vector Bounding
VSMUL	Vector Scalar Multiplication	**VMUL**	Vector Multiplication
VABS	Vector Absolute Value	**VIBND**	Vector Inverse Bounding
VSDIV	Vector Scalar Division	**VDIV**	Vector Division
VSUM	Vector Sum	**VMAX**	Maximum of a Vector
VCLIP	Vector Clipping	**VSADD**	Vector Scalar Addition
VADD	Vector Addition	**VMIN**	Minimum of a Vector

CORRELATION FUNCTIONS SUPPORTED:

ACFD	Autocorrelation Function, Double Precision	**CCFD**	Crosscorrelation Function, Double Precision
ACFS	Autocorrelation Function	**CCFS**	Crosscorrelation Function

TRIGONOMETRIC FUNCTIONS SUPPORTED:

DSPSIN	Sine	**DSPLOG**	Log_{10}
DSPLIN	Log_e	**DSPPWR**	$Log(Re^2+Im^2)$
DSPCOS	Cosine	**DSPMAG**	$SQRT(Re^2+Im^2)$

FILTER FUNCTIONS SUPPORTED:

FIR	Linear-Phase Filter Design Program	**IIRINI**	Initialization of IIRFIL
IIR	Recursive Filter Design Program	**FIRFIL**	Filtering of Data Sequence with FIR Filter
FIRLOD	Loads FIR Filter Coefficients into Smart Carrier	**IIRFIL**	Filtering of Data Sequence with IIR Filter
IIR_LOD	Loads IIR Filter Coefficients into Smart Carrier	**FIRBNK**	Frequency Sampling Filter
FIRINI	Initialization of FIRFIL	**RAVEG**	Running Average

WEIGHTING FUNCTIONS SUPPORTED:

HAMW	Hamming Window	**BINW**	Binary Window
HANW	Hanning Window	**H512**	Hamming Window, 512 Points
H128	Hamming Window, 128 Points	**TRIANG**	Triangular Window

FOURIER TRANSFORM FUNCTIONS SUPPORTED:

FF64	Radix-2 FFT of 64 complex or 128 real values with windowing	**FFWIND**	Load a user supplied FFT window
FF128	Radix-2 FFT of 128 complex or 256 real values with windowing	**FF512**	Radix-2 FFT of 512 complex or 1024 real values with windowing
FF256S	Radix-4 Straight line FFT of 256 complex or 512 real values	**FF1024**	Radix-2 FFT of 1024 complex or 2048 real values with windowing
FF256	Radix-2 FFT of 256 complex or 512 real values with windowing	**FF2048**	Radix-2 FFT of 2048 complex or 4096 real values
		FF4096	Radix-2 FFT of 4096 complex or 8192 real values
FFINIT	Initialize FFT Data Tables values		

INTERPOLATION AND DECIMATION FUNCTIONS SUPPORTED:

DOWNIN	Initialization of DOWN	**ISPLIN**	Spline-Interpolation
DOWN	Filtering and Down-Sampling		
IPOLIN	Initialization of IPOL		
IPOL	Filtering and Interpolation		

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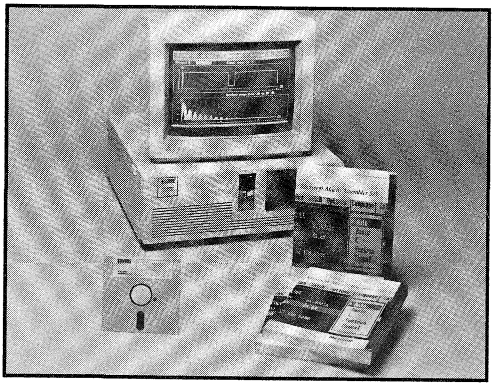
SPECIFICATIONS -- PCI-20203S Series Software Libraries

PARAMETER	CONDITIONS	SPECIFICATION
Distribution Media	360 KByte Format	5.25" Floppies
Language Interfaces	Microsoft BASIC	PCI-20203S-1
	Microsoft C	PCI-20203S-2
	Borland TURBO PASCAL	PCI-20203S-3
	Microsoft FORTRAN	PCI-20203S-4
	All Four Languages	PCI-20203S-5
Compatible Hardware	Data Acquisition & Control	Burr-Brown
Smart Carrier	TMS320C25 board	PCI-20202C-1,-2
Memory Expansion	Module	PCI-20201M-1,-2
Analog Input	Module, General Purpose	PCI-20002M-1
	Module, High Speed	PCI-20019M-1
	Module, Very High Speed	PCI-20023M-1
Analog Output	Module, 12-Bit Resolution	PCI-20003M-2,-4
	Module, 16-Bit Resolution	PCI-20006M-1,-2
Software Functions		See Table 2.
Speed Benchmarks	PCI-20202C-2 (40MHz)	
Looped Algorithms	FFT of 64 Complex Values	1.3 mS
	FFT of 128 Complex Values	2.3 mS
	FFT of 256 Complex Values	4.6 mS
	FFT of 512 Complex Values	9.4 mS
	FFT of 1024 Complex Values	20 mS
Straight Line Algorithm	FFT of 256 Complex Values (Requires Memory Expansion)	2.5 mS
Memory Requirements	*Smart* Carrier Program Memory	
Complete Library	Including:	
	Looped FFT Algorithms	12KWords
	Straight Line FFT Algorithm	29KWords



BURR-BROWN®

PCI-20204S-1 DSP Software
PCI-20208S-1 Macro Assembler

DSP Software Development Pak Crossassembler, Disassembler and Monitor/Debugger

FEATURES

- Designed for the Texas Instruments TMS320C25 Signal Processor
- Can be used on all IBM PC Compatible Machines running MS DOS
- Compatible with the PCI-20202C Series *Smart* Carrier Systems
- Compatible with the PCI-20206S Series of *Smart* Carrier Drivers
- Supports TMS320 Program Generation, Test, and Optimization

APPLICATIONS

- Custom Algorithm Development and Evaluation
- Digital Filtering
- Data Acquisition and Control
- Vibration Analysis
- Audio Synthesis
- Pattern Recognition
- Process Control

DESCRIPTION

The PCI-20204S-1 DSP Software Development Package provides full program development capabilities for the industry standard signal processor, the Texas Instruments TMS320C25. A Crossassembler, Disassembler, and Monitor/Debugger are provided. To further ease the software development process, the DSP Software Development Package is fully compatible with the PCI-20206S series of DSP Carrier Drivers.

The crossassembler consists of a set of macro definitions for the Microsoft Macro Assembler (available separately from Burr-Brown as the PCI-20208S-1). The advantages of using this macro assembler are the full use of the extensive macro facility, and use of the standard MS DOS linker to link modules that were assembled separately. The crossassembler can be used on all IBM PC Compatible machines running under the MS DOS operating system. Programs for the Smart Carrier can be written with a standard text editor such as Wordstar or Word. The recognized TMS320 mnemonic opcodes and the operand syntax conform with the definitions in the Texas Instruments TMS320C25 User's Guide. A utility is included to load the assembled and linked program into the *Smart* Carrier (PCI-20202C series).

Once the code is written, assembled and linked into a TMS executable file by the cross-assembler, the Monitor/Debugger can be used to interactively test and debug it. All of the carrier's resources including program memory, data memory, TMS processor registers, and carrier control registers can be interactively displayed or modified.

The Monitor/Debugger includes facilities for loading the program onto the carrier, single stepping, and setting or clearing of breakpoints. Up to 10 breakpoints can be set. Breakpoints can be activated immediately, or after a preprogrammed number of occurrences.

A separate disassembler is also provided with the package. This program will disassemble code residing on the carrier. Output can be sent directly to the screen or to a file. In the screen option, two windows are provided. The user can select any section of the code to appear in either window.

Example and demonstration programs are included in the complete manuals to assist users. Comprehensive error flagging is incorporated and the error codes are generally self explanatory.

SUMMARY of ASSEMBLER AND DISASSEMBLER COMMANDS and FUNCTIONS:

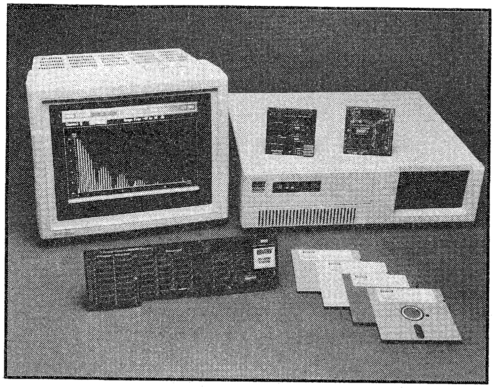
AORG	Absolute Origin Directive	**QUIT**	Return to DOS
.WORD	Define a Word in Program Memory	**START**	Defines the Start Address of the code to be disassembled
.dbas	Define Data Address		
.TDATA	Assigns a name to the value of a data location counter	**END**	Defines the End Address of the code to be disassembled
.debug	Invokes Debug option	**FILE**	Name of the File where code is written to
DIS	Start Disassembling		

SUMMARY of MONITOR/DEBUGGER COMMANDS and FUNCTIONS:

DPM	Dump Program Memory	**WPO**	Write to Port
DDM	Dump Data Memory	**RPO**	Read Port
DIR	Display Internal Registers	**SBP**	Set Breakpoints
DER	Display External Registers	**DBP**	Display Breakpoints
MPM	Modify Program Memory	**CBP**	Clear Breakpoints
IPM	Initialize Program Memory	**EXE**	Execute Program
MDM	Modify Data Memory	**RUN**	Run Program
CDM	Clear Data Memory	**SST**	Single Step
FDM	Fill Data Memory	**BSE**	Number Base Selection
MIR	Modify Internal Registers	**HLP**	Help Information
MER	Modify External Registers	**END**	End Monitor
FDD	Find Value in Data RAM	**STA**	Start Program
FDP	Find Value in Program RAM	**SNP**	Snapshot, execute breakpoints with set number of loops
CEI	Clear External Interrupt		

SPECIFICATIONS PCI-20204S-1, PCI-20208S-1

PARAMETER	CONDITIONS	SPECIFICATION
Distribution Media	360 KByte Format	5.25" Floppies
Compatible Hardware	Data Acquisition & Control	Burr-Brown
Smart Carrier	TMS320C25 board	PCI-20202C-1,-2
Memory Expansion	Modules	PCI-20201M-1,-2
Input/Output	Modules	All PCI-20000
Computer Requirements		IBM PC Compatible
Operating System		MS/PC DOS
Software Function		
Crossassembler, Disassembler, Monitor/Debugger	Requires Macro Assembler	PCI-20204S-1
Macro Assembler	Microsoft	PCI-20208S-1
DSP Carrier Drivers	Provides High-Level Control & Communication Capability	PCI-20206S Series



BURR-BROWN®

PCI-20206S Series
DSP Carrier Drivers Software

FEATURES

- Compatible with the PCI-20202C series *Smart* Carrier System
- Compatible with the DSP Software Development Package (PCI-20204S-1)
- Provides a High-Level Language Interface to the Hardware from: BASIC, C, TURBO PASCAL and FORTRAN
- No Detailed Knowledge of the Hardware is Required
- Supports all Control and Communications Functions Including DMA

APPLICATIONS

- Development of Custom DSP Applications
  - Digital Filtering
  - Data Acquisition and Control
  - Vibration Analysis
  - Audio Synthesis
  - Machine Heath Monitoring
  - Process Control

DESCRIPTION

The PCI-20206S series of DSP Carrier Drivers give the user a simple and consistent method of communicating with the *Smart* Carrier from his high-level language program. These drivers are useful for those who have created their own TMS320C25 programs using the PCI-20204S Software Development Pak. They provide an easy method of loading programs onto the carrier, starting and stopping program execution, passing parameters to and from the carrier's TMS program and transferring data between the PC and the carrier. The drivers act to minimize the need for a detailed knowledge of the *Smart* Carrier. This is accomplished by a family of mnemonic commands that translate the desired functions into the required hardware register statements. There are routines to handle almost every form of communications and control that is needed while using the *Smart* Carrier. Use of the drivers also reduce the chance of making errors in control or communications protocol. Several of the most popular high-level languages are supported, including: BASIC, C, TURBO PASCAL and FORTRAN.

The drivers themselves are memory resident routines that are normally loaded when the computer boots up. The user's application program can call the necessary drivers as needed. Header files, which are provided for each language, serve to direct a given call statement to the appropriate memory address. Calls are made through a user defined interrupt dispatch vector. This permits the use of multiple interface languages at the same time. In addition, several *Smart* Carriers can be installed in the same computer.

Example code is included in the complete User Manual. Comprehensive error flagging is incorporated and the error codes are generally self explanatory.

In addition to being available separately, the equivelent of the PCI-20206S DSP Carrier Drivers are imbeded in the PCI-20203S DSP Library Plus.

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SUMMARY OF INITIALIZATION FUNCTIONS:

PCINIT	Initialize a carrier unit	**PCBACK**	READ an array from memory
PC_OPT	Set system OPTIONS	**LOADF**	LOAD a program onto the carrier
PC_ERR	Find the last ERROR that occurred	**PC_MEM**	Check for the MEMORY expansion module
PCRES	Put the carrier into the RESET mode	**PCPACV**	Get PACER clock values
PCHOLD	Put the carrier into the HOLD mode	**PC_VEC**	Set dispatch VECTOR
PCGO	Put the carrier the RUN mode	**PCLOAD**	WRITE an array to memory

SUMMARY of COMMUNICATIONS FUNCTIONS:

PCRDW	Wait/Read the word in theICM register	**PCWRCS**	WRITE to the CSR register
PCRDWB	Wait/Read array from the ICM register	**PCRDIC**	Immediate Read of the ICM register
PCWRW	Wait/Write a word to the ICM register	**ICMOUT**	Is the ICM register available to be written to?
PCWRWB	Wait/Write an array to the ICM register		
ICMIN	Has the carrier written a word to the ICM register?	**PCWRIC**	Immediate Write to the ICM register
		ISTAT	Test STAT IN from the carrier
PCSOUT	Set STAT OUT bit in the CSR register	**PCWRLP**	WRITE to the LPA register
PCRDCS	READ the CSR register		

SUMMARY OF DMA ROUTINES:

PCRDMA	Start wait-mode DMA, carrier to host	**DMACHK**	Check status of background DMA
PCWDMA	Start wait-mode DMA, host to carrier	**DMASTP**	Stop background DMA in progress
PMARGO	Start background DMA, carrier to host	**DMACON**	Setup DMA controller chip
DMAWGO	Start background DMA, host to carrier	**PASPAR**	Do handshake required for DMA start

SPECIFICATIONS -- PCI-20206S Series

PARAMETER	CONDITIONS	SPECIFICATION
Distribution Media	360 KByte Format	5.25" Floppies
Language Interfaces	Microsoft BASIC Microsoft C Borland TURBO PASCAL Microsoft FORTRAN	PCI-20206S-1 PCI-20206S-2 PCI-20206S-3 PCI-20206S-4
Compatible Hardware *Smart* Carriers Memory Expansion	Data Acquisition & Control TMS320C25 board Modules	Burr-Brown PCI-20202C-1,-2 PCI-20201M-1,-2
Computer Requirements Operating System		IBM PC Compatible MS/PC DOS
Software Functions	See Summary Table	Hardware Control & Communications

FEATURES

- Designed for Scientific Programming
- Supports Real-Time Data Collection and Analysis
- Interfaces with the PCI-20000 Hardware System
- Uses Math Coprocessor (8087/80287/80387) for High Speed
- High-Level Math, Analysis, & Transformation Calls
- High-Level Calls for Graphics Display
- Built-In Text & Array Editors

BURR-BROWN®

PCI-20301S Series

ASYST High-Level Language Interface

> The ASYST Series interface is a new Burr-Brown product. Please check with your Burr-Brown sales office for the exact availability status.

APPLICATIONS

- Data Acquisition & Monitoring
- Process & Experiment Control
- Automatic Test Equipment
- Spectrum & Signal Analysis
- Statistical Analysis
- Technical Report Generation

DESCRIPTION

ASYST is an integrated high level programming language intended primarily for scientific and engineering applications. The language is a close relative of FORTH originally developed for astronomical and optical research. Many powerful instructions ("Words") have been added to the original product to increase programming efficiency and versatility. Individual words perform tasks that are the equivalent of whole programs in most other languages. Hundreds of these high-level commands are provided for functions such as FFT, curve fitting, matrix inversion, integration, ANOVA, automatic graphics plotting, etc. ASYST utilizes the computers math coprocessor (8087/80287/80387) for enhanced speed performance. The popular "calculator-type" stack orientation and reverse Polish notation are employed. Stack operands can contain complete arrays. ASYST provides the PC programmer with power and speed usually associated with mini and mainframe computers. For example, a 1024 point FFT takes about 2 seconds. This is comparable to mini-computers costing four times the price. Real-time data can be collected from laboratory instruments, sensors and transducers. ASYST interfaces to real world signals through PCI-20000 hardware. This modular system includes analog input, analog output, digital I/O, and counter/timer (including frequency, pulse-width, and period measurements) capabilities. Up to 80 analog input channels can be read with one board. The PCI products supported at this time are listed below. Complete specifications for all PCI Carriers and Modules can be found in this Handbook. Please contact the factory if special needs exist.

Data from any source can be processed and displayed, while outputs are generated to produce stimulus or feedback control signals. An on-line "help" system operates interactively to provide quick reference information. The "word guessing" feature suggests a list of possible words when an incorrect entry is made. Programs and data can utilize LIM expanded memory up to the 8Mbyte limit. Data inputs from the PCI-20000 can be written "direct-to-disk" at rates up to 45kHz. For flexibility, the software is offered in three modules (volumes), each supporting unique capabilities. They include:

Module 1 -- System/Graphics/Statistics

Module 2 -- Advanced Analysis

Module 3 -- Data Acquisition Interface

Module 1. This volume contains the ASYST language "shell". It provides basic programming capabilities including: control structures (logic), graphics, arithmetic, standard statistics, array operations, and RS-232 support. Control structures can include:if..then...else, begin...until, begin...while...repeat, case...of...endcase, and do...loop. Comparisons can involve =, <,>, ≤, ≥, <>, not, and, or, and xor. Two, full-screen editors are built into the system. One is for entering and modifying text and the other is for manipulating arrays. Special routines are included for string conversions, input/output file manipulations, and gamma, bessel and error functions.

Data types encompass single or double precision real, integer, or complex values; strings; and named scalars or arrays. Automatic or user-controlled conversions are available when using mixed data-types. Arrays may have up to 16 dimensions and may be as large as 64Kbytes each. Array functions support sub-arrays, reversal of indices, transposition of dimension, lesser dimension subsets, individual elements, catenation, lamination, auto entry of array data, scrolling, format control of array data display, generalized inner and outer products, and matrix multiplication.

Standard arithmetic operations include +, -, *, /, **, min, max, neg, abs, inv, sqrt, ln, exp, conj, sin, cos, tan, sec, csc, cot, sinh, cosh, tanh, sech, csch, coth, asin, acos, atan, asec, acsc, acot, asinh, acosh, atanh, asech, acsch, and acoth. All operators work directly (without loops) on all elements of an array. Mixed expressions of arrays and scalars, or arrays of different dimensions are permitted.

Statistical functions provide mean, variance, mode, median, moments, standard deviation, cumulative distributions, random number generation, as well as Gaussian, Chi-square, and Student-T distributions.

High-resolution graphics can be displayed on IBM-type EGA or Hercules monitors and can be outputted to several types of printers and plotters. High-level features support automatic line graphs, scatter plots, bar and pie charts, and plotting with error bars. Options include: color graphics, superposition of plots, multiple graphics windows, polar plots, autoscaling and data fitting, linear or logarithmic display along either axis, strip chart recorder emulation, and replotting data subsets with a single keystroke. On-screen graphic cursors, controlled by the arrow keys, are also included. Figures 1 and 2 suggest some of ASYST's graphics capabilities.

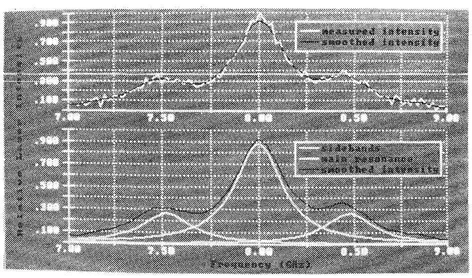

FIGURE 1.

Module 2. Module 2 is an extension to the data reduction and analysis capabilities offered in Module 1. However, in all cases Module 1 and Module 2 must be used together. Major additions include: polynomial mathematics and evaluation; advanced graphics; vectors and matrices; solutions to simultaneous equations; eigenvalues and eigenvectors; curve fitting; non-linear regression; advanced statistics; and transforms.

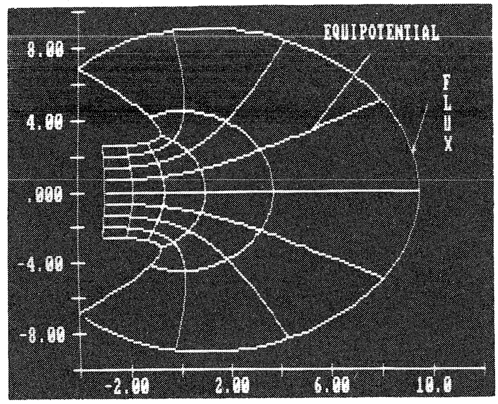

FIGURE 2.

Polynomial operations involve multiplication, synthetic division, integration, differentiation, shifting, and root extraction. Added to the graphics capabilities are axonometric and contour plots, as well as plotting with hidden lines removed. Treatment of vectors and matrices is broadened with matrix inversion, QR factorization, Gram-Schmidt orthogonalization, and determinants. Also included are functions for ANOVA, data smoothing, peak detection, integration, differentiation, convolution, filtering, least squares polynomial curve fitting, non-linear curve fitting, multiple regression, and several FFT-related algorithms.

Module 3. Module 3 is an extension to Modules 1 and 2. It furnishes a high-level software interface to the PCI-20000 hardware. The hardware, in turn, provides the actual input/output path to the real world signals. A comprehensive group of words (calls) provide a clear and consistent "bridge" to the PCI system. As a result a detailed knowledge of the hardware is not required to invoke extensive data collection, output, and control operations.

PCI-20000 hardware accepts a wide range of signals including voltage, current, resistance, on-off, and frequency. These can represent speed, distance, time, weight, strain, temperature, open-closed, motion, direction, pressure, flow, and pH, etc. Because each application is different, Burr-Brown offers many configuration options with its modular hardware system. The "Multifunction Carrier" supports the most widely used set of I/O types. Built into the carrier are analog input, digital I/O, and counter/timer/burst generator functions. Additional I/O types, channels, and features can be easily added by using the two plug- in module positions. Optional modules can provide both analog outputs, and analog input channel expansion. For speed performance estimates, please refer to Tables 10.2E and 10.2G (in Section 10). Those PCI hardware products currently supported by ASYST are summarized in the chart below.

Product	Type	Analog Input	Analog Output	Digital I/O	Counter/ Timer	Burst Generator	Notes
PCI-20098C-1	Multifunction Carrier	8/16Ch	-	16Ch	2Ch	1	Single-ended/Differential PGA=1,10,100; DMA
PCI-20003M-2	Analog Output Module	-	2Ch	-	-	-	12-Bit, ±10V
PCI-20003M-4	Analog Output Module	-	2Ch	-	-	-	12-Bit, ±10V or 4-20mA
PCI-20006M-1	Analog Output Module	-	1Ch	-	-	-	16-Bit, ±10V
PCI-20006M-2	Analog Output Module	-	2Ch	-	-	-	16-Bit, ±10V
PCI-20031M-1	Analog Expander Module	16/32Ch	-	-	-	-	Up to 80 Ain Chs with 2 PCI-20031M

SUMMARY - ASYST is a high-level scientific programming language designed to give researchers and engineers an integrated data acquisition, analysis, and graphics output environment. Depending upon the application, the software modules can be used in various combinations. Modules 1 and 2 can be used together without Module 3 to provide general programming capabilities. While data acquisition is not included in these volumes, analysis can be conducted on internal (stored) data. Communications with the outside world is provided by Module 3. Module 3 links the ASYST programming language to the PCI-20000 hardware to facilitate input, output, and control.

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FEATURES

- Easy-to-use, menu-driven software
- Compatible with PCI-20000 Hardware
- Real-time data acquisition
- Real-time process control - open or closed loop
- Real-time analysis and data reduction
- Built-in curve-fitting and FFT routines
- Real-time graphics display
- Automatically interfaces with related products such as: Real Time Access, Labtech Chrom and Lotus 1-2-3
- Foreground/background operation under MS/PC DOS

BURR-BROWN®

PCI-20040S-1

LABTECH NOTEBOOK

Integrated Data Acquisition, Control and Analysis Software for Personal Computers

LABTECH NOTEBOOK contains new features. Please check with your Burr-Brown Sales Office for exact availability status.

DESCRIPTION

The PCI-20040S-1 is the industry standard LABTECH Notebook, designed for PCI products (see Figure 1). Notebook couples to most PCI hardware elements. Data acquisition, test, measurement, control and analysis tasks are reduced to menu-driven choices. As a result, minimum computer skills are required. Programming options allow the automation and customization of advanced analysis, presentation, and report generation features. Voltage, current, thermocouple, RTD, pulse, frequency and digital input data can be recorded and displayed in real-time while open- and closed-loop proportional-integral-derivation (PID or on/off) outputs are generated. In addition to digital outputs, both voltage and current analog outputs are available.

LABTECH Notebook is an integrated, general-purpose software package for data acquisition, monitoring and real-time control. It runs on the IBM PC, XT, AT and other PC-compatible computers. Notebook provides an analog and digital interface to the real- world through PCI boards, carriers, and modules. It insulates the user from the need to write a software program to control the hardware. It replaces laboratory notebooks and hand-keying of data in the same way that spreadsheet programs such as Lotus 1-2- 3 replaced paper spreadsheets in business offices.

Because LABTECH Notebook is menu-driven, and extremely easy to learn and use, it requires very little computer skill on the part of the operator. The conditions which define the current run are displayed on the screen and are readily modified. All of the conditions pertaining to a run can be easily saved or recalled as a group. LABTECH Notebook reduces complicated data acquisition and control procedures to single-button operations, so that repetitive tests and process-monitoring activities are greatly simplified.

Flexibility is a key feature of LABTECH Notebook. To this end, each channel can be set up with different characteristics. Sampling rates may vary from channel to channel, and on

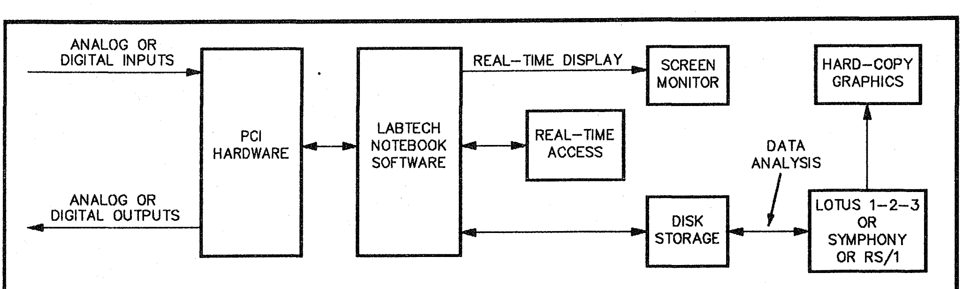

FIGURE 1. LABTECH Notebook Functional Diagram.

each channel the sampling rate may vary at different times during a run. Notebook's data monitoring and filing capabilities are equally versatile.

Channels can be used for purposes other than simple inputs or outputs. LABTECH Notebook has the ability to derive channels from other channels. For example, channels can "operate" on others by calculating averages, derivatives, integrals, etc., in real-time. The list of mathematical, logical, statistical and signal processing functions is quite extensive. These derived channels can also be used in determining triggers or as inputs to control loops.

Stored data can be "played back" as though it were being acquired in real-time. This provides a facility for making comparisons with data previously acquired or with data that has been theoretically derived.

Open- and closed-loop control algorithms are readily implemented. In the open-loop mode, the user defines one period of any imaginable waveform and the signal is then clocked out automatically during the run. For closed-loop control, both proportional-integral-derivative (PID) and "bang-bang" (on/off) loops can be set up.

LABTECH Notebook includes a powerful curve-fitting function. It uses an iterative routine to fit an arbitrarily complex model (up to ten parameters) to the collected data. This routine can be set up to take advantage of the PC's optional 8087 (or 80287) co- processor. The 8087 offers 80-bit real number processing, reduces round-off error, and allows faster computation.

When the user purchases an analysis or spreadsheet program, such as DADiSP, Lotus 1-2-3, or Symphony, additional functionality is gained. LABTECH's data files can be automatically imported into one of these programs for further reduction or analysis. Some of the programs will also provide word processing or data base capabilities. It is possible to build a "seamless" interface between LABTECH and these other programs, making it easy to go from data acquisition to a final report without writing down or keying in a single piece of data.

BASIC OPERATION

Again, LABTECH Notebook is a menu-driven program. There are no commands for the user to remember. Setup conditions for data acquisition, process control, data storage, and real-time display are all entered in response to prompts from the program.

An option table displays a list of setup conditions on the left- hand side of the screen. The corresponding values for each of the setup conditions appear in the column to the right of the list. This is the basic format of all of Notebook's option tables. Changing any value is easy. Simply move the "cursor" (highlighted rectangle) up or down the entry column (using the cursor control keys) until the appropriate value is located. Often a selection is made from a drop-down menu showing the optional entries. In other cases a new value is simply typed in and the Enter key is pressed.

DATA ACQUISITION

LABTECH Notebook can perform data acquisition in either a "normal" or "high-speed" mode. In the normal mode, acquisitions may be performed at sampling rates from 0.001Hz to 900Hz. In this mode, real-time display of data is available to the user, and data may also be permanently stored in user-defined disk files. In the high-speed mode, rates up to 89kHz can be obtained. However, the maximum speeds depend upon the particular PCI and computer hardware being used.

In the normal mode each channel may have different setup conditions. That is, they may have different channel types, scale factors, sampling rates, etc. As Figure 2 illustrates, the time period for each channel may be divided into several stages, each stage having a different sampling rate, duration, and/or starting method.

The series of stages may be repeated by setting an appropriate iteration count for the channel. Figure 3 shows a channel which has been set up to go through several loops, each consisting of a pass through all the channel's stages (except the first, which is used only during the first loop).

Any stage may be initiated in one of three ways:

- Normal starting, where a stage begins as soon as the previous stage ends (the first stage begins as soon as the run is initiated).
- Trigger starting, where a digital input or an analog level on any channel (or combination thereof) is received before the stage can begin.
- Time delay starting, where a stage begins only after a user- specified time has elapsed.

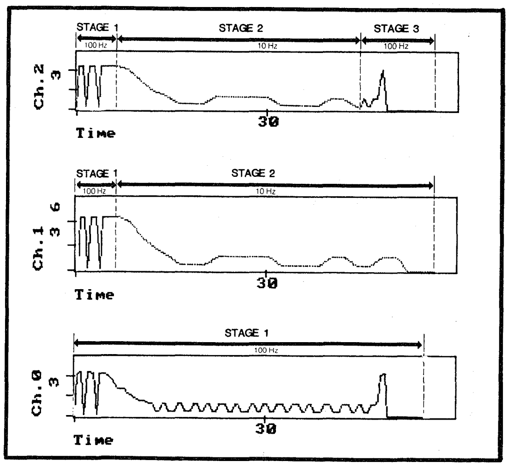

FIGURE 2.Using Stages in a Data AquisitionRun

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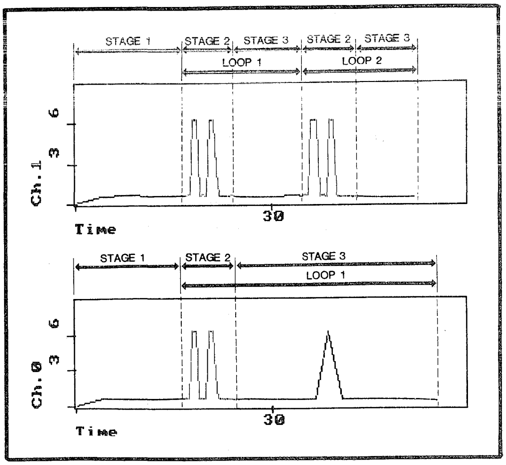


FIGURE 3. Using Loops in a Data Acquisition Run

A stage may run until:

- A stated time period has elapsed, or
- An analog or digital trigger occurs.

In the high-speed mode, real-time display of data is not available. All channels have identical setup conditions, and multiple stages and loops are not available. A high-speed run may be started using either the normal, trigger, or time-delay method.

PROCESS CONTROL

Both open- and closed-loop process control are available using LABTECH Notebook.

- When open-loop control is specified, the contents of a data file are sent, point-by-point, to the hardware interface.
- With closed-loop analog control the output is determined according to a PID equation. This equation provides an output signal which is a function of the input from an A/D channel and four PID variables which are specified during setup: loop gain, loop reset, loop rate, and set point.
- With closed-loop digital control both on-off (bang-bang) and alarm controls are supported. The input signal is compared to upper and lower limits specified during setup, and the appropriate output is generated.

DATA STORAGE

Depending upon the mode selected, data can be stored in RAM or continuously written to disk. Eight data storage modes are available including: ASCII and binary formats. Each data file may receive data from one or more data acquisition channels. Notebook also allows you to place header lines, names, and unit labels in data files. Data files from LABTECH Notebook may be imported directly into analysis or spreadsheet programs with compatible file formats (e.g., Lotus 1-2-3). For example, data manipulation, statistics, and data base management are all available using Lotus 1-2-3. In addition, publication-quality graphs may be generated using 1-2-3's PrintGraph function.

An analysis or spreadsheet program can be invoked directly from the Notebook's main menu. There is no need to leave Notebook.

Using spreadsheet programs can greatly simplify post-processing tasks. Lotus 1-2-3, for example, can set up and save worksheet templates which reduce data manipulation and graphing functions to single-key operations.

REAL-TIME DISPLAY

The real-time display function is available during normal mode data acquisition and control runs. Figure 4 shows an example of a possible display. As can be seen, the display is in the form of X-Y graphs, Y-time graphs, vertical bars, digital meters, and (not shown) horizontal bars. Up to 50 signals can be displayed in up to 15 windows. The presentation and scaling of the displays are under the control of the user. Scrolling of the horizontal axis is provided in the Y-time mode.

LABTECH supports several display standards, including CGA (4 colors) EGA (8 colors), Hercules and Compaq monochrome.

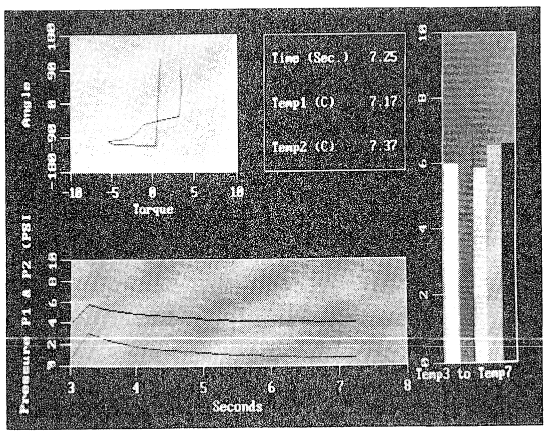


FIGURE 4. Real-Time Display.

NONLINEAR REGRESSION ANALYSIS -- CURVE-FIT

Notebook offers a curve-fitting routine which enables you to fit an arbitrarily complex model to experimental data.

A mathematical model consisting of independent variables and parameters is entered by the user. Initial estimates for the parameters are also entered. Along with this equation, a data file with experimental data is provided.

Full statistical data is presented on the quality of the fit, the accuracy of the fitted parameters, and inter-parameter correlation. A graph showing both the experimental and theoretical curves can be produced. Figure 5 shows an

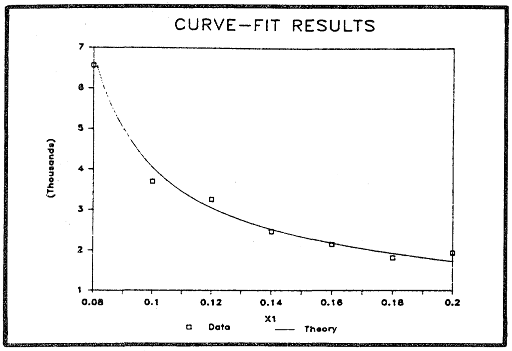


FIGURE 5. Graph of Theoretical Data vs Experimental Data-- Output from Nonlinear Regression Analysis.

example of such a graph. An analysis of variance is also performed by the curve-fitting function. The output from this analysis consists of estimates of the parameter standard deviations and a parameter correlation matrix. These results allow the user to determine the quality of the fit to the theoretical model.

PROGRAMMING OPTION

For those who want to automate data acquisition or process control runs, Notebook offers a programming option. Using this option the user can write routines to start and repeat runs, perform filing chores between runs, and branch on conditions.

DOS SYSTEM UTILITY

If at any time during a LABTECH Notebook session the user wishes to run a program under the DOS operating system, the DOS system utility may be selected from the menu. Scientific application programs, word processing programs, or specialized user-written programs may be executed using this function.

SPECIFICATIONS -- PCI-20040S-1

When a reference is made to a PCI-20000 part without a "-#" (dash number), it applies to all available dash numbers.

PARAMETER	CONDITIONS	SPECIFICATION
LABTECH Notebook Compatibility	PCI-20001C, 41C, & 98C Carriers, PCI-20002M, 3M, 4M, 5M, 7M, 19M, & 21M Modules, PCI-20089W, 91W, & 93W Boards, & PCI-20000 Termination Panels and Accessories.	Version 4.36
DATA ACQUISITION		
Sampling Rate	See Hardware items below	Up to 89kHz
Run Duration		Up to 270k hours
Input Types		Analog, digital, pulse, frequency
Starting Methods		Delayed, triggered
PROCESS CONTROL		
Sampling Rate	See Hardware items below	Up to 250Hz
Control Modes		Open loop and PCI
Input Types		Analog, digital, pulse, frequency
Output Types		Analog and Digital
DATA STORAGE		
Types		RAM and disk
Modes	ASCII real and integer, binary real and integer; hex; binary	Real and integer
REAL-TIME DISPLAY		
Speed	Maximum(4)	900Hz
Types		Y-time, X-Y, bars, meters
Number	Screen partitions	Up to 15
Colors		Four (CGA), eight (EGA)

Continued...

12

PARAMETER	CONDITIONS	SPECIFICATION
PC REQUIREMENTS		
Type		IBM PC, XT, AT or compatible
Drives		Hard disk recommended
Memory		640K RAM recommended
DOS		3.0 or greater
Display		Graphics board required
CARRIERS		
PCI-20001C Series	Channels(1)	Up to 3 Modules Supported
	PCI-20001C-1	No I/O functions
	PCI-20001C-2, see PCI-20004M below	32 digital I/O channels
PCI-20041C Series	Channels(1)	Up to 3 Modules Supported
	PCI-20041C-1,-3, see PCI-20004M below	32 digital I/O channels
PCI-20098C-1	Channels(1)	Up to 2 Modules Supported
	see PCI-20004M below	16 digital I/O channels
BOARDS	12-bit resolution	
PCI-20089W-1	Analog Input, Channels(1) (SE/Diff)	16/8
PCI-20091W-1	High-Speed Analog Input, Channels(1)	8
PCI-20093W-1	Analog Output, Channels(1)	8
MODULES		
PCI-20002M-1(2)	Can be used with PCI-20005M Expander	Analog Input
Channels(1)	Single-ended/differential	16 chs / 8 chs
Gain	Programmable	1, 10, 100, 1000
A/D Ranges	Jumper-selected	±5V, ±10V, 0-10V
Sampling Rate	Normal mode, minimum	1 milliHz
	Maximum, PC/AT	300/900Hz
	High speed, minimum	20Hz
	Maximum, PC/AT	4kHz/10kHz
	Free Run, approximate, PC/AT	16kHz/25kHz
Thermocouples		
Types		B, E, J, K, R, S, T
Sampling Rate	Maximum, PC/AT	30Hz/100Hz
PCI-20003M Series		Analog output
Channels(1)	PCI-20003M-2, voltage output	Two channels
	PCI-20003M-4, current or voltage output	Two channels
Resolution		12-bits
D/A Ranges	Voltage output	±15V, ±10V, 0-10V
	Current output	4-20 and 5-25mA
Data Rate	Open loop, maximum, PC/AT	300Hz/1400Hz
	PID, maximum, PC/AT	20Hz/70Hz(3)
PCI-20004M-1	Specs also apply to PCI-20001C-2 and PCI-20098C-1	Digital input/output
Bytes(1)	Eight channels each, programmable as I/O	Four
Logic Levels		TTL
Sampling Rate		
Input	Maximum, PC/AT	300Hz/900Hz
Output	Maximum, open loop, PC/AT	400Hz/1500Hz
	Maximum, closed loop PC/AT	70Hz/250Hz
PCI-20005M-1(2)	Can be used with PCI-20002M	Analog expander
Channels(1)	Single-ended differential in normal mode only	32 channels/16 channels
PCI-20007M-1		Counter/timer
Channels(1)	Count and measure frequency (±1HZ)	Four channels
Count	Maximum	65,535 channels
Read Rate	Maximum, PC/AT	300Hz/900Hz
Input Speed	Maximum input frequency	8MHz
Pulse Output	Frequency range (duty cycle dependent)	Up to 8MHz

Continued...

PARAMETER	CONDITIONS	SPECIFICATION
PCI-20019M-1	High speed	Analog input
Channels[1]	Single-ended	Eight channels
A/D Ranges	Jumper-selected	± 5V, ± 10V, 0-10V
Sampling Rate	Normal mode, minimum	1 milliHz
	Maximum, PC/AT	300Hz/900Hz
	High-speed mode, minimum	20Hz
	Maximum, PC/AT (Requires PCI-20007M-1)	50kHz/80kHz
PCI-20021M-1		Analog output
Channels[1]	Voltage output	8 channels
Resolution		12-bits
D/A Ranges		± 5V, ± 10V
Data Rate	Open loop, maximum, PC/AT	300Hz/900Hz
	PID, maximum, PC/AT	20Hz/70Hz[3]

NOTES: (1) The number of channels apply to "each" module used.

(2) LABTECH supports a maximum of two PCI-20005M-1 Expanders with each PCI-20002M-1 A/D Module.

(3) Using an 8087/80287/80387 Co-Processor greatly increases speed.

(4) Speed without additional supplementary hardware (i.e., "Scroller Card").

(5) Other gains can be resistor-selected by the user.

12

FEATURES

- Operates in LABTECH Notebook's foreground/background environment
- Works as an inter-program communications link between LABTECH Notebook and most application programs
- Provides for real-time acquisition of data into the application program
- The application program can write data to instrumentation
- Provides for real-time modification of Notebook's process control environment
- Provisions made for the synchronization of the application program to the real-time environment

BURR-BROWN®

PCI-20065S-1

LABTECH Real Time Access

DESCRIPTION

LABTECH Notebook has the unusual capability of operating as a real-time multitasking subsystem on a personal computer with PC/MS-DOS. Notebook can be "in the background" carrying out a complex schedule of data acquisition and control while the user at the console is running some other DOS application program. Until the advent of Real Time Access (RTA), however, the two programs ran independently, and did not communicate with each other.

Real Time Access provides for inter-program communications. It allows the foreground application to access the real-time data being acquired simultaneously by Notebook. To the application program, the data looks as if it is coming from an ordinary DOS file or device. The user gains great flexibility in managing real-time data analysis and control.

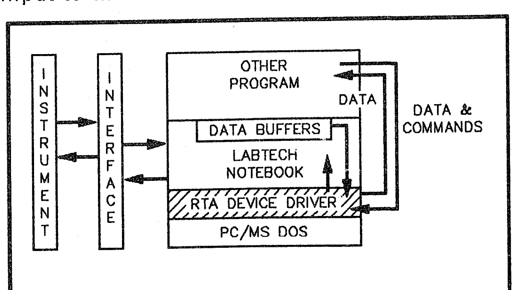
This flexibility and power comes whether or not you write your own programs, since virtually any existing application program that can access files can access data acquired in real-time from PCI products and LABTECH Notebook. Applications programs need not have been specially written to work with the RTA device. From the foreground application program's point of view, the device is indistinguishable from an ordinary file. So, existing spreadsheets, statistical analysis programs, quality control programs, graphics programs and more can gain real-time data acquisition capabilities.

Foreground programs communicate with Notebook running in the background. They may access any or all of the data being acquired by Notebook under the control of the Notebook scheduler. In addition, the foreground programs may initiate data acquisition or process control events by themselves.

Access is via a DOS device driver, communicating with a "porthole" in LABTECH Notebook's code. The driver creates a virtual real-time data acquisition and process control device appearing to the application program as an ordinary device or file. Therefore, the program can communicate to Notebook by sending commands using standard write statements in the language of the foreground program.

Reading is done in one of several modes. In one mode, all data accumulated in the buffer since the last read request is passed to the foreground program, assuring that no data will be skipped. In another mode, only the latest data point in the buffer is passed to the foreground program. Yet another command allows for the immediate collection of a new data point regardless of when the last one had been collected and put in the buffer. Reading can also be set to return with no data if none has been collected since the last read command, or to wait for data to be entered in the buffer. This last feature provides a simple way for the foreground program to synchronize itself to the data acquisition rate.

The application program may optionally write a command stream modifying Notebook's acquisition and control parameters, or it can send data directly to the PCI hardware. These commands may be sent by the program, by simply copying a field, or by direct console input to the device driver.



Notebook acquires data from instrumentation and places it into a data buffer area in memory. This buffer may be freely accessed by the application program, which can input real-time data by ordinary file reading operations.

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PCI-20067S-1

DADiSP WORKSHEET

Scientific Spreadsheet for Post-Acquisition Signal Analysis

FEATURES

ANALYSIS CAPABILITIES

- Waveform Generation
- Peak Analysis
- Signal Editing
- Trigonometric Functions
- Calculus Functions
- Fourier Analysis
- Frequency Domain Analysis
- Time Series Analysis
- Statistical Analysis
- Complex Number Support
- Engineering Units Processing

GRAPHICS CAPABILITIES

- One to 64 Analysis Windows
- Scroll, Zoom, Cursor
- Table Display

PROGRAMMING CAPABILITIES

- Virtual Signal Management
- Macro Definitions
- Command Files

DESCRIPTION

The DADiSP Worksheet provides menu-driven, post-acquisition data analysis and display. It does for science and engineering what financial spread-sheets have done for business. It eliminates the need to spend valuable time programming specialized routines. DADiSP allows the user to set up a worksheet, or analysis chain, simply by typing formulas.

Each worksheet contains windows analogous to cells in a financial spreadsheet -- except that a DADiSP window manages an entire waveform. The user can define up to 64 of these windows in a given worksheet. Every window acts as a processing step and displays a graph of the data transformed by that step. Any change in the data in one window is automatically updated in all the other windows using that data.

Because DADiSP pages the signal to disk as it is scrolled through a window, the software can handle signals of virtually any length. The program processes as much signal as the memory can handle, stores the processed data, calls up the next batch of signal data from the disk and continues until all of the signal data is processed. The user can zoom any window to full screen size for detailed manipulation and study. Pop-up boxes provide background information on a window and carry scientific units through compound calculations. The Worksheet data is stored in individual DADiSP Laboratory books that permit individual users of the DADiSP system to keep their work separate from other users.

To analyze or manipulate the data, the user simply types the desired command or formula into the desired window using any of more than 150 built-in functions. The functions include 42 trigonometric, calculus and common arithmetic operations; 14 Fourier analysis and related functions such as fast Fourier transforms and complex algebra; ten statistical functions; 21 signal editing and peak analysis operations; and 32 functions for generating complex waveforms.

Special user-defined functions are easily generated by calling up a user macro table and typing in the desired formula for the macro. For example, an autocorrelation macro could be generated by using a number of the standard DADiSP functions such as "convolute two signals". And a chain of operations can be set up by typing in the formulas in consecutive windows -- with the results of each step displayed in sequence, window by window.

The DSP Pipeline function allows the running of external programs, such as LABTECH Notebook or the user's own analysis routines, within the DADiSP environment and the importing of new or modified data directly into a worksheet. Pipeline adds flexibility to DADiSP by dynamically linking the Worksheet environment to user-written or commercially available software.

DADiSP supports a variety of printers for hardcopy output and can even send data files to external plotter drivers to customize graphs. DADiSP can import and export data files in a variety of formats including ASCII, Lotus PRN, byte, integer and floating point.

DADiSP WORKSHEET FUNCTIONS

Waveform Generation

GSIN	Sine wave
GCOS	Cosine wave
GTAN	Tangent curve
GSEC	Secant curve
GCSC	Cosecant curve
GCOT	Cotangent
GASIN	Arcsine
GACOS	Arcosine
GATAN	Arctangent
GASEC	Arcsecant
GACSC	Arccosecant
GACOT	Arccotangent
GSINH	Hyperbolic sine
GCOSH	Hyperbolic cosine
GTANH	Hyperbolic tangent
GSECH	Hyperbolic secant
GCSCH	Hyperbolic cosecant
GCOTH	Hyperbolic cotangent
GASINH	Hyperbolic arcsine
GACOSH	Hyperbolic arccosine
GATANH	Hyperbolic arctangent
GASECH	Hyperbolic arcsecant
GACSCH	Hyperbolic arccosecant
GACOTH	Hyperbolic arccotangent
GSQRWAVE	Square wave
GTRIWAVE	Triangle wave
GEXP	Exponentiation
GLOG	Log
GIN	Natural log
GLOG10	Log base ten
SGQRT	Square root
GLINE	Any line

Peak Analysis, Signal Editing, and Related Operations

FMIN	Find Minimum Value
FMAX	Find maximum value
FPEAK	Find first peak
FVALL	Find first valley
FPEAKN	Find next peak
FVALLN	Find next valley
FPEAKP	Find previous peak
FVALLP	Find previous valley
MOVE	Move cursor right
PUT	Put cursor on a given x-value
NMOVE	Move cursor on the given sample number
EXTRACT	Extract part of a signal
REVERSE	Reverse a signal
CONCAT	Concatenate any number of signals
PROTECT	Save the signal in current window
CLEAR	Delete the signal from current window
GETPT	Value of nth sample of the signal
DELTAX	Spacing between the samples
MAX	Maximum value of the signal
MIN	Minimum value of the signal
SIGSIZE	Number of points in the signal

Trigonometric, Calculus, and Other Common Functions

SIN	Sine
COS	Cosine
TAN	Tangent
SEC	Secant
CSC	Cosecant
COT	Cotangent
ASIN	Arcosine
ACOS	Arccosine
ATAN	Arctangent
ASEC	Arcsecant
ACSC	Arccosecant
ACOT	Arccotangent
SINH	Hyperbolic sine
COSH	Hyperbolic cosine
TANH	Hyperbolic tangent
SECH	Hyperbolic secant
CSCH	Hyperbolic cosecant
COTH	Hyperbolic cotangent
ASINH	Hyperbolic arcsine
ACOSH	Hyperbolic arccosine
ATANH	Hyperbolic arctangent
ASECH	Hyperbolic arcsecant
ACSH	Hyperbolic arccosecant
ACOTH	Hyperbolic arccotangent
EXP	Exponentiation (to the power of e = 2.7182)
LOG	Log
LN	Natural log
LOG10	Log base 10
SQRT	Square root
ABS	Absolute value
SINC	Sinc function (sin[x]/x)
FLOOR	Round down (to next lower integer)
CEILING	Round up (to next higher integer)
DERIV	Derivative
INTEG	Integral
LDERIV	Left derivative
RDERV	Right derivative

+	Addition
-	Subtraction
*	Multiplication
/	Division
^	Power

Fourier Analysis and Related Functions

DFT	Discrete Fourier transform
IDFT	Inverse discrete Fourier transform
FFT	Fast Fourier transform (magnitude/angle form)
FFTC	Fast Fourier transform (real/imaginaryform)
IFFT	Inverse Fourier transform (magnitude/angle form)
IFFTC	Inverse Fourier transform (real/imaginary form)
REAL	Real part
IMAGINARY	Imaginary part
MAGNITUDE	Magnitude
ANGLE	Angle
CONJUGATE	Complex conjugate
POLAR	Convert to polar representation (magnitude/angle)
CARTESIAN	Convert to Cartesian representation (real/imaginary)
CONV	Convolute two signals

Statistical Functions

MEAN	Mean
STDEV	Standard deviation
STATS	Mean and standard deviation
PARTSUM	Calculate partial sums of the signal
AMPDIST	Calculate amplitude distribution
MOVAVG	Calculate the moving average
LINREG	Linear regression of one signal
LINREG2	Linear correlation of two signals
SUMS	Sum any number of signals
AVG	Average any number of signals

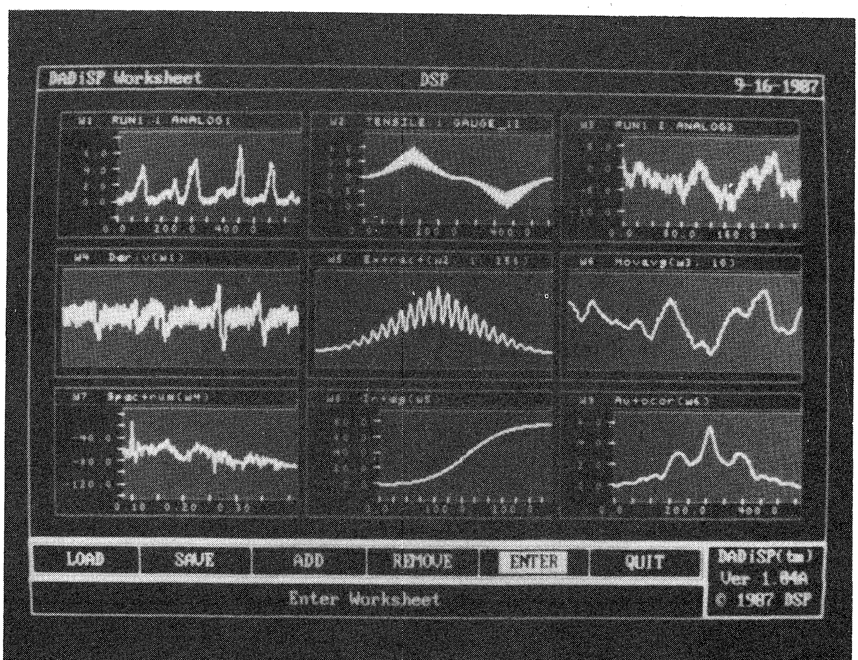


FIGURE 1. Typical Display.

FEATURES

- Menu-driven, no programming required
- Easy to learn user interface
- Emulates a digital oscilloscope
- Supports the PCI-20000 Hardware System
  - Records up to 80 channels
  - Up to 180kHz sample rate
  - Pre-trigger capability
- Displays up to eight channels concurrently
- Replays recorded data from disk for visual analysis
- Can magnify presentation in both vertical and horizontal directions
- Dual cursors display both time and voltage values (in engineering units)
- Directs output to screen, printer, and/or disk
- Works with IBM PC, PC/XT, PC/AT and compatible computers

APPLICATIONS

- Electronic product and component testing
- Aerospace and automotive systems evaluation
- Biomedical signal analysis
- Vibration analysis
- Audio, speech and acoustics analysis
- Geophysical/seismic evaluation
- Frequency response analysis
- Motion studies
- Control system analysis
- GO/NO-GO Testing

OVERVIEW

The SNAPSHOT series (PCI-20068S series) is an integrated group of easy-to-use software products for recording, analyzing, displaying, and storing real world signals. When used with PCI- 20000 hardware products, your personal computer becomes a state-of-the-art measuring and control system. At this time, SNAPSHOT recognizes the function and specifications of 20 different PCI Boards, Carriers, and Modules. All aspects of the PCI hardware's operation are included in the intuitive menu-driven interface. No previous computer or programming experience is required. To insure smooth operation, each keyboard entry is automatically checked for consistency. Instantaneous feedback is provided to guide proper parameter selection. The SNAPSHOT software series currently consists of six modular products. SNAPSHOT STORAGE SCOPE is the core product for the rest of the family. The relationship between the individual parts is described in Figure 1. Modularity enables the user to add the desired level of processing capabilities as needed. By coupling the various SNAP- products together, comprehensive signal processing, generation and control functions are readily accomplished. This extension to the PCI product family can be used with IBM PC, PC/XT, PC/AT and all compatible computers.

BURR-BROWN®

PCI-20068S-1 SNAPSHOT STORAGE SCOPE
PCI-20068S-2 SNAP-CALC
PCI-20068S-4 SNAP-FILTER
PCI-20068S-5 SNAP-ACTION
PCI-20068S-7 SNAP-GENERATOR
PCI-20068S-8 SNAP-STREAM

SNAPSHOT STORAGE SCOPE Series

Software for Data Acquisition and Display

> The SNAPSHOT Series contains new products. Please check with your Burr-Brown sales office for exact availability status.

SNAPSHOT STORAGE SCOPE (PCI-20068S-1) is an easy-to-use, completely menu-driven software product designed to emulate data acquisition and digital storage oscilloscope systems. Facilities for acquiring, graphing, manipulating, storing, and retrieving data are included. Sample rates up to 180,000 readings per second can be accomplished in an IBM PC/XT computer. Operation is simplified by a logical and convenient user interface. SNAP-

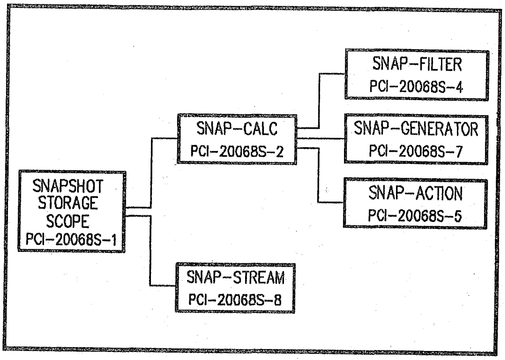


Figure 1. How the SNAPSHOT series software products work together. SNAP-FFT can be used with SNAPSHOT STORAGE SCOPE or a separate data acquisition product. The other SNAP products require the indicated "companion" products to their left in the diagram. For example: the use of SNAP-ACTION requires both SNAP-CALC and SNAPSHOT STORAGE SCOPE.

SHOT STORAGE SCOPE totally automates the operation of the PCI-20000 hardware system. Up to 80 analog inputs are supported in the single-ended mode (or 40 differential inputs). Unit conversion is readily accomplished. For example, raw data representing torque and RPM can be acquired and converted to proper units. In additon, horesepower could be computed and displayed along with the other parameters.

The start of the acquisition process can be internally or externally triggered on an analog or digital signal. Fast hardware trigger circuitry provides precisely timed acquistions and insures that no data points will be missed. It is of special significance that the acquisition and display of both pre- and post-trigger data are easily accomplished. An analog trigger can have a user-defined slope (+ or -) and amplitude (-10V to +10V). A digital trigger can be defined by a TTL signal. Test sequences can include synchronized analog and digital outputs. This can be very useful for control and excitation functions.

Acquired data can be permanently stored in a user-defined disk file for future analysis. Depending upon the application, the user can choose different storage criteria: store all acquired data, store upon operator command, and store by exception based upon calculations and comparisons.

From one to eight channels can be displayed at the same time, each in a different color. Graphs can be presented in a channel verses time (Y-T) or channel verses channel (X-Y) format. In the DMA mode, plots are updated on the screen in parallel with the acquisition. This provides a real-time "look" to the presentation on acquisitions longer than a few seconds. Recorded data can be recalled from disk for further visual analysis aided by convenient cursor, offset, and zoom functions. Dual cursors provide quick and accurate readout of absolute or relative values of amplitude and time. The display screen is divided into four sections: *Operator Information, Labels, Waveform Display* area, and *User Options* (see Figure 2). The *operator information* provides current setup values including channel sensitivity (volts/division), channel gain, sweep time, time per X-division, number of data points collected for each channel, and the sampling time between points. Each channel displayed has ten grid marks in each direction providing the type of graticule background typically found on an oscilloscope. Channel *labels* can be customized so that the waveforms can be easily identified. *User options* are listed along the bottom line of the display. Each option has a short label describing the command, which can be executed by pressing the specific function key assigned to it. Minimal keystrokes are required to issue commands, specify parameters and select files. In addition to graphical displays, data can also be presented in tabular form to show long-term trends and precise amplitude levels.

Because SNAPSHOT STORAGE SCOPE is completely menu-driven it requires no programming skills or the memorization of commands. There are four types of menus: Command, Setup, Configuration and Parameter menus. Command menus are displayed on the bottom line of the screen and are selected by pressing the function key that corresponds to the listed command. Commands can be used to either perform an action, such as data collection, or to select a new menu. The Setup menus provide a list of the parameters that may be changed by the operator. Configuration Menus provide entries related to the setup of the hardware and software environments. Parameter Menus are used to review and select the values that control the data collection process and the graphics display. Keyboard entries are automatically checked. If an invalid entry is detected, guidelines for a proper input are displayed.

SNAP-CALC (PCI-20068S-2) is an "add-on" to SNAPSHOT STORAGE SCOPE (PCI-20068S-1). This additional software enhances the basic analysis and signal processing capabilities. SNAP-CALC provides the unique ability to concurrently acquire and analyze data. Previously acquired data can also be analyzed as a post-process. The user interface is consistent with the other SNAPSHOT products and requires no programming except to define analysis equations.

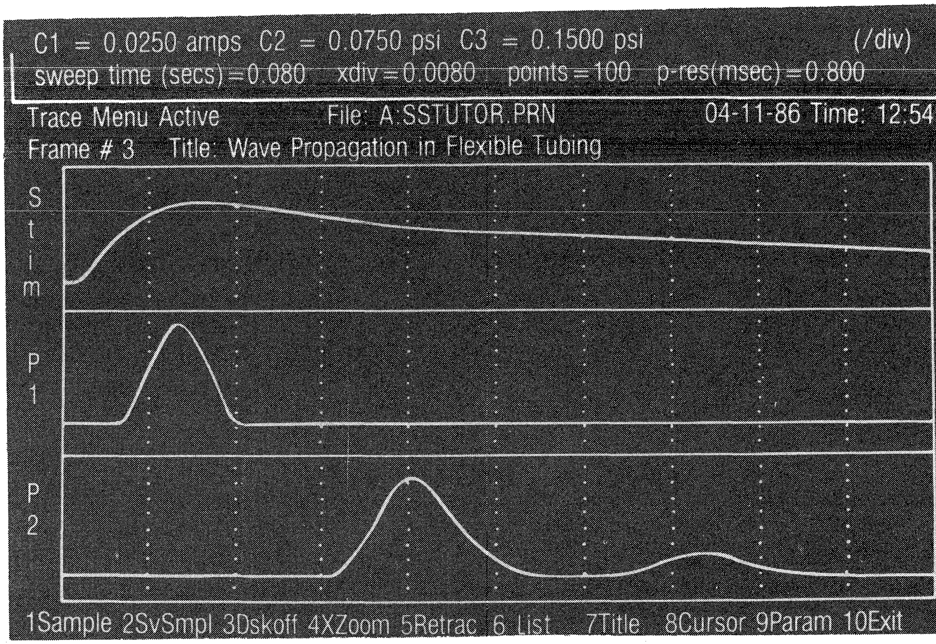


FIGURE 2. **Screen Display** of plotted data provides immediate feedback regarding performance. The display identifies the sensitivity of each channel in engineering units, number of points collected, user-specified title, date and time of the test, channel labels, and menu options. Data can be displayed in a channel-vs-time or channel-vs- channel format. Up to eight channels can be displayed on the same screen.

SNAP-CALC supports a wide range of mathematical functions including algebraic, calculus, correlation, trigonometric, logic, filtering, and statistical. The user has the option of selecting three types of integration, differentiation, and trigonometric units. Acquired waveforms can be edited and then displayed, stored, and used as inputs to other SNAPSHOT products. Editing capabilities include copying, moving and deleting a waveform.

Frequently used constants, functions, equations, and subroutines can be stored as macro definitions and recalled instantly whenever needed. Programming knowledge is not required to specify macros; they are defined with the same single keystroke language used to define equations. All operators are displayed on a help screen for easy reference. Menu parameters can also be saved for quick loading and setup of a new application.

SNAP-FILTER (PCI-20068S-4) adds digital filtering capabilities to the other data acquisition and analysis functions in the SNAPSHOT series. Its purpose is to remove unwanted frequencies from an acquired waveform. The user can selectively remove desired frequency ranges and graphically view the results. Applications include signal-to-noise enhancement, attenuation of power line pickup, pass band limiting, and noise suppression. Figure 4 is a typical display showing both the input and output waveforms to a low-pass filter. Support for low-pass, high-pass, band-pass, and band-reject filters are included. Finite impulse response (FIR) designs, with linear phase response, can be used to preserve the time relationship between the signal's components. Infinite impulse response (IIR) designs can be used to emulate common analog filters with their very sharp attenuation. For smoothing noisy data, a low-pass Hanning moving average filter is available. Filters with up to 400 coefficients can be constructed.

The specification of a particular filter requires only a few key strokes. This includes the filter type and frequency range. Cut-in and cut-off frequencies are limited only by the data acquisition hardware's sampling rate as defined in the specification table. Advantages of digital filters over analog filters include higher noise immunity, accuracy independent of component tolerances, ease of tuning, and characteristics independent of time and temperature. An internal linear- regression routine easily fits data to a straight line. SNAP-FILTER is a software add-on to SNAP-CALC (PCI-20068S-2) and SNAPSHOT STORAGE SCOPE (PCI-20068S-1), both of which are required.

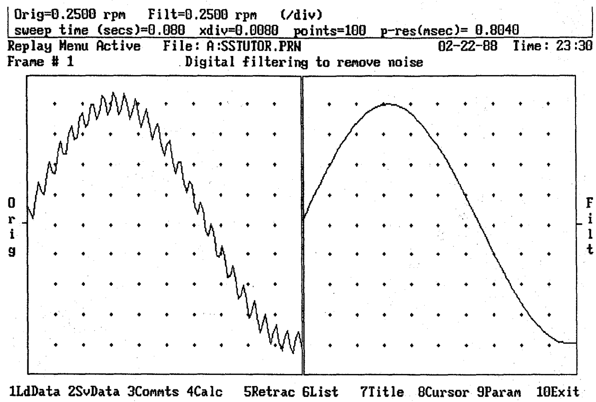


Figure 3. The waveform on the left is a 3Hz sine wave with 60Hz noise. The waveform on the right shows the result of low-pass digital filtering with SNAP-FILTER.

SNAP-ACTION (PCI-20068S-5) adds extensive decision-making capabilities to the other data acquisition and analysis functions in the SNAPSHOT series. Its purpose is to perform user-defined actions when specific test conditions occur. Applications include automated go/no-go testing, predicting and capturing failures, adaptive control, factory automation, quality control, and data recording by exception. SNAP-ACTION's conditional processing provides decision-making capability within equations by using IF...THEN...ELSE logic to automatically decide whether to take actions based on analyzed data. The syntax of the IF...THEN...ELSE function is:

IF (condition) THEN (actions) ELSE (actions),

where conditions are relational comparisons that can be AND'ed or OR'ed together to provide a multitude of conditions. Logical operators include greater-than, less-than, equal-to, and not- equal to comparisons. Comparisons can be made between channels, or with respect to constants, elapsed time, and statistical properties that summarize a waveform (such as its maximum, minimum, standard deviation, variance, or average). Elapsed time can be defined in either seconds, minutes, or hours to record data at regular intervals. Action can include:

1) Setting analog and digital outputs
2) Pausing or aborting an acquisition
3) Assigning values to variables
4) Saving the current data frame to disk (recording "data by exception").

Data by exception stores the current frame (up to 32,768 points of data) to a disk file with the current date and time. The data can be replayed in SNAPSHOT. Only a few keystrokes are required to define criteria, make decisions, and automatically take user- defined actions. A multitude of conditions can be specified and each condition can have a unique set of actions. A typical application is suggested in Figure 5. SNAP-ACTION is a software add-on to SNAP-CALC (PCI-20068S-2) and SNAPSHOT STORAGE SCOPE (PCI-20068S-1), both of which are required.

SNAP-GENERATOR (PCI-20068S-7) adds signal-generation capabilities to the other data acquisition and analysis functions in the SNAPSHOT series. Its purpose is to generate user-defined waveforms to act as inputs or stimuli to drive a system under test. Applications can include automated product evaluation, driving an X-Y plotter with stored data, biomedical pacing/stimulation, and product life testing. SNAP-GENERATOR works in conjunction with PCI-20000 analog output (D/A) modules (PCI-20003M, 6M and 21M) to produce a wide range of both standard and arbitrary (custom) waveforms. Standard trigonometric waveforms with both linear and logometric sweeps can be generated. Swept waveforms can be very useful for determining the transfer function and frequency response of systems.

Consistent with the other SNAPSHOT products, SNAP-GENERATOR is completely menu-driven and requires no programming skills to operate. Custom signals can be represented in a number of ways: by tabular inputs with up to 32K points per cycle, by mathematical expressions, by acquired data, and by modified (processed) acquired data. Besides specifying the shape of a waveform, the voltage level and DC offset (within the range of the D/A) can also be defined. Waveforms can be set for continuous

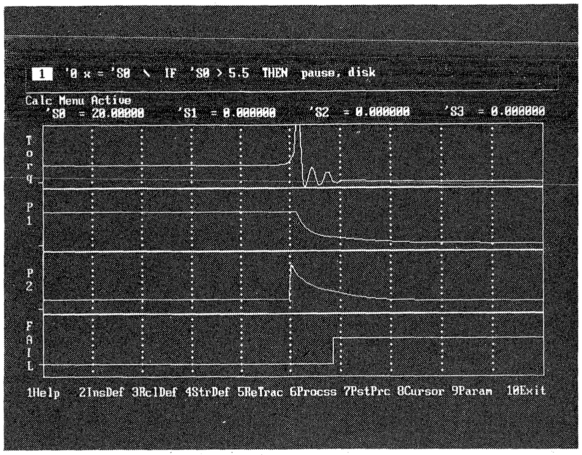


Figure 4. In this example peak torque is 20 ft-lb. This exceeds the set limit of 5.5 ft-lb indicating a system failure. The actions taken include recording the data to both the screen and disk and pausing the acquisition process.

output, gated on for a specific time period, delayed from a trigger, or set to generate a predetermined number of cycles. Depending upon the PCI module selected, up to eight output signals can be simultaneously produced. When SNAP-GENERATOR is used in conjunction with the PCI-20041C-3 DMA carrier, synchronous signal generation and input acquisition are supported. Normally, the repetition frequency for the inputs and outputs are equal. However, with the addition of a PCI-20007M-1 rate generator module, independent rates can be set. These capabilities result in a high performance, low-cost alternative to conventional laboratory instruments that are usually limited to a single output channel. SNAP-GENERATOR is a software add-on to SNAP-CALC (PCI-20068S-2) and SNAPSHOT STORAGE SCOPE (PCI-20068S-1), both of which are required.

SNAP-STREAM (PCI-20068S-8) is an "add-on" to SNAPSHOT STORAGE SCOPE (PCI-20068S-1). The additional software adds increased mass storage capabilities to the other data acquisition and analysis functions in the SNAPSHOT series. Its purpose is to provide for the continuous transfer of data to "disk-storage" type devices, including: RAM disk, hard disk, and floppy disk. Streaming eliminates time gaps and lost data points that often occur when acquiring large amounts of data at high speed. The amount of data that can be acquired is limited only by the available disk space. Transfer speeds of 50kHz-100kHz have been achieved in the machines tested. The actual transfer rate in a specific application is highly dependent upon the particular data acquisition and computer hardware employed. An automatic function pre-tests the actual streaming parameters to ensure that the system will perform satisfactorily, avoiding overrun errors and lost data.

SNAP-STREAM is menu-driven and is very easy-to-use. No programming is required. Applications can include data logging, data archiving, event analysis, environmental monitoring, and product or process conformance testing. In order to support the highest possible data recording rate, SNAP-STREAM takes control of all computer resources during the data transfer process. Therefore, data analysis, display and other SNAPSHOT functions are suspended until the streaming operation is complete. The full complement of SNAPSHOT capabilities are available after the acquisition is complete (as a post-process). The entire data record (of any size) can be reviewed within SNAP-STREAM to provide an overview of the recorded event. Further detailed analysis, processing, and presentation can be accomplished by transferring the data into the SNAPSHOT environment.

PCI hardware provides a uniquie pre-trigger capability while streaming. The data file can contain up to 32,768 samples from before the trigger occurred. Other features of SNAP-STREAM include a test of the available disk space and disk optimization for improved performance. SNAP-STREAM is compatible with most PCI-20000 modules and all DMA-equipped boards and carriers. Please refer to the Hardware Compatibility Table in this data sheet.

SPECIFICATIONS--SNAPSHOT Series Products--PCI-20068S Series

All Speed benchmarks were measured in a 80286 type computer (PC/AT) running at 12MHz, unless otherwise indicated.

PARAMETER	CONDITIONS	SPECIFICATION
Compatibility		
Computer		IBM PC, XT, AT
Memory (RAM)	Required	640K
Disk Drives	Required	Hard disk or two Floppy drives
Coprocessor		Recommended
Acquisition Hardware	See Hardware Compatibility Table	PCI-20000 System
Analog Input		80 channels max
Data Points	Maximum, Total for All Channels	32,768
Channels	PCI-20019M/23M-1 (SE)	8
	with 2 PCI-20031M-1 (SE)	64
	PCI-20002M-1 (SE/Diff)	16/8
	with 2 PCI-20005M-1 (SE/Diff)	80/40
Signal Gain	PCI-20002M-1	1,10,100,1000
	PCI-20019M/23M-1	1
Resolution		12-Bits
Sample Rate	Minimum	6.7/hour
DMA	8088 Computer @ 4.7MHz, Max	
	PCI-20002M-1, Single Channel	32K/second
	PCI-20002M-1 + PCI-20031M-1	Multi-channel
	G=1,10	12K/second
	G=100	8K/second
	PCI-20019M-1	89K/second
	PCI-20023M-1	180K/second
	PCI-20091W-1	89K/second
	80286 Computer @ 12MHz, Max	
	PCI-20002M-1, Single Channel	32K/second
	PCI-20002M-1, G=1,10	12K/second
	G=100	8K/second
	PCI-20019M-1	89K/second
	PCI-20023M-1	129K/second
	PCI-20091W-1	89K/second
	PCI-20098C-1	38K/second
	80386 Computer @ 16MHz, Max	
	PCI-20002M-1, G=1,10	12K/second
	G=100	8K/second
	PCI-20019M-1	89K/second
	PCI-20023M-1	180K/second
	PCI-20091W-1	89K/second
	PCI-20098C-1	38K/second
Non DMA	80286 Computer @ 12MHz, Max	
	PCI-20002M-1, G=1,10	10K/second
	G=100	6K/second
	PCI-20019M-1	89K/second
	PCI-20023M-1	130K/second
	PCI-20089W-1	10K/second
	PCI-20091W-1	89K/second
	PCI-20098C-1	38K/second
	80386 Computer @ 16MHz, Max	
	PCI-20002M-1, G=1,10	12K/second
	G=100	6K/second
	PCI-20019M-1	89K/second
	PCI-20023M-1	180K/second
	PCI-20089W-1	12K/second
	PCI-20091W-1	89K/second
	PCI-20098C-1	38K/second

Continued...

12

PARAMETER	CONDITIONS	SPECIFICATION
Triggering	Free Run or Triggered	Analog or digital
	Analog, Internal/External	
	Using PCI-20020M-1	
	Less Than, Greater Than, and Window --	
	Trigger Level	± 70mV to ± 10V
	Response Time	3.5μS
	Digital, External	TTL Levels
	Response Time	
	1 of 8 bits	0.8μS
	External Sync	0.5μS
Sweep Time	Maximum	200 days
	Minimum	10/sample rate
Display		
Channels		1 to 8
Interface	IBM or Compatible	CGA, EGA, Hercules
Format		Cursor Readout, Plot, Tabular
Cursor	User-defined units	Absolute, Relative
Zoom	X direction	± 100 times
	Y direction	± 500 times
Offset	Y direction only	± 10V
Data Storage	Data formats	ASCII, Exponential Hex, Compacted Hex
Output Signals	Analog and digital	
Analog	Control and Excitation Non-DMA	
Speed	PCI-20003M-2, 6M-1/-2	3400/second
	PCI-20021M-1	2000/second
	Waveform Generation	Using DMA
	Requires PCI-20041C-3	
	PCI-20003M-2, 6M-1/-2	30,000/second
	PCI-20021M-1	2000/second
Channels	PCI-20003M-2, 6M-2	2
	PCI-20006M-1	1
	PCI-20021M-1	8
Digital	Control and Excitation	Non-DMA
Speed	PCI-20001C-2, 4M-1, 41C-2/-3, or 98C-1	3400/second
Channels	TTL Levels	8 bits

HARDWARE COMPATIBILITY TABLE -- SNAPSHOT/PCI Hardware Compatibility Table.

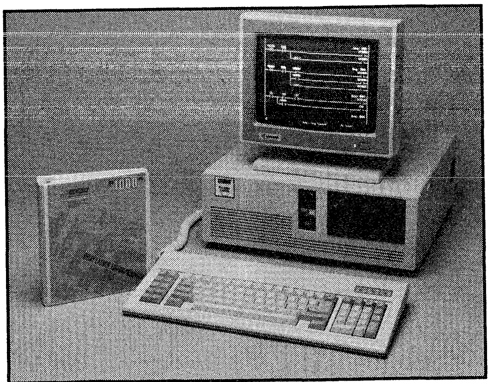
For performance information please refer to the SNAPSHOT Specification table.

Boards/ Carriers	DMA Option	Analog Input/ Expanders[3]	Analog Trigger	Digital Trigger	Rate Generator	Analog Output
PCI-20001C-1	No	PCI-20002M-1 PCI-20005M-1 PCI-20019M-1 PCI-20031M-1 PCI-20023M-1 PCI-20031M-1	PCI-20020M-1 & Software	No	PCI-20007M-1	PCI-20003M-2, 3M-4, 6M-1, 6M-2, 21M-1
PCI-20001C-2	No	PCI-20002M-1 PCI-20005M-1 PCI-20019M-1 PCI-20031M-1 PCI-20023M-1 PCI-20031M-1	PCI-20020M-1 & Software	Yes	PCI-20007M-1	PCI-20003M-2, 3M-4, 6M-1, 6M-2, 21M-1
PCI-20041C-2	No	PCI-20002M-1 PCI-20005M-1 PCI-20019M-1 PCI-20031M-1 PCI-20023M-1 PCI-20031M-1	PCI-20020M-1 & Software	Yes	On Carrier	PCI-20003M-2, 3M-4, 6M-1 6M-2, 21M-1
PCI-20041C-3	Yes	PCI-20002M-1 PCI-20005M-1 PCI-20019M-1 PCI-20031M-1 PCI-20023M-1 PCI-20031M-1	PCI-20020M-1 & Software	Yes	PCI-20007M-1[1]	PCI-20003M-2, 3M-4, 6M-1 6M-2, 21M-1
PCI-20098C-1	Yes[2]	On Carrier PCI-20031M-1	PCI- 20020M-1 & Software	Yes	On Carrier	PCI-20003M-2, 3M-4, 6M-1, 6M- 2, 21M-1
PCI-20089W-1	No	On Board None	Software	Yes	On Board	None
PCI-20091W-1	Yes	On Board None	Software	Yes	On Board	None

NOTES: 1) The PCI-20041C-3 has an on-board rate generator. A second rate generator, the PCI-20007M-1, is only required when it is desired to simultaneously generate an analog output waveform and do an analog input acquisition at different clock rates.

2) The PCI-20098C-1 supports DMA transfers for analog inputs only. Therefore, the simultaneous analog acquisition/waveform generation mode is not available.

3) When using the PCI-20001C or 41C carriers, you can choose from three different analog input modules. To add additional channels, use the expander module indicated.



BURR-BROWN®

PCI-20073S-1

RELAY LADDER LOGIC
RD1000/PC
Software for Process Monitoring and Control

FEATURES

- Runs On Readily Available Personal Computers
- Uses Standard Relay Ladder Symbols
- Can Be Programmed On or Off Line
- Load and Test Rung by Rung
- On-line Monitoring of I/O States
- Supports Analog I/O, Digital I/O & Counters
- PID & Digital (On/Off) Control
- Supports up to 4000 Rungs, 100 Stepper Drums & 100 PID Loops
- Scan Time: 2.5mSec/1000 bytes of Program (in PC/AT @ 8MHz)
- Math Functions, Logic, & Jumps
- Program Storage & Recall from Disk
- Supports Color or Monochrome Monitors
- Help Screen on Command
- Password Security

APPLICATIONS

- Process Monitoring
- Batch Process Control
- Continuous Processing
- Energy Management
- Pilot Plants

DESCRIPTION

This software integrates the industry standard, symbolic Ladder Logic Language with the Burr-Brown PCI-20000 Hardware System. It brings to the Personal Computer (PC) user a combination of features unparalleled by typical programmable logic controllers (PLCs). The capability, flexibility, and low cost of todays PCs means that you can solve real- world problems more efficiently than ever before. PCI-20000 products offer the industry's most comprehensive array of input/output options. The system includes both dedicated I/O boards for small applications and expandable Carrier/Module components for large or complex applications. Inherent in the PC is the capability to create and store any number of monitoring/control setups. Thus, changing from one application to the next is fast and convenient. This is of particular interest in pilot plants and in multiple use facilities. When not being used for monitoring/control applications, the PC is available for other uses including: word processing, data reduction, report generation, and statistical analysis, etc.

SYMBOLS INCLUDED

The Relay Screen Editor uses conventional Relay Ladder Symbols, enhanced with additional functions. The symbols are selected and entered with single keystrokes. A help screen can be accessed at any time to prompt the user. Some of the most important symbols are listed below.

Normally Open Contacts
Normally Closed Contacts
Analog Inputs
Analog Outputs
Read Thumbwheel Inputs
Number Conversions

Invert (NOT)
Coils
Math functions
Logical tests
Jumps to subroutines or labels
Horizontal & Vertical lines

FUNCTIONS INCLUDE

Inversion
One-shots
Timers
Counters
Shift registers

Special capabilities include PID control and 16-step by 16-output stepper drums. Each symbol has a specific name associated with it to define its function or, in the case of I/O, its channel assignment. Digital and analog I/O as well as counting/timing functions are supported.

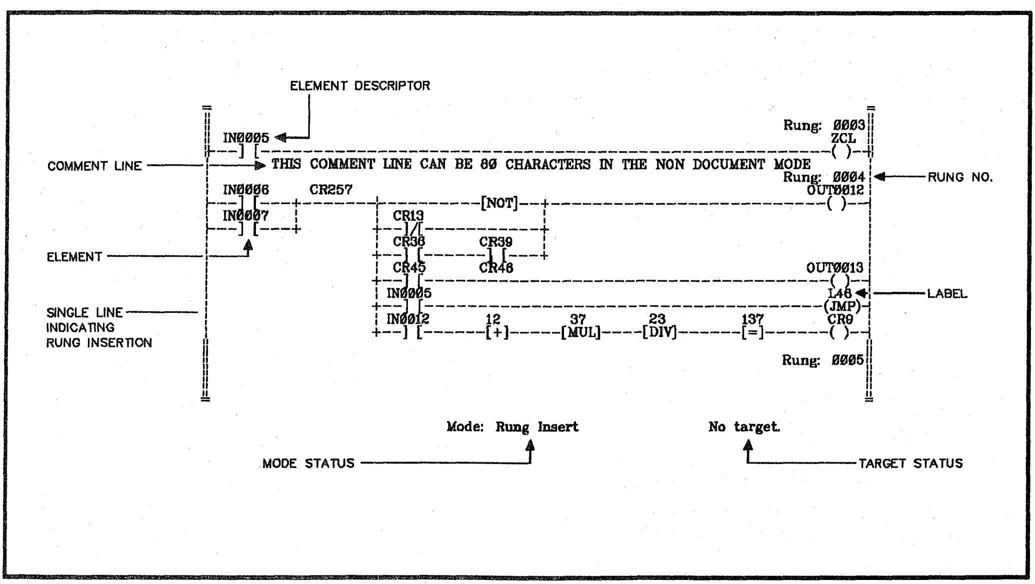
The Editor also allows extensive manipulation of setup programs. This includes: forwards and backwards searches for rungs, elements or labels; saving, deleting, or inserting rungs; saving or reading disk files and loading, linking, and running programs. A running program may be monitored, as well as modified, on-line. Security measures incorporate password protection, which may be used to prevent unauthorized program changes.

An IBM PC/XT/AT or a true compatible is required. These include the "386" type machines and the PS/2 Model 30. Also needed are two floppies (5 1/4 or 3 1/2 inch), or a hard disk, and 512Kbytes of available RAM. To execute PID loops, a math coprocessor is also necessary.

I/O HARDWARE SUPPORTED

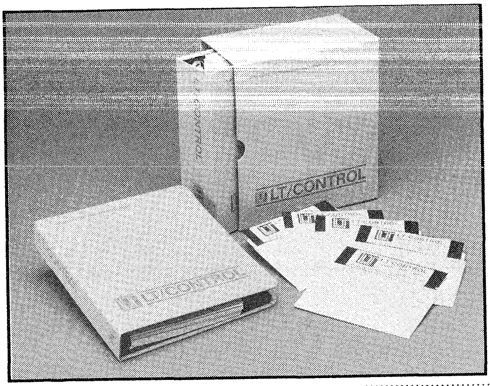
PCI-20001C-1	Carrier Board
PCI-20001C-2	Carrier Board with DI/O
PCI-20002M-1	Analog Input Module
PCI-20003M-2/4	Analog Output Module, 12-Bit
PCI-20004M-1	Digital I/O Module
PCI-20005M-1	Analog Input Expander Module
PCI-20006M-1/2	Analog Output Module, 16-Bit
PCI-20007M-1	Counter/Pulse Generator Module
PCI-20019M-1	High Speed Analog Input Module
PCI-20021M-1	Analog Output Module, 8 Channel
PCI-20041C-2/3	Carriers with DI/O
PCI-20087W-1	Digital I/O Board
PCI-20089W-1	Analog Input Board
PCI-20093W-1	Analog Output Board

Relay Ladder Logic supports the installation of up to 8 carriers (with up to 3 modules each) at any one time. If needed, the PCI-20055H Series PC Bus Expansion Enclosures are available to add additional slots to your IBM compatible PC. Connection between your PC and the expansion enclosure is accomplished with the PCI-20063A-1 Host Interface Adapter.



Rung Editor/Monitor Screen

BURR-BROWN®



PCI-20097S-1
LABTECH CONTROL
Integrated Industrial Monitoring and Control Software

FEATURES

PROCESS MONITORING

- Up to 600 functional blocks: analog, digital, RTD, thermocouple, strain, counter, frequency, RS-232, calculated channels, etc.

DATA LOGGING

- Trigger immediately, delayed, and with pre--trigger data saved
- Alarm on hi-hi, high, low or lo-lo
- Alarm from system input, calculated value, Time-of-day or user input
- Logs continuously or in response to event/alarm triggers or user input

PROCESS CONTROL (With 4 level password security)

- PID alarm, on-off (bang-bang), cascade
- On-line process tuning

REAL-TIME DISPLAY

- Trendline, T vs Y, X vs Y, horizontal and vertical bars graphs, digital meters, etc.
- Displays scroll as necessary
- Unlimited window scan time
- Up to 50 windows/screen, 50 trend lines/screen and 16 colors/window
- Up to 64 display screens
- Displays updated at 125 samples/sec (12MHz 80286/80287)

EGA/VGA GRAPHICS INTERFACE

- User built process depictions, drawn with mouse and/or library selections
- 16 colors foreground and background possible

ON-LINE ANALYSIS

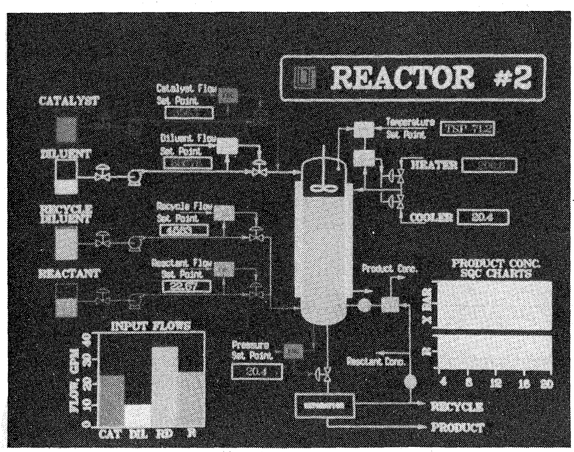
- Many calculation functions including arithmetic, exponential, trig, differential, integral, comparison, statistical, and logical
- Data transformations include polynomial, real-time FFT, digital filter, BCD to decimal, and thermocouple linearization
- Post processing includes curve-fitting and FFT
- Easily interfaced to spread sheet programs

DESCRIPTION

LABTECH Control software operates with all IBM PC/XT/AT and compatible computers and is fully supported by the PCI family of data acquisition and control hardware. No programming is required. All features are selected through a series of easy-to-use menus. A wide variety of process signal types are valid including those from analog transducers (voltage or current) and discrete, pulse and frequency devices. Both open loop and closed loop (PID) control algorithms are included. Custom, color graphic "flow diagrams" can provide display of real-time and trend information to the operator. Alarms can be set to call the operators attention or they can automatically trigger any desired action. Data can be stored on floppy or hard disk or written to a printer to provide historical records.

In some cases the input/output characteristics of the data acquisition and control system are determined by the choice of I/O hardware. All PCI Series Termination Panel components are supported. The major characteristics of selected PCI-20000 components are shown below.

- PCI-20001C General Purpose Carriers
  - 32 points (bits) of digital I/O
  - Each Carrier can hold up to 3 Modules
- PCI-20041C High Performance Carriers
  - 32 points (bits) of digital I/O
  - Internal programmable Rate Generator
  - Each Carrier can hold up to 3 Modules
- PCI-20098C-1 Multifunction Carrier
  - 16/8 analog inputs (SE/Diff)
  - 16 points (bits) of digital I/O
  - Internal programmable burst generator
  - 2 counter/timers
  - Supports 2 modules
- PCI-20002M-1 12-Bit Analog Input Module
  - 16 Single-ended or 8 differential channels
  - Gain of 1, 10, 100, or 1000 under soft-ware control
  - Input ranges of ±10V, 0-10V, or ±5V
- PCI-20005M-1 Analog Input Expansion Module
  - Adds 32 Single-ended or 16 Differential channels to Analog Input Modules
- PCI-20003M-2,-4 12-Bit Analog Output Modules
  - 2 Channels ±10V, 0-10V, or ±5V
  - Current output (5-25 or 4-20mA) on PCI-20003M-4
- PCI-20004M-1 Digital Input/Output Module
  - 32 TTL-level digital input/output points
  - Compatible with standard opto-isolators
- PCI-20007M-1 Counter/Timer/Pulse Generator Module
  - Event counting, frequency measurement
  - Rate generator up to 2MHz output
  - 4 Counter channels
- PCI-20019M-1 High Speed Analog Input Module
  - 8 single-ended inputs, 12 bit resolution
- PCI-20021M-1 Analog Output Module
  - 8 channel, 12 Bit resolution
  - ±5V or ±10V ranges
- PCI-20087W-1 Digital I/O Board
  - 32 Channels, TTL Levels
  - Buffered Outputs
- PCI-20089W-1 12-Bit Analog Input Board
  - 16 Single-ended or 8 differential channels
  - Gain of 1, 10, or 100 under software control
  - Input ranges of ±10V, 0-10V, or ±5V
  - 32kHz Sample Rate
  - PCI-20091W-1 High Speed Analog Input Board
  - 8 single-ended inputs, 12 bit resolution
- PCI-20093W-1 Analog Output Board
  - 8 channel, 12 Bit resolution
  - Voltage and Current Outputs
  - ±5V, ±10V and 0-20 mA ranges

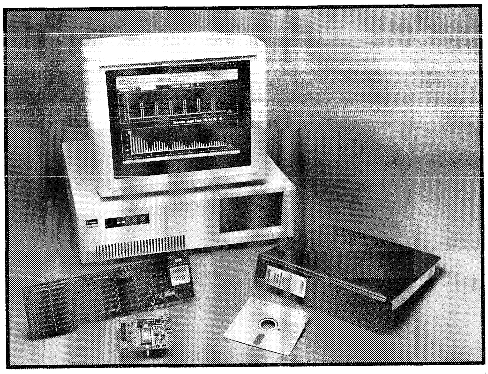


Typical Screen Display.

PERFORMANCE BENCHMARKS

Computer	Function	Speed (Loops/Sec)
PC/AT (80286) @ 12 MHz with 80287	Process Monitoring Process Control	900/115 * 235
80386 @ 16 MHz with 80387	Process Monitoring Process Control	1000/395 * 600

* with real-time trend display



BURR-BROWN®

PCI-20205S-1

DSPview Analyzer Software

FEATURES

- Completely Menu-Driven
- Controls the A/D Conversion Process
- Performs FFT Spectral Analysis
- Displays both the Time Signal and its Spectrum
- Displays the Power Spectrum in a Waterfall Format
- High Resolution Graphics Display
- Demonstrates some of *DATA PROFESSIONAL's* Capabilities

APPLICATIONS

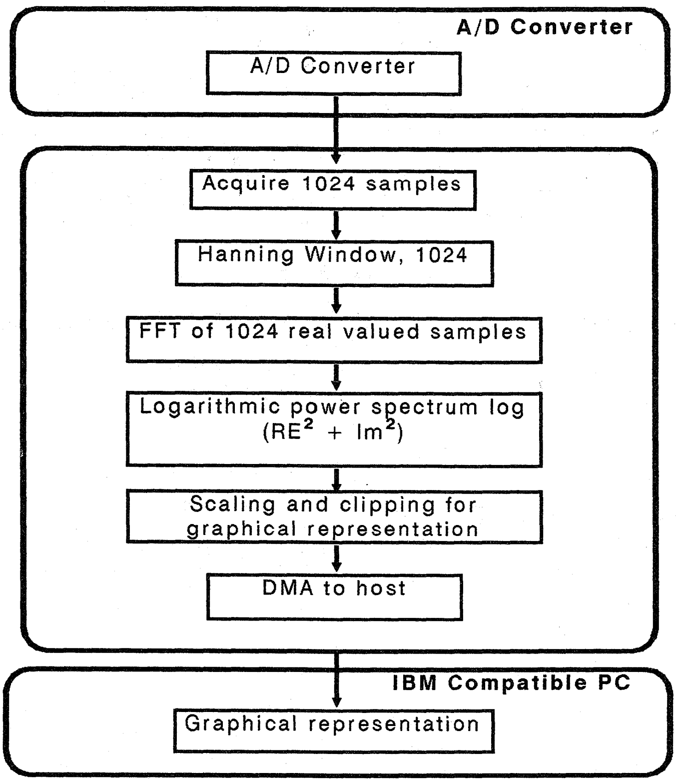
- Perform Spectral Analysis in:
  - Audio System Assessment
  - Biomedical Signal Analysis
  - Machine Heath Monitoring
  - Vibration Analysis
  - Power Utility Load Evaluation
- Develop familiarity with DSP Techniques
- Teaching and experimentation in Schools, Laboratories, Industry

DESCRIPTION

DSPview is a signal analysis utility that demonstrates the capabilities of the *Smart* Carrier in data acquisition and spectrum analysis applications. Actual data collection is performed using the PCI-20202C series *Smart* Carriers and any one of the available analog input modules (PCI-20002M-1, PCI-20019M-1 or PCI-20023M-1). Analog data are acquired in real-time and passed through an FFT transformation. The input signal and the spectrum are displayed in several different forms, including waterfall diagrams. With DSPview, several measurement tasks can be carried out, including the measurement of harmonic distortion and resonance analysis. The digital signal processing portion of DSPview is built entirely from a subset of the routines found in the Burr-Brown DSP Library Plus (PCI-20203S series).

A complete, descriptive, user manual is included with DSPview. Figure 1. illustrates how DSPview implements the data collection, analysis and display function.

Figure 1. Flow Diagram of FFT Analysis.



SPECIFICATIONS -- PCI-20205S-1

PARAMETER	CONDITIONS	SPECIFICATION
Distribution Media	360 KByte Format	5.25" Floppies
Hardware Requirements *Smart* Carrier Analog Input Module	Burr-Brown Memory Expansion Not Required	PCI-20000 System PCI-20202C-1,-2 PCI-20002M-1 or PCI-20019M-1 or PCI-20023M-1
Computer Requirements Type Graphics Adapter Monitor	Hard Disk Recommended True IBM PC or Compatible User Selectable Colors	 PC/XT/AT EGA Color or Monochrome
Analog Inputs Active Channels Acquisition Speed	 Select from channels 0-7 Selectable	 1 1k to 180kHz
Functions FFT Analyzer Dynamic Range Display	 Set up A/D Converter Display Time Function Display Power Spectrum One-shot Waterfall Diagram Running Waterfall Diagram Time Function Power Spectrum	All Menu Driven 72 dB In Volts In dBs

12

Additional Software

Available from Others

There is a large and growing body of high-performance software for use with the PCI-20000 System. Much of this software has been developed by organizations who specialize in a particular type of software. On the following pages, we feature vendor-supplied information regarding selected software packages for your consideration. Each of these software packages interfaces to products within the Burr-Brown PCI-20000 product line, and each is optimized for a particular application area. We invite you to consider them for your application.

For further information or for purchase of any of these software products, you should contact the vendor directly. Any product warranties will be provided by the vendor, not by Burr-Brown. The product information in this section is based on material supplied by the vendors. Burr-Brown assumes no responsibility for omissions or inaccuracies.

CODAS

Hardware and Software for PC Based Oscillograph

Available from: **Dataq Instruments, Inc** • 825 Sweitzer Ave. • Akron OH 44311, USA
Telephone: 216-434-4284 • Telex: 650-281-7028

FEATURES

- Continuous data streaming to floppy or hard disk at rates up to 7000 samples per second
- Simultaneous real-time data plotting directly on the computer's monitor through the unique Graphics Accelerator Card
- Two selectable real time data display modes: continuous smooth scroll plotting (like chart recorder), and triggered sweep (like oscilloscope)
- Supports eight channels of display
- Works with PCI-20000 Data Acquisition System

DESCRIPTION

Computer-based Oscillograph and Data Acquisition System (CODAS) is a combination hardware/software package allowing continuous data throughput to floppy or hard disk while maintaining a real- time display directly on the host computer's monitor.

REAL-TIME DATA ACQUISITION TO DISK

Continuous streaming of acquired data to the selected disk may be enabled or disabled by a simple keystroke. The quantity of data to be acquired is not limited by the size of RAM, but rather by the size of available disk space. Such an approach allows real- time data acquisition capacities in the tens of megabytes if necessary, while still maintaining the ability to acquire small or moderate sized data sets.

REAL-TIME DISPLAY

While data is being acquired to disk, a real-time plot of the data is presented on the computer's monitor through the CODAS high-speed Graphics Accelerator Card. Waveforms generated by the analog input channels are displayed in a unique, continuous, smooth scroll format. This plotting technique provides the ultimate in waveform display continuity that exactly mimics the continuous plot nature of a chart recorder. Alternatively, a triggered sweep (oscilloscope type) display appearance may be enabled. Such a display mode readily adapts to higher frequency input signals by overcoming the natural limitation of the eye attempting to follow a fast-moving, scrolling graph. Up to eight channels may be simultaneously plotted on the monitor. The real- time display is always active and independent of disk storage activity.

POST-ACQUISITION SUPPORT

Included with the CODAS package is waveform analysis software allowing the review and qualification of data previously acquired to disk. Specific waveform voltages may be measured as well as timing intervals on the same or different channels. Data sets of any size may be reviewed on the computer's monitor using the smooth scroll waveform presentation. Scrolling through the data set may be done in either a positive or negative time direction in a manner similar to reviewing the paper record of a chart recorder. A high waveform scroll speed of over 6000 points per second allows even the largest data file to be reviewed in seconds - from beginning to end. A copy and paste utility is included that allows any waveform group to be copied and pasted to one or more separate data files on floppy or hard disk for further analysis. Hard copy can be made using such popular analysis packages as Lotus 1-2-3, and DADiSP.

THE FIX

Software for Process Management and Control

Available from: **Intellution, Inc.** • 220 Norwood Park South • Norwood, MA 02062.
Telephone: 617-769-8878 • FAX: 617-769-1990

FEATURES

- Multi-tasking under the MS/PC-DOS operating system
- No programming required, menu-driven
- Direct digital control, supervisory control, sequencing control, statistical control, and batch control capability
- Highly efficient, easy-to-use, I/O drivers for PCI-20000 data acquisition hardware
- User defined color graphics displays

DESCRIPTION

THE FIX provides comprehensive data acquisition, process management and control software for IBM compatible PCs. The interface to the "real world" is furnished by the PCI-20000 hardware family. Interactive menus are used to configure the system. These blocks allow the construction of complex control networks without programming. In addition, the operator can modify and tune the control strategy, on-line, without disturbing the system.

Two ways are provided to create custom interactive process graphic displays in full color: character graphics and pixel graphics. These choices give all the flexibility needed to yield the highest performance and best-looking displays available. Character graphics displays draw quickly because the symbols are pre-configured. An EPROM chip supplied with the system provides over 128 different instrumentation symbols. These include horizontal and vertical valves, solenoid and modulated valves, pumps, pipe, ladder logic symbols, tank sides and bar graph segments. The pixel graphics option provides the ultimate in flexibility and high resolution. Because pixel displays are completely free format, special symbol sets can be created. Full color, 640 by 350 resolution is supported.

The On-Line Spreadsheet Interface (OSI) provides a mechanism for transferring real-time data to other application programs including Lotus Symphony.

The Historical Trending Package provides an automatic and comprehensive means of sampling, storing and displaying process data over long periods of time. The Trend package provides data handling, display and exporting features. Data collection and display operations are performed on-line giving maximum flexibility for process analysis. With the Trend Display program, the operator can view up to eight points on a single time-value graph in full color. A movable time cursor provides an exact value/status readout of selected points.

THE FIX is available in five different configurations that make it very easy to fit exact system needs. All configurations feature the same easy-to-use menus, on-line PC-DOS functions and comprehensive operations. Standard features include:

- Familiar I/O blocks for data acquisition and control functions
- On-line help screens
- Logging of all operator actions
- User-specified passwords and display security

1. <u>SCADA Base-Line</u>. The SCADA Base-line package provides a very economical way to get started. It performs:

- Data acquisition
- Analog and digital alarm detection and message generation
- Real-time trending
- On-line calculations

In addition, the SCADA Base-line package will support the following FIX options:

- Historical Trending
- On-line Report Generator
- On-line Spreadsheet Interface
- Graphic Printing Program

2. <u>SCADA Expanded</u>. The SCADA Expanded package forms the foundation for a full-sized FIX system. It contains advanced data handling and I/O communications functions. It can also be upgraded with any of the powerful and popular FIX system add-on packages: 12

- Direct Digital Continuous Control
- Statistical Process Control
- Batch and Sequencing Control

3. <u>Continuous Control</u>. The Control package add-on creates a direct-digital-control system. Traditional control blocks can be chained together to form complex control loops. The Control package has on-line loop tuning for ratio and PID plus an on-off controller for heating and cooling operations. A Drum Sequencer is included for simple batch and sequential operations.

4. <u>Statistical Process Control</u>. This package provides automatic or manual sampling of the process, as well as six types of on- line alarming based on statistical analysis.

5. <u>Batch Control</u>. When the Batch Control package is added it gives continuous and batch control capability.

GENESIS

Software for Process Control

Available from: **Iconics, Inc.** • 132 Central Street, Suite #110 • Foxborough, MA 02035, USA
Telephone: 617-543-8600

FEATURES

- No Programming Required
- Powerful Intuitive User Interface
- Icon-Driven Creation of Control Strategies
- Freehand Drawing of Process Displays
- True Real-Time Multitasking Operating System
- Over 40 Industry-Standard Control Algorithms
- Variable Scan Rates for Individual Control Algorithms
- Standard and User-Defined Graphics Symbol Libraries
- 20 User-Defined Function Keys for Fast Operator Response
- Real-Time Trending with Instantaneous "Snapshot"
- Real world interface through the PCI-20000 System Hardware
- On-line Help

DESCRIPTION

GENESIS transforms the IBM or compatible PC into a multi-function CAD workstation for creating, simulating and implementing real-time data acquisition and process control strategies. Absolutely no programming is required. Simply point the mouse and click, it's that easy. The complete GENESIS system includes the Control & Graphics Buildings (GENESIS-CGB) and a powerful Run-Time System (GENESIS-RT).

GENESIS-CGB
Process Architecture Builder

The mouse-driven Process Architecture Builder provides CAD tools to graphically create and edit data acquisition and control strategies. The user selects, positions, and connects icons representing control algorithms. User-built strategies are self- documenting and require no programming. Hard-copy reports are available in graphical or tabular formats. GENESIS resident Expert Checker detects and reports inconsistencies.

Graphics Display Builder

The Graphics Display Builder is an interactive graphics tool for creating dynamic process displays. Icon-based pick-and-place construction techniques are used to build and edit operator displays. Dynamic displays are created by graphically connecting display objects to the process database. The GENESIS icon library contains over 60 standard symbols representing tanks, motors, pipes, valves, faceplates, indicators and instruments. New symbols and symbol libraries are easy to create and modify. Custom displays can be attached to individual function keys for fast and easy operator access during run-time.

GENESIS-RT
Run-Time System

The Run-Time System is a real-time process management and control function built around a powerful multitasking operating system which is co-resident with DOS. The Operating System employs a prioritized pre-emptive scheduler with real-time interrupt support for communications and keyboard operations.

The Run-Time System includes:

Operator Interface--An operator window provides the interface to all data acquisition and control functions. A split-screen feature allows viewing displays in one window while simultaneously modifying parameters in another. Under password control, process parameters can be changed from the keyboard.

Comprehensive Alarm Management -- Alarms are prioritized and chronologically recorded. Alarms can be displayed via an Alarm Summary Display, or printed. Alarm squelching quickly inhibits unimportant alarms. Unacknowledged alarms are displayed regardless of the current active display.

Real-Time Trending -- Up to 20 variables may be trended simultaneously, and any five can be displayed in one-, six- and 30-minute time intervals. A "snapshot" feature allows the operator to instantly capture any number of trend plots for later replay.

System Security -- Selected parameters can be protected by one of three password security levels. The system may not be accidentally halted or re-booted from the keyboard.

Data Historian -- The Data Historian is an advanced long-term data collection and information management function. Up to 40 variables may be logged simultaneously on user-selectable files of one-hour, eight-hour, 24-hour and one-week periods. Archived data is recorded to hard disk in a format compatible with Lotus or other popular spreadsheet programs. Each log entry is time- and date-stamped. Individual log titles identify each report.

Genesis supports a wide range of Burr-Brown PCI-20000 I/O Hardware. Up to 40 control loops can be executed in 1/4 second on an 8MHz PC/AT. Up to 400 points of input/output channels can be supported.

LABTECH CHROM

Software for Chromatography Analysis

Available from: **Laboratory Technologies Corp.** • 400 Research Drive • Wilmington, MA 01887
Telephone: 508-657-5400 • FAX: 508-658-9972

FEATURES

- CHROM works as a unit with LABTECH Notebook and the PCI-20000 hardware system for data acquisition
- Multi-channel operation -one PC can handle several chromatographs or channels
- Notebook's foreground/background capability allows data collection to proceed simultaneously with analysis of data from a previous run
- User-friendly menu-driven system, requiring minimal training or operator expertise
- Smoothes raw data by convolution and eliminates spikes in data
- Streams data to disk continuously
- Sophisticated baseline drawing algorithms, allowing accurate analysis of fused peaks, drifting baselines, etc.
- Produces annotated graphical display on inexpensive dot-matrix printers, eliminating the need for chart recorders
- Provides detailed results report, with peak area, peak start, peak maxima, peak end -- provides for follow-on analysis, display or validation
- Interfaces to popular systems like 1-2-3, and Symphony for further analysis

DESCRIPTION

LABTECH CHROM is a software program that turns an IBM compatible PC into a chromatography integrator and data archive. It accepts raw chromatographic data and method parameters as its input, and it produces chromatographic peak areas and retention times as output. It works with LABTECH Notebook and Burr-Brown's PCI- 20000 hardware system.

LABTECH CHROM provides a basic integration capability for use as a system building block, or for stand-along composition determination. It is oriented toward production capillary gas chromatography or liquid chromatography, in which the chromatographic runs may contain many thousands of data points.

With the LABTECH CHROM approach, raw data is archived on permanent hard disk storage. This data is always available for reprocessing with different analysis methods. A complete trail of the analyses is maintained. This trail conforms to good laboratory practices, and is suitable for scrutiny by federal and stated agencies such as the Food and Drug Administration and the Environmental Protection Agency. CHROM is extremely well suited for unattended operation with autosampling devices that perform continuous or semi-continuous analyses.

EASE OF USE

CHROM is extremely easy to learn and use. Its user interface is similar to LABTECH Notebook and Lotus 1-2-3. To set up the analysis method, the user is presented with a fill-in-the-blanks worksheet. This worksheet contains the existing method as a starting point. The method is modified very easily, by moving the cursor to the item to be changed, and typing in the new value. When all the changes have been made, the method is automatically saved to permanent disk storage, and becomes the new existing analysis method.

ANALYSIS METHOD PARAMETERS

The analysis method parameters include the following:

1. Maximum spike width and minimum spike amplitude
2. Number of points for smoothing/convolution
3. Automatic slope sensitivity (optional)
4. Maximum peak width, minimum peak height, maximum baseline width, maximum baseline drift, and slop check width
5. Report detail level

ONSPEC

Software for Process Control

Available from: **Heuristics, Inc.** • 9723A Folsom Blvd., Suite 231 • Sacramento, CA 95827 USA
Telephone: 916-369-6606 • Telex: 4940010

FEATURES

- Real-time displays
- Process status displaysAnalog and digital data logs
- Shift summary and historical logs
- Trend graphs
- Multitasking
- Input/Output Interface via PCI-20000 Hardware

APPLICATIONS

- Process Monitoring
- Real-Time Process Control
- Plant documentation
- Batch controls
- Safety Compliance

DESCRIPTION

The ONSPEC family of process control software products runs on IBM PC/XT/AT and compatible computers. It is modular in design to allow the user to select the features necessary for a specific use. ONSPEC Control Software combines an excellent operating system, spreadsheet, editor and process controller. The family supports process control, real-time displays, alarms, trending, historical reporting, analysis, modeling, and simulation.

Displays are created using a standard process control character set that replaces the foreign language character set in your PC. An EPROM is supplied that is plugged into your color graphics board. Configuration information is stored in data tables using fill-in-the-blank data entry. ONSPEC supports extended RAM up to 8Mbytes, allowing several programs to run concurrently. Available programs include: ONSPEC with Supertrends, Control Blocks, and Superintendent. These tools allow you to orchestrate and direct data acquisition, process control, and management.

ONSPEC interfaces to the "real world" via the Burr-Brown PCI-20000 data acquisition and control hardware system. The control engineer now has the freedom to develop designs with greater flexibility and lower cost than ever before. Tools are included for design, simulation, and supervisory control. Superintendent is a real-time expert system that performs safety evaluations, and control procedures. It brings standard operating procedures on line and can interact with the process I/O hardware and operators continually to make sure regulations are followed and exceptions documented. Also available is SQC, a statistical quality control program, ONNET to provide networking capabilities, ACT to tune control loops, and Supertrends for an electronic implementation of the digital trend pen recorder.

SQC runs concurrently with ONSPEC control software and Superintendent to provide information on the degree of control for each process variable in a process. SQC limits can be established, referenced to alarm action, and stored in an historical file as a record of the process. Retrieved data can be manipulated through SQC calculations and operations to improve product quality.

ACT improves plant safety and operation with Automatic Controller Tuning. It creates an optimal tuning algorithm and then calculates and tunes the parameters. ACT also tunes supervisory control algorithms supplied with ONSPEC Ladder Logic and ONSPEC Control Blocks.

The exchange of information between people and computers, people and people, and computers and computers is essential in today's control environment. ONSPEC is designed with multi-machine requirements in mind. It provides powerful communications options including:

- **ONSPEC Remote** Support provides remote terminal color graphic display and editor capability to an ONSPEC supervisory control system.
- **ONSPEC Remote Link** adds four communications ports to a PC. Devices can be connected to these ports so that up to four additional users can be supported simultaneously.
- **ONNET** is a communications program that allows two ONSPEC programs running on separate computers to exchange data.
- **ONSPEC Network** provides each computer in a networked system the ability to access data from remote computers, run remote peripherals, and have full computing capabilities at each station and remote console.

PCI-20000 HARDWARE SUPPORTED

PCI-20001C-1 Carrier
PCI-20001C-2 Carrier with 32 Digital I/O Points
PCI-20002M-1 12-Bit, 16-Channel Analog Input Module
PCI-20003M-2 12-Bit, Two-Channel Analog Output Module
PCI-20087W-1 32 point Digital I/O Board
PCI-20089W-1 12-Bit, 16-Channel Analog Input Board

Please check with the factory if other I/O hardware requirements exist.

UNKELSCOPE

Software for Data Acquisition, Analysis, Display and Control

Available from: **Unkel Software, Inc.** • 62 Bridge St. • Lexington, MA 02173 USA
Telephone: 617-861-0181

FEATURES

- Supports PCI-20000 Interface Hardware
- Completely Menu-Driven Software
- Real-Time Y vs T and X vs Y Displays
- Stores and Retrieves Data from Disk
- Extensive Triggering Capabilities
- Extensive In-Program Processing:
  Transducer Calibration and Conversion,
  Integration, Differentiation, etc.
  High, Low and Bandpass Filters
- Compute and Plot Spectral Density, Correlations
- Graphic Editing of Data:
  Zoom In On Data
  Read-Out Time, Voltage From Each Of Two Cursors
- Compute Enclosed Areas, Curve Fit Data
- Process control -- Proportional, PID, On/Off
- Macro Capability to Automate and Customize Applications

DESCRIPTION

UnkelScope is an integrated software package for data acquisition, control, and data display. It is a menu-driven interface that turns IBM PC compatibles into a comprehensive replacement for a strip chart recorder, X-Y plotter, or oscilloscope. Extensive data analysis capabilities are included. UnkelScope requires no special computer instincts and is appropriate for scientists, engineers and technical support staff in a broad range of disciplines. Applications are found in research, development, teaching, production and testing. The hardware interface to the "real world" is through the popular PCI-20000 series components

Real-time X vs Y and the normal signal vs time plots are supported. Stored data can be compared with current data. Other features allow: data examination, finding particular values, finding enclosed areas, and curve fitting. The macro feature allows automation of the measurement and analysis process.

BASIC OPERATION

SETUP FOR DATA ACQUISITION

Parameters are all specified with menus. The up and down arrow keys find the parameter and the desired value is selected (shown in reverse video) using the left and right arrow keys. Data sampling and display setups are shown on a single screen avoiding confusion.

DATA ACQUISITION, DISPLAY AND STORAGE

For low-speed signals, sampled data is plotted in real-time on the computer's monitor. For higher speeds, a full set of data is taken and is then plotted. Plots are well annotated with time, data, and trace labels. Data can be saved in a disk file, and then retrieved and re-plotted by UnkelScope.

IN-PROGRAM PROCESSING

Extensive processing capabilities include: FFT-related functions, digital filtering (to improve signal quality), integration, differentiation, and commonly used transformations. Experiments can be controlled using open-loop, proportional, PID or on/off algorithms.

MACRO DEFINITIONS

An established sequence of data taking, processing and display can be automated using the macro capability. There is no new programming language to learn. UnkelScope simply remembers your keystrokes as you take it through the procedure the first time.

SPECIFICATIONS

Maximum channels	8 sampled, 2 displayed
Horizontal Axis	Time or any analog input
Slowest sampling	Once each 500 seconds
Fastest sampling	89kHz
Triggering options	Auto, single sweep, with signal source from external, keyboard, or analog input.

PCI hardware support now includes:

- PCI-20041C-2 or PCI-20041C-3 Carrier
- PCI-20019M-1 Analog Input Module
- PCI-20003M-2 Analog Output Module (required for process controllers)
- PCI-20091W-1 Analog Input Board

HOTLINE

Software for Data Acquisition, Display and Control

Available from: **Industrial Control Specialists, Inc.** P.O.Box 6471 Lake Charles, LA 70605, USA
Telephone: 318-474-3163

FEATURES

- PCI-20000 compatibility
- Operates with IBM and compatible personal computers
- User friendly, no programming required
- Enhanced graphics display
- Historical trend display without compression
- Control functions: PID, On/Off, And, Or, Not, Switch
- Excellent graphics builder and database editor
- Alarm functions: Displays, Reports, Verification
- PID tune display
- Builds data files acceptable by Lotus 1-2-3
- Long-term archive of data with on-line recall
- Tailored to user's special functions
- Quantity discounts available

DESCRIPTION

The Industrial Control Specialists Data Acquisition, Display, and Control System is a program written for an IBM Personal Computer or compatibles and plug-in data acquisition and control hardware from the Burr-Brown PCI-20000 product line. The program drives the acquisition equipment in real time, converts the raw data to engineering units, and displays the data on an enhanced color monitor and on a printer. The data is displayed in table format, graphic format, trend format, alarm format, and in alarm reports. The operator's interface has been designed for simple input with few displays, but with maximum data on each display. The system is menu driven with extensive use made of function keys to reduce operator input. The color display used is the Enhanced Color Display having a resolution of 600 X 350 pixels.

DATA ACQUISITION

The Data Acquisition, Display, and Control System will acquire raw analog and digital data from the PCI-20000, convert the data to engineering units and status conditions, and display the data on an enhanced color monitor, and on a printer.

Configuration consists of defining the types of input/output modules installed on the carrier and parameters associated with each module. Once configured, the multiplexer will scan analog and digital data without stopping, and store the converted data in memory for access by the host computer.

CONVERSION OF ANALOG DATA TO ENGINEERING UNITS

Conversion routines are included for the following types of measured variables:

1. IC thermocouples (type J), degrees F
2. CA thermocouples (type K), degrees F
3. Differential liquid flow
4. Differential gas flow
5. Differential stream flow
6. Linear flow element (magnetic meter, vortex shedding, etc.)
7. Linear input element (pressure, level, weight, analysis, etc.)
8. Calculated variable.

DATA DISPLAY

The Enhanced Color Display is capable of eight colors in two intensities and has a resolution of 600 pixels horizontal X 350 pixels vertical. This display is a significant enhancement over the normal color display. Data will be displayed in table format, graphics format, alarm format and trend format. The multi-color capability of the monitor is utilized in the data base editor also.

The Data Acquisition, Display, and Control System is menu driven. Displays on the monitor guide the user in all functions of the system. The same technique is used to guide the operator in the use of the Data Base Editor. Instructions are included in the displays that direct the operator in each function of the system. Extensive use is made of the function keys. The 25th line of the monitor display will always define the functions assigned to the ten special function keys. As displays change, the assignments of the function keys will change.

CONTROL FUNCTIONS

Proportional/Integral/Derivative (PID) and Digital Output controls are included in the Data Acquisition, Display, and Control System. The PID function is implemented in a building-block manner, where an analog input entry in the data base serves as an input to a PID control entry in the data base, which serves as an input to an analog output entry in the data base. Thus to implement PID control, three entries must be defined in the data base: two which have real signals connected and one (PID) that is a pseudo entry (calculated variable). If cascade control is required, an additional analog input entry and PID entry must be defined in the data base. The Digital Control function provides for toggling digital outputs.

In addition to the standard provisions for digital input and digital output in the data base, entries in the digital data base may be assigned to any of several logical functions (AND, OR, NOT, SWITCH).

Section 13

GLOSSARY OF TERMS

This glossary consists of terms and their definitions as they normally pertain to the personal computer area and does not attempt to include every possible variation that might be used in the broader computer field that would include mainframes and specialized, dedicated machines.

A/D--A term that refers to the Analog to Digital conversion process. Analog voltages are received by the system, converted to digital numbers, then stored or analyzed by the computer.

acquisition--The process by which data is gathered by the computer for analysis or storage.

active filter--An electronic filter that combines active circuit devices, usually amplifiers with passive circuit elements, such as resistors and capacitors. Active filters typically have characteristics that more closely match ideal filters than do strictly passive filters.

alias frequency--a false lower frequency component that appears in analog data reconstructed from original data acquired at an insufficient sampling rate.

algorithm--A set of rules or detailed plan, with a finite number of steps, for solving a problem. An algorithm can be used as a model for a computer program.

analog--A continuous signal or process.

ANSI--American National Standards Institute.

array--Data arranged in single or multidimensional rows and columns.

ASCII--American Standard Code for Information Interchange. Code that is used to represent symbols in computers.

ASCII Files--Files on disk which contain ASCII coded data.

assembler--A program that converts a list of computer instructions written in a specific assembly-language format into binary instructions that can be executed by a specific processor.

assembly-language program--A program written directly with processor commands using mnemonic representations of the commands. The program is then processed by an assembler to produce executable machine code.

asynchronous--A communications protocol where information can be transmitted at an arbitrary, unsynchronized point in time, without synchronization to a reference timer or "clock".

background--A secondary task performed by the computer in conjunction with the primary or foreground task.

bandpass filter--A type of filter that allows a band of signal frequencies between two set frequencies to pass while attenuating all signal frequencies outside the bandpass range.

base address--A memory address that serves as a point of reference. All other points are located by offsetting (adding to or subtracting from) in relation to the base address.

BASIC--The most common computer language, BASIC is an abbreviation for Beginners All-purpose Symbolic Instruction Code. Relies on English-like instructions which accounts for its popularity and ease of learning.

baud rate--Serial communications data transmission rate; the number of bits-per-second.

binary-coded decimal--A code for representing decimal digits in a binary format.

BIOS--Basic input-output system. Part of the computer's software operating system, BIOS is responsible for controlling data inputs from, and outputs to, peripherals such as the keyboard, screen display, printer, floppy disk and hard disk.

bipolar--A signal range that includes both positive and negative values.

bubble memory--A type of non-volatile computer memory that uses magnetic domains (bubbles) for data storage. Access to information stored in bubble memory is serial and therefore relatively slow compared to RAM. However, bubble memory is faster than floppy or hard disk. In addition, bubble memory is considerably more rugged than mechanical memory devices making it desirable in many industrial applications.

buffer--A storage location used for holding information that is to be used at a later time.

bus--Conductors used to interconnect individual circuitry in a computer. The conductors as a whole are called a bus.

byte--A term referring to eight related bits of information. Eight bits equals one byte.

C--A programming language, developed around the concept of structured programming, that bears a strong resemblance to PASCAL.

cache memory--Fast memory used to improve the performance of a CPU. Instructions that will soon be executed are placed in cache memory shortly before they are needed. This process speeds up the operation of the CPU.

CAD--Computer-aided design. A computer-based drafting and documentation system used for design engineering.

CAE--Computer-aided engineering. A computer system designed to aid engineering development.

CAM--Computer-aided manufacturing. A computer system used for automating manufacturing operations.

call--A software instruction used to pass control to a subroutine of a program. At the completion of this subroutine, control is returned to the original program at the point of the "call" statement. Often used for specialized routines such as "analog read" from a data acquisition system.

Carrier--in the PCI-20000 Personal Computer Interface System, the Carrier is the motherboard that "carries" a configuration of I/O Modules to create a data acquisition/control system in a personal computer. The Carrier plugs into an expansion slot in an IBM PC, XT, AT, or another compatible personal computer.

central processing unit (CPU)--The central part of a computer system that performs operations on data. In a personal computer the CPU is typically a single microprocessor integrated circuit.

code--As a noun, the text of a computer program. As a verb, to "code" mean to write a program.

cold-junction compensation--A method of providing an artificial reference level and compensation for ambient temperature variations in thermocouple circuits.

command--An instruction given directly to an active program from a keyboard or terminal rather than from a program.

common-mode rejection ratio (CMR)--A measure of an instrument's ability to ignore or reject interference from a voltage common to its input terminals relative to ground. CMR is usually expressed in dB (decibels).

comparator--An electronic circuit used to compare two values and set an indicator that identifies which value is greater.

compiler--A particular type of high-level language used to preprocess a program in order to convert it to a form that a processor can execute directly.

concurrent--Software that can perform more than on task simultaneously.

configure--This is a process by which software or hardware is set by the user to function in a certain way.

contact closure--The closing of a switch, often controlled by an electromagnetic or solid state relay.

conversion time--The time required, in an analog input or output system, from the moment a channel is interrogated (such as with a read instruction) to the moment that accurate data is available. This could include: switching time, settling time, acquisition time, A/D conversion time, etc.

converter resolution--A term that refers to how accurately the A/D converter chip represents an analog signal with a binary value. Accuracy is determined by how many bits are used to make up the binary value.

coprocessor--Another computer processor unit that operates in conjunction with the standard CPU. Can be used to enhance execution speed. For example, the 8087 is designed to do floating-point arithmetic.

counter--In software, a memory location used by a program for the purpose of counting certain occurrences. In hardware, a circuit that can count pulses.

CPU--Acronym for central processing unit--refers to the microprocessor.

cross assembler--A computer program that translates machine language code so that it can be read by a different type CPU.

crosstalk--In communications, a phenomenon in which a signal in one or more channels interferes with a signal or signals in other channels. In an analog multiplexer, the ratio of the output voltage to the input voltage with all channels connected in parallel and turned off.

current loop--Communications method that allows data to be transmitted over relatively long distances and through relatively high noise environments. With a current loop, the voltage levels are converted to currents to that the signals are transmitted in the form of current instead of voltage in a closed-loop circuit. Current loops are less sensitive to noise pickup.

D/A--A term that refers to the output of analog voltage signals that were converted from digital numbers. Reverse of A/D.

DAS--Acronym for data acquisition system.

data acquisition--Gathering information from sources such as sensors and transducers in an accurate, timely and organized manner. Modern systems convert this information to digital data which can be stored and processed by a computer.

data reduction--The process of analyzing a large volume of data to extract and refine a subset of the data for some particular purpose. As in the statistical summarization of data.

debouncing--Either a hardware circuit or a delay built into software to prevent false inputs from a bouncing key or switch contact.

decibel--A logarithmic measure of the ratio of two signal levels: $dB = 20Log_{10}(V_1/V_2) = 10Log_{10}(P_1/P_2)$.

default--A value assigned or an action taken automatically unless another is specified.

digital--A signal which has distinct states. Digital computers process data as binary information having either 1 or 0 states.

digital-to-analog conversion--The process of changing discrete data into a continuously varying signal. Common uses are to present the output of a digital computer as a graphic display or as a test stimulus.

digital-to-analog converter (DAC)--A device that converts digital information into a corresponding analog voltage or current.

DIP switch--A set of switches contained in a dual in-line package.

direct memory access (DMA)--A method by which information can be transferred from the computer memory to a device on the bus while the processor does something else. Also one of three methods of transferring data acquisition system measurements to computer memory (the other methods being polling and interrupt).

DOS--Disk operating system.

down-load--The copying of information from one computer to another.

drivers--Part of the software that is used to control a specific hardware device such as a data acquisition board or a printer.

duplex--The ability to both send and receive data simultaneously over the same communications line.

dynamic range--The ratio of the full-scale range (FSR) of a data converter to the smallest difference it can resolve. Dynamic Range (DR) = 2^n. Generally expressed in dB, DR = 20 log 2^n. "n" is the resolution in bits.

event counter--A circuit used to count pulses that are related to the occurrences of a certain condition, such as an item coming off the end of the assembly line. An event counter can typically be preset, reset and can totalize.

expanded memory--Memory that exists outside of the normal PC computer memory area. May be referred to as bank switched memory.

expansion board--A plug in circuit board that adds features or capabilities beyond those basic to a computer, such as a data acquisition system expansion board.

expansion chassis--An enclosure used to increase the capabilities of a computer system by providing space for additional expansion boards.

expansion slots--The spaces provided in a computer for expansion boards that enhance the basic operation of the computer.

expert systems--A highly specialized data base and computational computer program that acts like a human expert on a particular subject.

extended memory--Memory that is addressable by the PC as part of the normal memory area of the computer, but is not used by DOS for user programs.

FFT (Fast Fourier Transform)--An algorithm which quickly determines frequency components of a waveform.

firmware--A program permanently recorded in a ROM and therefore essentially a piece of hardware that performs software functions. BIOS is an example of firmware.

floating-point numbers--Numbers that contain decimal parts or are presented in scientific notation (digits multiplied by a power of 10). Also known as "real" numbers. Integers are a subset of reals containing whole numbers only.

foreground--In a PC system, the activity subject to direct operator intervention. Other (background) activities continue as previously defined.

front end--The preprocessing of data before a program uses it. Could refer to signal conditioning in a data acquisition system.

GPIB--General-purpose interface bus. A standard bus used for controlling electronic instruments with a computer. Also designated IEEE-488.

ground--An electrically neutral wire having the same potential as the surrounding earth. Normally, a non-current-carrying circuit intended for safety purposes.

handshake/handshaking--Method whereby two communicating electronic devices verify the integrity of the communication.

hardware--The visible parts of a computer system, such as the circuit boards, chassis, enclosures, peripherals, cables, etc. It does not include data or computer programs.

hexadecimal--A numbering system to the base 16.

hierarchical--A method of organizing data with a series of levels, each with further subdivisions, as in a pyramid or tree structure.

high-level language--A program used to simplify the creation of computer code. Allows the specification of a computer action using a smaller number of steps than assembly language.

IEEE-488--The Institute of Electrical and Electronic Engineers' designation for the GPIB instrumentation control bus standard.

I^3 Bus--Intelligent Instrumentation Interface Bus. A patent- pending interconnection bus for modular data acquisition components which is used to create a complete personal computer interface system.

input/output (I/O)--The process of transferring data from or to a computer system including communications channels, operator interface, or data acquisition and control channels.

instrumentation amplifier (IA)--An amplifier circuit with both high-impedance differential inputs and high common-mode rejection.

integer--A whole number, not requiring a fraction, a decimal point or scientific notation for representation.

integrating A/D converter--an A/D conversion technique in which the analog input is integrated over time. Different types of integrating A/D converters include dual slope, triple slope, and charge-balancing types.

interface--A device which allows two devices to communicate. For example, a computer can interface with printers, other computers, analog signals, etc.

interpreter--A high-level language in which the command statements are converted, one at a time and in the order they are used, into code that can be executed by the processor.

interrupt--A computer signal indicating that the CPU should suspend its current task to service a designated activity. One of three methods for transferring data acquisition measurements to the computer's memory (the other methods being DMA and polling).

interrupt handler--The section of a program that performs the necessary operations to service an interrupt when it occurs.

I/O address--A method that allows the CPU to distinguish between the different boards in a system. Unique addresses usually are set with DIP switches. All boards must have different addresses.

I/O mapping--Method of connecting I/O devices to the CPU ion an addressable fashion without using memory space. Disk drives, printers and monitors are usually I/O mapped. However, there is a limited address space available and a limited set of I/O instructions. For these reasons, advanced data acquisition systems tend to be memory mapped.

isolation amplifier--An amplifier with electrically isolated inputs and outputs which allows it to amplify a differential signal superimposed on a high common-mode voltage.

isolation voltage--The voltage which an isolated circuit can normally withstand. Isolation voltage is usually specified from input to input and/or from any input to the amplifier output, or to the computer bus.

isothermal--A process or area that is maintained at a constant temperature.

K--Kilo. In referring to computers, a "kilo" is 1024 or 2 to the 10th power. (Note that it is actually slightly more than an even 1000.)

latch--A term used to indicate that the state of a digital signal will remain stored until changed by the CPU or specified external command signal.

linearity--The adherence of a device's response to a straight line relationship.

linker--A program which combines different sections of a compiled program.

listener--A device on the GPIB bus that receives information from the bus.

machine language--Binary code that is executed directly by a computer CPU and translated into electronic actions. Machine language is different for each CPU type.

macro--A small set of program steps combined to act as a single, more powerful, program step.

math coprocessor--Companion processor to the microprocessor. Contains hard coded programs to carry out fast and highly precise floating point operations along with mathematical functions.

memory--Electronic devices that enable a computer to store and recall information. In its broadest sense, memory refers to any hardware capable of serving that end, e.g., disk, tape, or semi-conductor storage.

mnemonics--A method of helping a software programmer remember the various commands of a specific computer system. A relatively easy-to-remember alphabetic code is assigned to each command and usually consists of letters extracted from, and thus suggestive of, the command it symbolizes.

modem--A device used to translate serial data to/from a form that can be transmitted/received over telephone or other communication channels. (Short for MOdulator-DEModulator.)

modular--The use of building blocks (modules) in a computer or data acquisition system. A modular device, for instance, is one that is built, tailored and expanded by connecting various mutually compatible components. An example of a modular data acquisition system is the PCI-20000 Personal Computer Interface System.

Module--In the PCI-20000 Personal Computer Interface System, the Instrument Modules provide specialized data acquisition functions. A configuration of Instrument Modules is combined with a motherboard Carrier to create a data acquisition/control system in a personal computer.

monotonicity--The desirable characteristic of a digital-to- analog converter to produce a continuously increasing analog output for a correspondingly increased digital input code.

multidrop--A single communications line used to connect three or more points.

multiplexer (mux)--An array of semiconductor or electromechanical switches with a common output used for selecting one of a number of input signals.

multitasking--The characteristic of an operating system that allows a processor to perform several operations at once.

noise--An undesirable electrical interference to a signal. Sources of noise include the AC power line, motors, generators, transformers, fluorescent lights, soldering irons, CRT displays, computers, electrical storms, welders, radio transmitters, and others.

nonvolatile--A memory or data storage device that retains its information content when electrical power is removed. Ordinary RAM is volatile whereas ROM, bubble memory, battery-backed-up CMOS RAM, floppy, and hard disks are nonvolatile.

Nyquist Sampling Theorem--If a continuous bandwidth-limited signal contains no frequency components higher than a specified frequency, then the original signal can be recovered without distortion if it is sampled at a rate of at least twice the specified frequency.

offset binary--A coding scheme for converting analog signals to a decimal equivalent. The smallest analog voltage will equal a decimal 0. The highest analog voltage would equal a large (i.e., 4095, 32768) digital value. That is, negative decimal representations are not used.

operating system--The master control program that governs the operation of a computer system. Software or firmware that manages the internal memory allocation and the control of peripheral devices for applications programs.

optical isolation--Two networks connected only through an optoelectric transmitter and receiver with no electrical continuity between the two networks.

overhead--The amount of computer processing resources, such as time or memory, required to accomplish some task.

Pascal--A high-level programming language originally developed as a tool for teaching the concepts of structured programming. It has evolved into a powerful general-purpose language popular for writing scientific and business programs.

passive filter--A filter circuit using only resistors, capacitors, and inductors. (No active devices such as integrated- circuit amplifiers.)

PCI--Personal computer instrumentation. Prefix for a series of personal computer interface products from the Burr-Brown Corporation and Intelligent Instrumentation Incorporated. For example, the PCI-20000 is a modular, board-level data acquisition and control system that fits directly inside a PC.

peripheral--The input-output and data storage devices attached to a computer such as disk drives, printers, keyboards, displays, data acquisition systems, etc.

PID--Proportional, integral, derivative. A three-mode control algorithm.

polling--A round-robin canvassing of data acquisition inputs synchronized in software to a clock or external trigger. One of three methods of transferring data acquisition measurements to the computer's memory (the others being DMA and interrupt).

port--A communications connection on a computer or a remote controller.

protocol--The exact sequence of bits, characters and control codes used to transfer data between computers and peripherals through a communications channel.

quantizing error--The inherent uncertainty in digitizing an analog value due to the finite resolution of the conversion process. This error can be reduced only by increasing the resolution of the converter.

queue--A temporary storage location or list of things to be done such as messages that are awaiting transmission.

random access memory (RAM)--Computer memory that allows data to be read or written at a particular location without having to pass sequentially through preceding locations.

range--Refers to the maximum allowable full-scale signal (input or output) that yields a specified performance level.

rate generator--A device that provides a TTL - level pulse output at a software-programmable frequency.

read only memory (ROM)--Computer memory in which data can be routinely read but written to only using special means when the ROM is manufactured. ROM is used for storing data or programs on a permanent basis.

real numbers--Numbers that can express a fractional value. Also called floating-point numbers.

real time--Data acted upon immediately instead of being accumulated and processed at a later time.

real-world--Referring to events, signals and conditions that occur naturally or in everyday life.

reduction or data reduction--The selection of data subsets based on given criteria. Some examples of such criteria are: Frequency: Filtering, smoothing. Position: Cross section, sub array. Math Operations: Averaging, standard deviation.

repeatability--The ability of an instrument to give the same output or reading under repeated identical conditions.

resolution--The smallest significant number to which a measurement can be determined. For example, a converter with 12- bit resolution can resolve 1 part in 4096.

ribbon cable--A flat cable in which the conductors are side by side rather than in a bundle.

routine--A self-contained program designed to accomplish a specific task.

RS-232C--A serial asynchronous communications standard used to connect modems, terminals and printers with serial interfaces. Although RS232C is only specified for use in transmission lengths up to 50 feet, it is often used for greater distances at lower baud rates.

RTD--Resistance temperature detector. An electrical circuit element characterized by a positive coefficient of resistivity.

R/W--Read/write, abbreviation.

sample/hold--A circuit which acquires and stores an analog voltage on a capacitor for a short period of time.

sampling theorem--See Nyquist Sampling Theorem.

Seebeck Effect--The basic principle behind thermocouples. When a circuit is created by the junctions of two dissimilar metals and the junctions are held at different temperatures, a current caused by the difference in temperature between the two junctions will flow in the circuit.

sensitivity--A measure of the minimum change in an input signal that an instrument can detect.

sensor--A device that responds to a physical stimulus (heat, light, sound, pressure, motion, etc.) and produces a corresponding electrical output.

serial I/O--A common form of data transmission, in which the bits of each character are sent one at a time over the line.

serial port--A communications interface that uses one data line to transfer data bits sequentially. On the IBM PC the serial port refers to a standard serial interface which uses the RS-232C and ASCII standards.

set point--A "level" or control point in a feedback system.

settling time--The time required, after application of a step input signal, for the output voltage to settle and remain within a specified error band around the final value. The settling time of a system includes that of all of the components of the system.

shielded cable--A cable with foil or other sheathing around it to stop radio frequency interference and magnetic fields from generating extraneous signals on cable conductors.

signal-to-noise ratio--On a communications line, the ratio of signal strength to the level of noise.

simultaneous sample/hold--A data acquisition system in which several sample/hold circuits are used to sample a number of analog channels at the same instant. One sample/hold per analog channel is required.

software--The non-physical parts of a computer system that includes computer programs such as the operating system, high-level languages, applications programs, etc.

span--The difference between the lower and upper limits of a range. Span is expressed in the same units as the range.

spike--A transient disturbance of an electrical circuit. Due, for example, to load variations on the AC power line.

stability--The ability of an instrument or sensor to maintain a consistent output when a constant input is applied.

strain relief--A bracket or clamp used to secure a cable so that it does not become disconnected accidentally or apply stress at the point of connection to the system.

subroutine--A sequence of computer instructions that perform a specific task and can be called repeatedly in a program whenever that specific task is required.

successive-approximation A/D converter--An analog-to-digital conversion method that sequentially compares a series of binary-weighted values with an analog input to produce an output digital word in "n" steps, where "n" is the bit resolution of the A/D converter. This process is analogous to weighing an unknown quantity on a balance scale using a set of binary standard weights.

surge--A sudden change (usually an increase) in the voltage on a power line. A surge is similar to a spike, but is longer lasting.

surge protector--A device placed in an electrical circuit to prevent spikes and some surges that might otherwise damage electronic equipment connected to that circuit.

synchronization--The coordination of the activities of several circuit elements together.

syntax--Comparable to the grammar of a human language, syntax is the set of rules used for forming statements in a particular programming language.

20K-- A slang term for the PCI-20000 Personal Computer Interface System.

talker--A device on the GPIB bus that simply sends information on to the bus without actually controlling the bus.

termination panel--A circuit board with screw terminations or another connector system that allows convenient connection of field signals to a data acquisition system.

throughput rate--The maximum repetitive rate at which a data conversion system can operate with a specified accuracy. It is determined by summing the various times required for each part of the system and then by taking the inverse of this time.

time stamp--Information added to a message, record, or other unit of data indicating the time at which it was processed by the system.

transducer--A device that converts length, position, temperature, pressure, level, etc. to a different energy form (i.e., voltage or current).

triac--A solid-state switching device used to switch alternating current waveforms.

trigger--Pulse or signal that is used to start or stop a particular action. Triggers are frequently used to control data acquisition processes.

turnkey--A system that combines all the hardware and software required for a specific application.

universal asynchronous receiver-transmitter (UART)--An electronic circuit that translates the data format between a parallel representation within computer and the serial method of transmitting them over a communications line.

uninterruptible power supply (UPS)--A power conditioning unit placed between the commercial power service and the protected device. The UPS uses line power to charge batteries, which in the case of a power failure can drive electronic circuitry to produce the appropriate AC requirements for some time period.

virtual memory--A method of making disk storage appear like RAM memory to the CPU, thus allowing programs to run that need more RAM memory than is installed in the system. This technique is slow compared to "real memory.

volatile memory--Memory that does not retain its contents when power is removed.

voltage-to-frequency converter (VFC)--A device which converts an analog input voltage into a sequence of digital pulses with frequency proportional to the input voltage.

word--The standard number of bits that a processor or memory manipulates at one time. Microprocessors typically use 8 or 16-bit words.

SUBJECT INDEX

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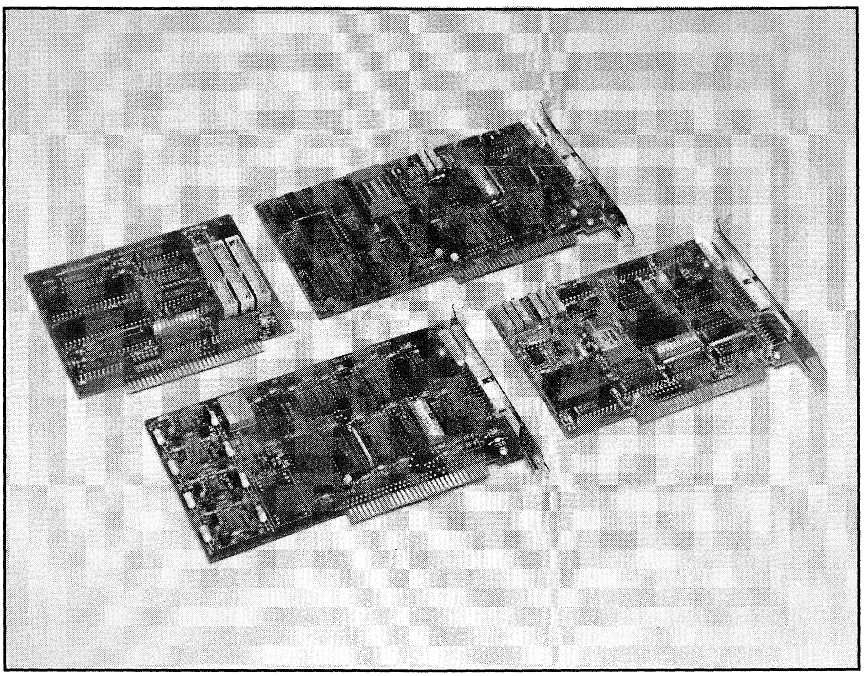

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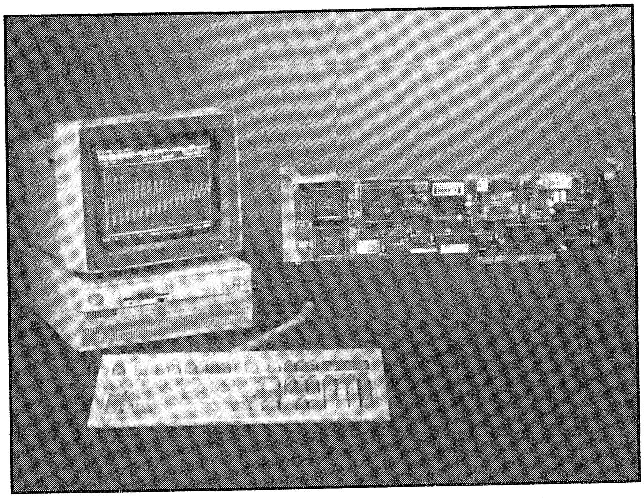

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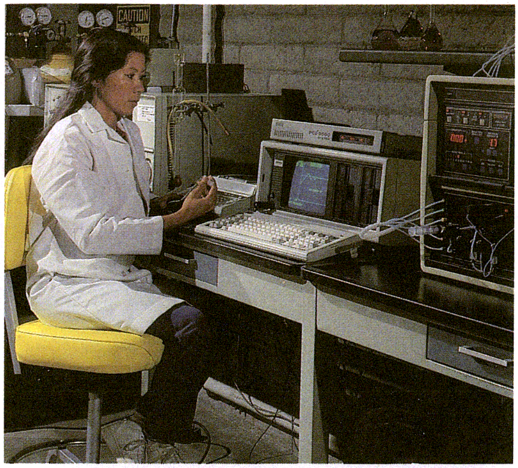

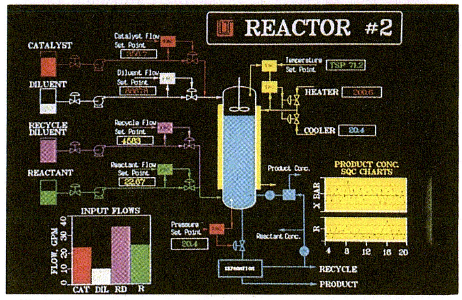
REACTOR #2
CATALYST
Catalyst Flow
Set Point
DILUENT
Diluent Flow
Set Point
RECYCLE DILUENT
Recycle Flow
Set Point
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REACTANT
Reactant Flow
Set Point
22.67
Temperature
Set Point
TSP 71.2
HEATER
200.6
COOLER
20.4
Product Conc.
PRODUCT CONC.
SQC CHARTS
X BAR
R
4 8 12 16 20
Pressure
Set Point
20.4
Reactant Conc.
RECYCLE
PRODUCT
INPUT FLOWS
FLOW, GPM
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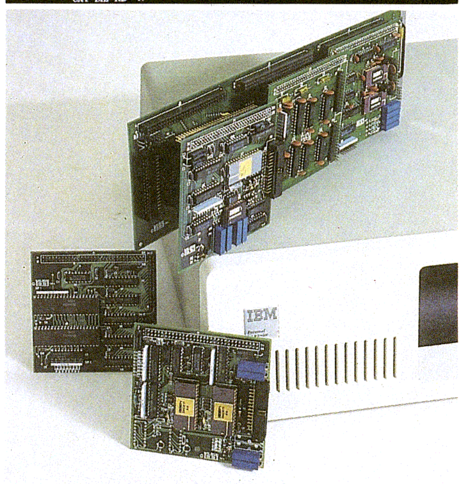
CAT DIL RD R


IBM

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