

# Linear Circuits Data Book

1984

**Op Amps, Comparators,  
Timers, Regulators,  
A/D Peripherals**



**TEXAS  
INSTRUMENTS**





# Linear Circuits

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**General Information**

**1**

**Thermal Information**

**2**

**Operational Amplifiers**

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**Voltage Comparators**

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**Appendix**

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# Linear Circuits Data Book



TEXAS  
INSTRUMENTS

*In Memoriam*  
*Bryan E. Zimmerman*  
1929 – 1983

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Information contained herein supersedes data published in The Linear Control Circuits Data Book, Second Edition, and the Voltage Regulator Data Book.

ISBN 0-904047-43-1

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European Edition

Edited by Alun Roberts

## INTRODUCTION

The rapid advance in high-tech digital processing creates new demands for microprocessor-compatible circuits that can sense, amplify, and convert analog signals or provide regulated power to a system. In this volume, Texas Instruments presents specifications and technical information on our broad line of integrated circuits designed for applications that involve analog signal conditioning. That product line includes:

- Operational amplifiers
- Voltage comparators
- Regulators
- Power supply monitors
- Switching-mode power supply circuits
- Hall-effect circuits
- Current mirrors
- Floppy-disk circuits for control, reading, or writing
- Timers
- A/D converters
- Video amplifiers
- Analog switches

These circuits span the recent rapid development of integrated circuit technology from classical bipolar through BIFET™ and BIDFET™ to TI's new LinCMOS™ processing that provides a step-function improvement in input impedance, power dissipation, and threshold stability. New surface-mount packages include both plastic and ceramic chip carriers and the small-outline packages that increase board density with little impact on power handling capability.

Ordering information and mechanical data are in the Appendix. Section 1 contains an alphanumeric index that lists page numbers for all the device types included, and each data sheet section provides a functional selection guide to the devices in that section.

While this volume offers design and specification data only for Linear components, complete technical data for any TI semiconductor product is available from your nearest TI sales office. A listing can be found at the back of this data book.



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# General Information



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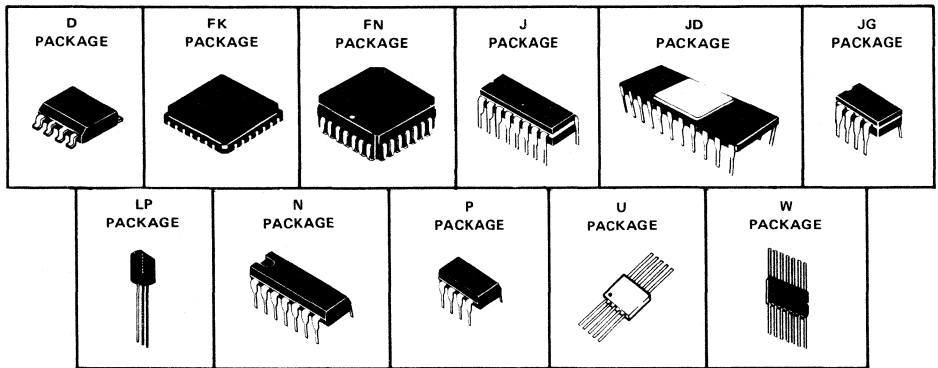




THERMAL RESISTANCE

PACKAGE	PINS	JUNCTION-TO-CASE THERMAL RESISTANCE $R_{\theta JC} (^{\circ}C/W)$	JUNCTION-TO-AMBIENT THERMAL RESISTANCE $R_{\theta JA} (^{\circ}C/W)$
D plastic dual-in-line	8	51	172
	14, 16	33	131
FK ceramic chip carrier	20	35	91
FN plastic chip carrier	20	37	114
J ceramic dual-in-line (glass-mounted chips)	14 thru 20	60	122
J ceramic dual-in-line <sup>†</sup> (alloy-mounted chips)	14 thru 20	29 <sup>†</sup>	91 <sup>†</sup>
JG ceramic dual-in-line (glass-mounted chips)	8	58	151
JG ceramic dual-in-line <sup>†</sup> (alloy-mounted chips)	8	26 <sup>†</sup>	119 <sup>†</sup>
LP plastic plug-in	3	40	160
N plastic dual-in-line	14 thru 20	72	143
	28	45	100
	40	40	100
P plastic dual-in-line	8	79	172
U ceramic flat	10, 14	55	185
W ceramic flat	14, 16	60	125

<sup>†</sup> In addition to those products so designated on their data sheets, all devices having a type number prefix of "SNC" or "SNM," or a suffix of "/883B" have alloy-mounted chips.



2  
Thermal Information

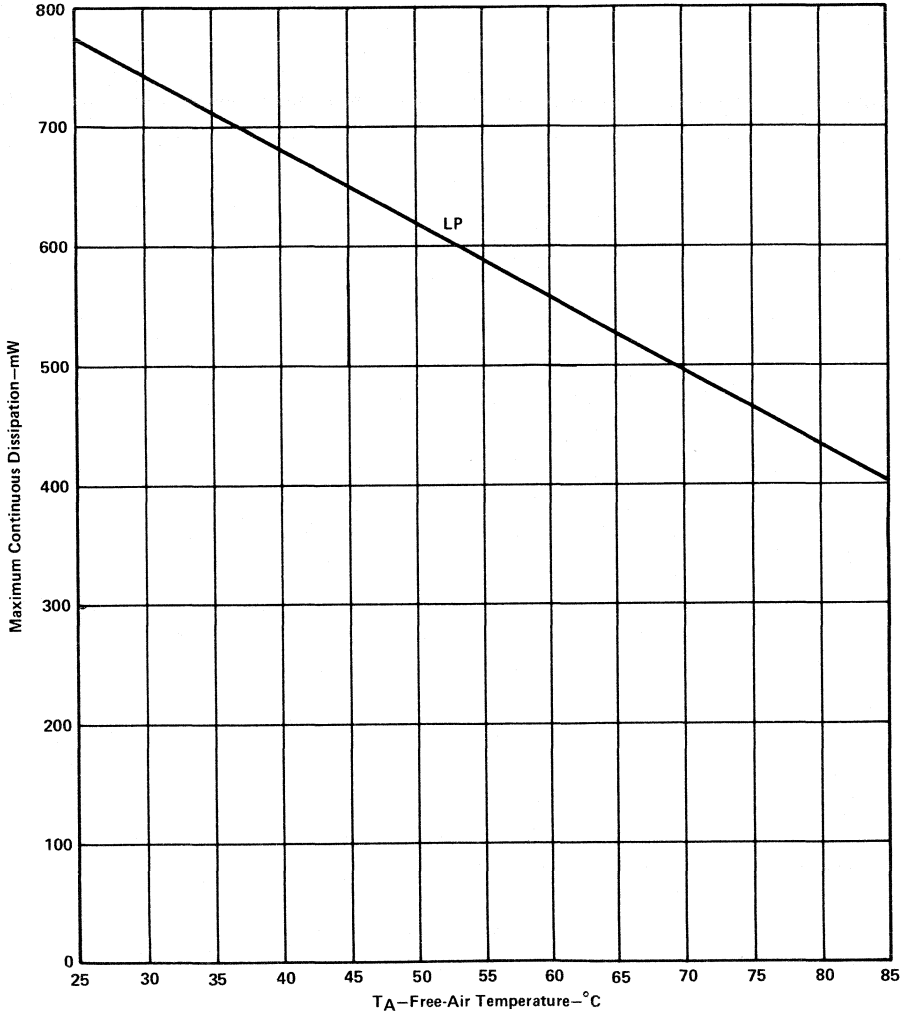
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## Thermal Information

PLASTIC PACKAGES

These curves are for use with the continuous dissipation ratings specified on the individual data sheets. Those ratings apply up to the temperature at which the rated level intersects the appropriate derating curve or the maximum operating free-air temperature.

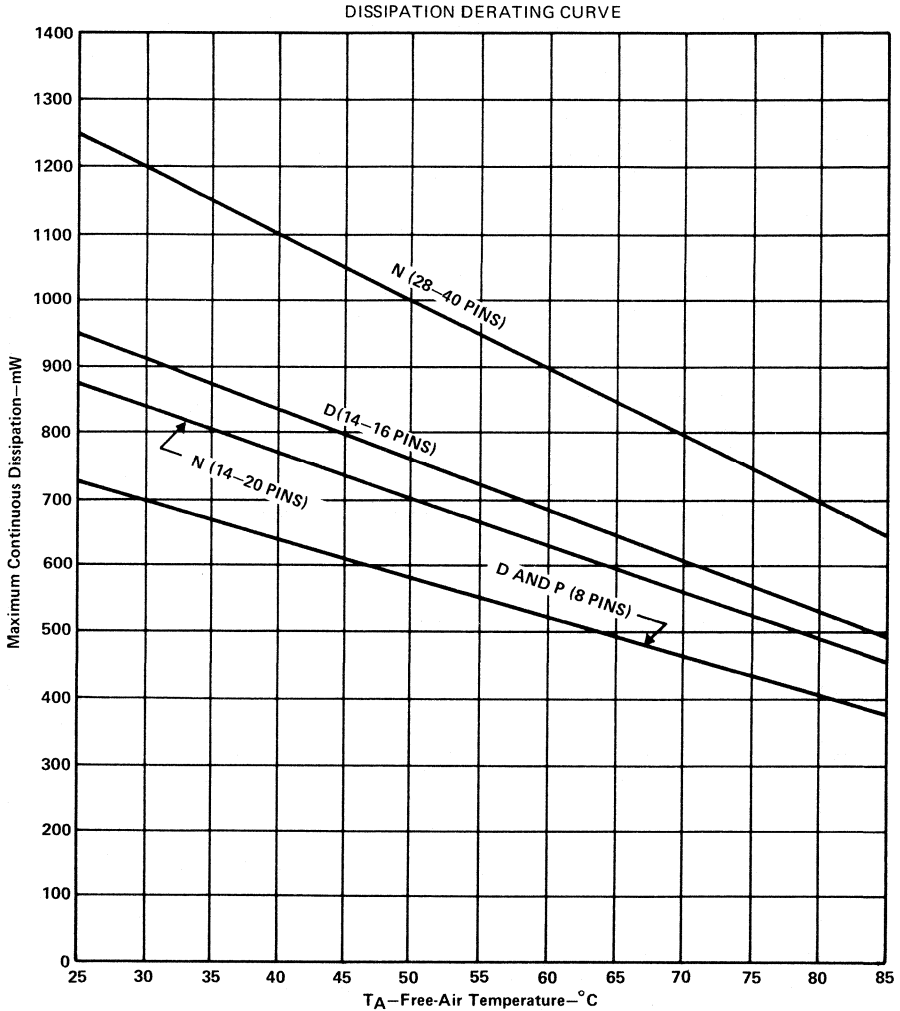
DISSIPATION DERATING CURVE



# THERMAL INFORMATION

## PLASTIC PACKAGES (CONTINUED)

These curves are for use with the continuous dissipation ratings specified on the individual data sheets. Those ratings apply up to the temperature at which the rated level intersects the appropriate derating curve or the maximum operating free-air temperature.



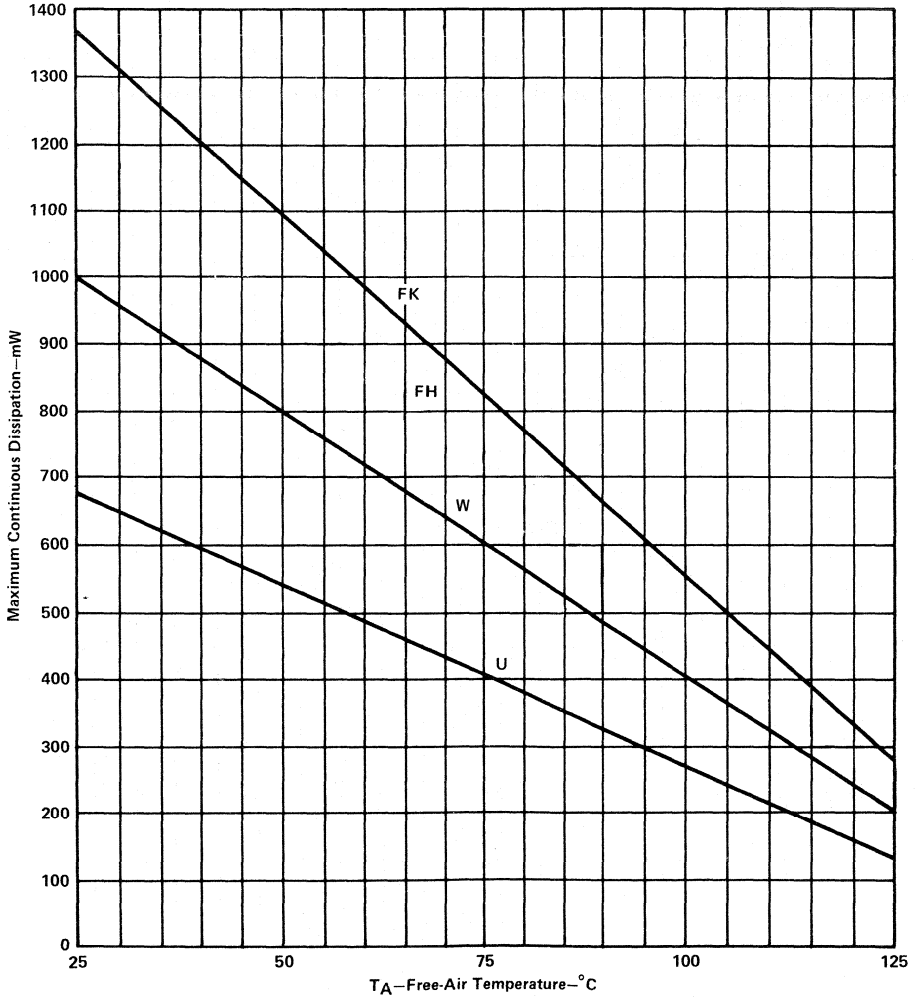
2

Thermal Information

FLAT PACKAGES

These curves are for use with the continuous dissipation ratings specified on the individual data sheets. Those ratings apply up to the temperature at which the rated level intersects the appropriate derating curve or the maximum operating free-air temperature.

DISSIPATION DERATING CURVE

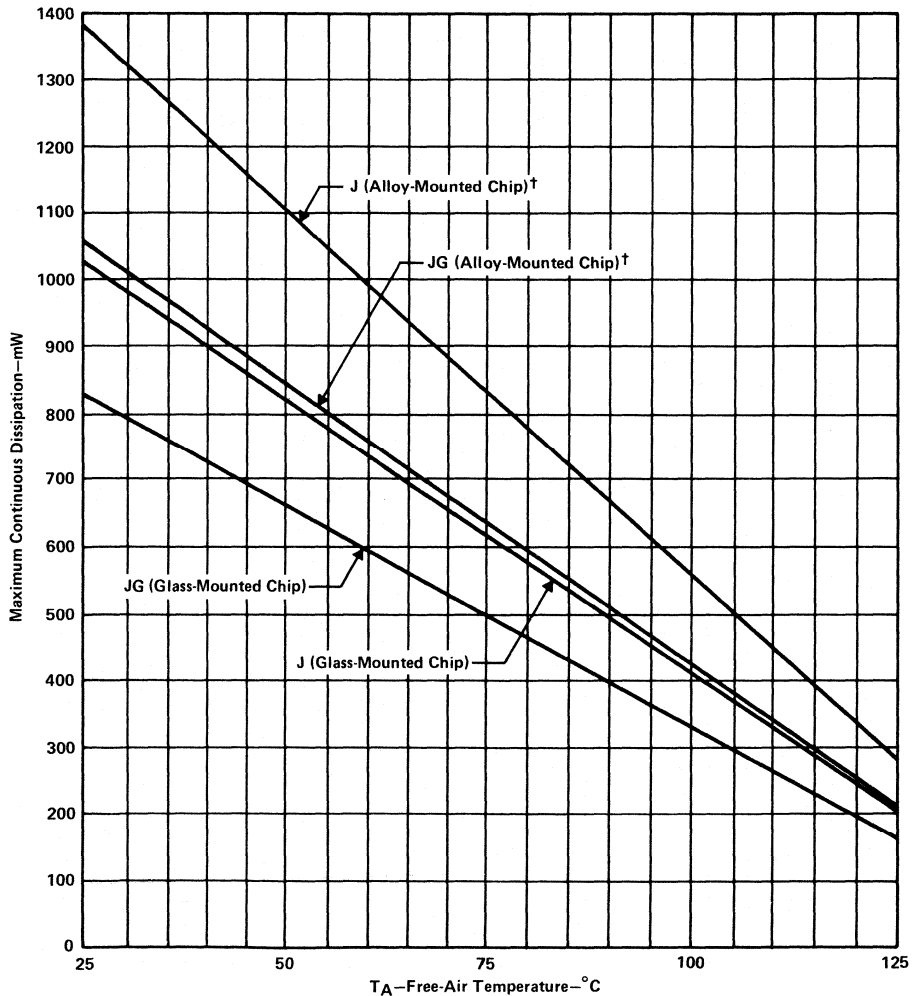


# THERMAL INFORMATION

## CERAMIC DUAL-IN-LINE PACKAGES

These curves are for use with the continuous dissipation ratings specified on the individual data sheets. Those ratings apply up to the temperature at which the rated level intersects the appropriate derating curve or the maximum operating free-air temperature.

DISSIPATION DERATING CURVE



† In addition to those products so designated on their data sheets, all devices having a type number prefix of "SNC" or "SNM", or a suffix of "/883B" have alloy-mounted chips.

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Thermal Information

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**Operational Amplifiers**



## OPERATIONAL AMPLIFIERS

noncompensated, single

military temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	B <sub>1</sub> (MHz) TYP	SR (V/ $\mu$ s) TYP	V <sub>IO</sub> (mV) MAX	I <sub>B</sub> (nA) MAX	A <sub>VD</sub> (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
TL080M	BIFET, Low Power	3	13	6	0.2	25	$\pm 3.5$	$\pm 18$	JG	3-121
$\mu$ A709AM	General Purpose	1	0.3	2	200	45 Typ	$\pm 5$	$\pm 18$	J,JG,U,W	3-187
$\mu$ A709M	General Purpose	1	0.3	5	500	45 T <sub>VD</sub>		$\pm 18$	J,JG,U,W	3-187
LM101A	High Performance	1	0.5	2	75	50	$\pm 5$	$\pm 22$	FK,JG,U,W	3-17
$\mu$ A748M	General Purpose	1	0.5	5	500	$\pm 10$	$\pm 2$	$\pm 22$	JG,U	3-205
TL060M	BIFET, Low Power	1	3.5	6	0.2	4	$\pm 1.5$	$\pm 18$	JG	3-89

industrial temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	B <sub>1</sub> (MHz) TYP	SR (V/ $\mu$ s) TYP	V <sub>IO</sub> (mV) MAX	I <sub>B</sub> (nA) MAX	A <sub>VD</sub> (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
TL070I	BIFET, Low Noise	13	13	6	200	50	$\pm 3.5$	$\pm 18$	D,JG,P	3-111
TL080I	BIFET, Low Power	3	13	6	200	50	$\pm 3.5$	$\pm 18$	JG,P	3-121
LM201A	High Performance	1	0.5	2	75	50	$\pm 5$	$\pm 22$	D,JG,P,W	3-17
TL060I	BIFET, Low Power	1	3.5	6	0.2	4	$\pm 1.5$	$\pm 18$	D,JG,P	3-89

commercial temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	B <sub>1</sub> (MHz) TYP	SR (V/ $\mu$ s) TYP	V <sub>IO</sub> (mV) MAX	I <sub>B</sub> (nA) MAX	A <sub>VD</sub> (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
TL070AC	BIFET, Low Noise	3	13	6	0.2	50	$\pm 3.5$	$\pm 18$	D,JG,P	3-111
TL070C	BIFET, Low Noise	3	13	10	0.2	25	$\pm 3.5$	$\pm 18$	D,JG,P	3-111
TL080AC	BIFET, Low Power	3	13	6	0.2	50	$\pm 3.5$	$\pm 18$	JG,P	3-121
TL080C	BIFET, Low Power	3	13	15	0.4	25	$\pm 3.5$	$\pm 18$	JG,P	3-121
$\mu$ A709C	General Purpose	1	0.3	7.5	1500	15		$\pm 18$	JG,P	3-187
$\mu$ A748C	General Purpose	1	0.5	6	500	20	$\pm 2$	$\pm 18$	D,JG,P	3-205
TL060AC	BIFET, Low Power	1	3.5	6	0.2	4	$\pm 1.5$	$\pm 18$	D,JG,P	3-89
TL060BC	BIFET, Low Power	1	3.5	3	0.2	4	$\pm 1.5$	$\pm 18$	D,JG,P	3-89
TL060C	BIFET, Low Power	1	3.5	15	0.2	3	$\pm 1.5$	$\pm 18$	D,JG,P	3-89
LM301A	High Performance	1	7.5	50	75	25	$\pm 5$	$\pm 18$	D,JG,P,W	3-17

3

Operational Amplifiers

## SELECTION GUIDE

internally compensated, single

military temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	B <sub>1</sub> (MHz) TYP	SR (V/ $\mu$ s) TYP	V <sub>IO</sub> (mV) MAX	I <sub>B</sub> (nA) MAX	A <sub>VD</sub> (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
TL291M	High Speed	20	50				$\pm 4$	$\pm 18$	JG	3-141
SE5534	High Performance	10	13	2	800	50	$\pm 3$	$\pm 20$	FH,FK,JG,U	3-77
SE5534A	High Performance	10	13	2	800	50	$\pm 3$	$\pm 20$	FH,FK,JG,U	3-77
TL081M	BIFET, General Purpose	3	13	6	0.2	25	$\pm 4$	$\pm 18$	FH,FK,JG	3-121
TL088M	BIFET, Low V <sub>IO</sub>	3	13	3	0.4	50	$\pm 3.5$	$\pm 18$	JG,U	3-131
TL071M	BIFET, Low Noise	3	13	6	0.2	35	$\pm 5$	$\pm 18$	FH,FK,JG	3-111
TLC271AM	LinCMOS, Programmable	2.3	4.5	5	0.001 Typ	10	4	16	FH,FK,JG	3-151
TLC271BM	LinCMOS, Programmable	2.3	4.5	2	0.001 Typ	10	4	16	FH,FK,JG	3-151
TLC271M	LinCMOS, Programmable	2.3	4.5	10	0.001 Typ	10	4	16	FH,FK,JG	3-151
uA741M	General Purpose	1	0.5	5	500	50	$\pm 2$	$\pm 22$	FH,FK,J,JG,U	3-195
LM107	High Performance	1	0.5	2	75	50	$\pm 2$	$\pm 22$	J,JG,U,W	3-21
TL061M	BIFET, Low Power	1	3.5	6	0.2	4	$\pm 1.5$	$\pm 18$	FH,FK,JG,U	3-89
TL066M	BIFET, Adjustable Low-Power	1	3.5	6	0.2	4	$\pm 1.2$	$\pm 18$	FH,FK,JG	3-99
TL321M	High Performance	0.6	0.3	5	-150	50	3	30	FH,FK,JG	3-143

automotive temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	B <sub>1</sub> (MHz) TYP	SR (V/ $\mu$ s) TYP	V <sub>IO</sub> (mV) MAX	I <sub>B</sub> (nA) MAX	A <sub>VD</sub> (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
LM218	High Performance	15	70	4	250	50	$\pm 5$	$\pm 20$	D,JG,P	3-39
TLC271AI	LinCMOS, Programmable	2.3	4.5	5	0.001 Typ	7	3	16	D,JG,P	3-151
TLC271BI	LinCMOS, Programmable	2.3	4.5	2	0.001 TYP	7	3	16	D,JG,P	3-151
TLC271I	LinCMOS, Programmable	2.3	4.5	10	0.001 Typ	7	3	16	D,JG,P	3-151
LM207	High Performance	1	0.5	2	75	50	$\pm 2$	$\pm 22$	J,N,W	3-21
TLC261AI	LinCMOS, Programmable		12	5	0.001 Typ		2	16	D,JG,P	3-185
TLC261BI	LinCMOS, Programmable		12	2	0.001 Typ		2	16	D,JG,P	3-185
TLC261I	LinCMOS, Programmable		12	10	0.001 Typ		2	16	D,JG,P	3-185

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Operational Amplifiers

## internally compensated, single

## industrial temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	B <sub>f</sub> (MHz) TYP	SR (V/ $\mu$ s) TYP	V <sub>IO</sub> (mV) MAX	I <sub>IB</sub> (nA) MAX	A <sub>VD</sub> (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
TL087I	BIFET, Low Offset	25	13	0.5	0.2	50	$\pm 4$	$\pm 18$	D,JG,P	3-131
TL071I	BIFET, Low Noise	3	13	6	0.2	50	$\pm 3.5$	$\pm 18$	D,JG,P	3-111
TL081I	BIFET, General Purpose	3	13	6	0.2	50	$\pm 3.5$	$\pm 18$	JG,P	3-121
TL088I	BIFET, Low V <sub>IO</sub>	3	13	1	0.2	50	$\pm 4$	$\pm 18$	D,JG,P	3-131
TL066I	BIFET, Adjustable Low-Power	1	3.5	6	0.2	4	$\pm 1.2$	$\pm 18$	D,JG,P	3-99
TL061I	BIFET, Low Power	1	3.5	6	0.2	4	$\pm 1.5$	$\pm 18$	D,JG,P	3-89
TL321I	High Performance	0.6	0.3	5	-150	50	3	30	JG,P	3-143

## commercial temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	B <sub>f</sub> (MHz) TYP	SR (V/ $\mu$ s) TYP	V <sub>IO</sub> (mV) MAX	I <sub>IB</sub> (nA) MAX	A <sub>VD</sub> (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
TL291C	High Speed	20	50				$\pm 4$	$\pm 18$	JG,P	3-141
LM318	High Performance	15	70	10	250	25	$\pm 5$	$\pm 20$	D,JG,P	3-39
NE5534	High Performance	10	6	4	1500	25	$\pm 3$	$\pm 20$	JG,P	3-77
NE5534A	High Performance	10	6	4	1500	25	$\pm 3$	$\pm 20$	JG,P	3-77
TL087C	BIFET, General Purpose	3	13	0.5	0.2	50	$\pm 5$	$\pm 18$	D,JG,P	3-131
TL071AC	BIFET, Low Noise	3	13	6	0.2	50	$\pm 3.5$	$\pm 18$	D,JG,P	3-111
TL071BC	BIFET, Low Noise	3	13	3	0.2	50	$\pm 3.5$	$\pm 18$	D,JG,P	3-111
TL071C	BIFET, Low Noise	3	13	10	0.2	25	$\pm 3.5$	$\pm 18$	D,JG,P	3-111
TL081AC	BIFET, General Purpose	3	13	6	0.2	50	$\pm 3.5$	$\pm 18$	JG,P	3-121
TL081BC	BIFET, General Purpose	3	13	3	0.2	50	$\pm 3.5$	$\pm 18$	JG,P	3-121
TL081C	BIFET, General Purpose	3	13	15	0.4	25	$\pm 3.5$	$\pm 18$	JG,P	3-121
TL088C	BIFET, Low V <sub>IO</sub>	3	13	1	0.2	50	$\pm 4$	$\pm 18$	D,JG,P	3-131
uA741C	General Purpose	1	0.5	6	500	20	$\pm 2$	$\pm 18$	D,JG,P	3-195
LM307	High Performance	1	0.5	7.5	250	25	$\pm 2$	$\pm 18$	D,J,JG,N,P,W	3-21
TL061AC	BIFET, Low Power	1	3.5	6	0.2	4	$\pm 1.5$	$\pm 18$	D,JG,P	3-89
TL061BC	BIFET, Low Power	1	3.5	3	0.2	4	$\pm 1.5$	$\pm 18$	D,JG,P	3-89
TL061C	BIFET, Low Power	1	3.5	15	0.2	3	$\pm 1.5$	$\pm 18$	D,JG,P	3-89
TL066AC	BIFET, Adjustable Low-Power	1	3.5	6	0.2	4	$\pm 1.2$	$\pm 18$	D,JG,P	3-99
TL066BC	BIFET, Adjustable Low-Power	1	3.5	3	0.2	4	$\pm 1.2$	$\pm 18$	D,JG,P	3-99
TL066C	BIFET, Adjustable Low-Power	1	3.5	15	0.4	3	$\pm 1.2$	$\pm 18$	D,JG,P	3-99
TL068C	BIFET, Buffer	1	7	15	0.4		$\pm 1.5$	18	LP	3-109

## SELECTION GUIDE

internally compensated, single

commercial temperature range (continued)

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	B <sub>I</sub> (MHz)		SR (V/μs)	V <sub>IO</sub> (mV)	I <sub>B</sub> (nA)	A <sub>VD</sub> (V/mV)	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
		TYP	TYP	MAX	MAX	MIN	MIN	MAX			
TLC251AC	LinCMOS, Programmable	0.7	0.6	5	0.001 Typ	10 Typ	1	16	D,JG,P	3-151	
TLC251BC	LinCMOS, Programmable	0.7	0.04	2	0.001 Typ	10 Typ	1	16	D,JG,P	3-151	
TLC251C	LinCMOS, Programmable	0.7	0.04	10	0.001 Typ	10 Typ	1	16	D,JG,P	3-151	
TLC271AC	LinCMOS, Programmable	0.7	0.04	5	0.001 Typ	10 Typ	3	16	D,JG,P	3-151	
TLC271BC	LinCMOS, Programmable	0.7	0.04	3	0.001 Typ	10 Typ	3	16	D,JG,P	3-151	
TLC271C	LinCMOS, Programmable	0.7	0.04	10	0.001 Typ	10 Typ	3	16	D,JG,P	3-151	
uA714C	Ultra-Low Offset Voltage	0.6	0.17	0.15	±7	100	±3	±18	JG,P	3-191	
uA714E	Ultra-Low Offset Voltage	0.6	0.17	0.075	±4	200	±3	±18	JG,P	3-191	
uA714L	Ultra-Low Offset Voltage	0.6	0.17	0.25	±30	50	±3	±18	JG,P	3-191	
TL321C	High Performance	0.6	0.3	7	-250	25	3	30	JG,P	3-143	
OP-07C	Ultra-Low Offset	0.6	0.3	0.15	±7	100	±3	±18	JG,P	3-63	
OP-07D	Ultra-Low Offset	0.6	0.3	0.15	±12	400 Typ	±3	±18	JG,P	3-63	
OP-07E	Ultra-Low Offset	0.6	0.3	0.75	+4	150	±3	±18	JG,P	3-63	

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Operational Amplifiers

internally compensated, dual

military temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	B <sub>j</sub> (MHz) TYP	SR (V/ $\mu$ s) TYP	V <sub>IO</sub> (mV) MAX	I <sub>B</sub> (nA) MAX	A <sub>VD</sub> (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
TL292M	High Frequency	20	50						JG	3-141
RM4558	High Performance	3	1.7	5	500	50		$\pm 22$	JG	3-73
TL072M	BIFET, Low Noise	3	13	6	0.2	35	$\pm 3.5$	$\pm 18$	FK,JG	3-111
TL082M	BIFET, General Purpose	3	13	16	0.2	25	$\pm 3.5$	$\pm 18$	FK,JG	3-121
TL083M	BIFET, General Purpose	3	13	6	0.2	25	$\pm 3.5$	$\pm 18$	FK,J	3-121
TL088M	BIFET, General Purpose	3	13	3	0.4	50	$\pm 3.5$	$\pm 18$	JG,U	3-131
TL288M	BIFET, General Purpose	3	13	3	0.4	50	$\pm 3.5$	$\pm 18$	JG,U	3-131
TLC272AM	LinCMOS, High Bias	2.3	4.5	5	0.001 Typ	10	4	16	FK,JG	3-161
TLC272BM	LinCMOS, High Bias	2.3	4.5	2	0.001 Typ	10	4	16	FK,JG	3-161
TLC272M	LinCMOS, High Bias	2.3	4.5	10	0.001 Typ	10	4	16	FK,JG	3-161
TLC27L2AM	LinCMOS, Low Bias	2.3	4.5	5	0.001 Typ	30	4	16	FK,JG	3-161
TLC27L2BM	LinCMOS, Low Bias	2.3	4.5	2	0.001 Typ	30	4	16	FK,JG	3-161
TLC27L2M	LinCMOS, Low Bias	2.3	4.5	10	0.001 Typ	30	4	16	FK,JG	3-161
TLC27M2AM	LinCMOS, Medium Bias	2.3	4.5	5	0.001 Typ	20	4	16	FK,JG	3-161
TLC27M2BM	LinCMOS, Medium Bias	2.3	4.5	2	0.001 Typ	20	4	16	FK,JG	3-161
TLC27M2M	LinCMOS, Medium Bias	2.3	4.5	10	0.001 Typ	20	4	16	FK,JG	3-161
MC1558	General Purpose	1	0.5	5	500	50	$\pm 2$	$\pm 22$	FK,JG,U	3-49
TL322M	Low Power	1	0.6	8	$-500$	200 Typ	$\pm 1.5$	$\pm 18$	JG	3-147
TL062M	BIFET, Low Power	1	3.5	6	0.2	4	$\pm 1.5$	$\pm 18$	FK,JG,U	3-89
LM158	High Gain	0.6		5	$-150$	50	3	30	FK,JG,U	3-32
TL022M	Low Power	0.5	0.5	5	100	72	$\pm 2$	$\pm 22$	U	3-81

## SELECTION GUIDE

internally compensated, dual

automotive temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	$B_1$ (MHz) TYP	SR (V/ $\mu\text{s}$ ) TYP	$V_{IO}$ (mV) MAX	$I_{IB}$ (nA) MAX	$A_{VD}$ (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
LM2904	High Gain	5	1	7	-250	100 Typ	$\pm 3$	$\pm 26$	D,J,G,P,U	3-32
RV4558	High Performance	3	1.7	6	500	50	$\pm 5$	$\pm 18$	D,J,G,P	3-73
TLC272AI	LinCMOS, High Bias	2.3	4.5	5	0.002 Typ	10	3	16	D,J,G,P	3-161
TLC272BI	LinCMOS, High Bias	2.3	4.5	2	0.002 Typ	10	3	16	D,J,G,P	3-161
TLC272I	LinCMOS, High Bias	2.3	4.5	10	0.002 Typ	10	3	16	D,J,G,P	3-161
TLC27L2AI	LinCMOS, Low Bias	2.3	4.5	5	0.002 Typ	30	3	16	D,J,G,P	3-161
TLC27L2BI	LinCMOS, Low Bias	2.3	4.5	2	0.002 Typ	30	3	16	D,J,G,P	3-161
TLC27L2I	LinCMOS, Low Bias	2.3	4.5	10	0.002 Typ	30	3	16	D,J,G,P	3-161
TLC27M2AI	LinCMOS, Medium Bias	2.3	4.5	5	0.002 Typ	20	3	16	D,J,G,P	3-161
TLC27M2BI	LinCMOS, Medium Bias	2.3	4.5	2	0.002 Typ	20	3	16	D,J,G,P	3-161
TLC27M2I	LinCMOS, Medium Bias	2.3	4.5	10	0.002 Typ	20	3	16	D,J,G,P	3-161
TL322I	Low Power	1	0.6	8	0.5	20	$\pm 1.5$	$\pm 18$	D,J,G,P	3-143

industrial temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	$B_1$ (MHz) TYP	SR (V/ $\mu\text{s}$ ) TYP	$V_{IO}$ (mV) MAX	$I_{IB}$ (nA) MAX	$A_{VD}$ (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
TL072I	BIFET, Low Noise	3	13	6	0.2	50	$\pm 3.5$	$\pm 18$	D,J,G,P	3-111
TL082I	BIFET, General Purpose	3	13	6	0.2	50	$\pm 3.5$	$\pm 18$	J,G,P	3-121
TL083I	BIFET, General Purpose	3	13	6	0.2	50	$\pm 3.5$	$\pm 18$	J,N	3-121
TL287I	BIFET, General Purpose	3	13	0.5	0.2	50	$\pm 3.5$	$\pm 18$	D,J,G,P	3-131
TL288I	BIFET, General Purpose	3	13	0.5	0.2	50	$\pm 3.5$	$\pm 18$	D,J,G,P	3-131
TL062I	BIFET, Low Power	1	3.5	6	0.2	4	$\pm 1.5$	$\pm 18$	D,J,G,P	3-89
LM258	High Gain	0.6		5	-150	50	3	30	D,J,G,P,U	3-32
LM258A	High Gain	0.6		3	-80	50	3	30	D,J,G,P,U	3-32
TLC262AI	LinCMOS, Programmable		12	5	0.001 Typ		2	16	D,J,G,P	3-185
TLC262BI	LinCMOS, Programmable		12	2	0.001 Typ		2	16	D,J,G,P	3-185
TLC262I	LinCMOS, Programmable		12	10	0.001 Typ		2	16	D,J,G,P	3-185

Operational Amplifiers

internally compensated, dual

commercial temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	B <sub>1</sub> (MHz) TYP	SR (V/ $\mu$ s) TYP	V <sub>IO</sub> (mV) MAX	I <sub>IB</sub> (nA) MAX	A <sub>VD</sub> (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
TL292C	High Frequency	20	50				$\pm 4$	$\pm 18$	JG,P	3-141
NE5532	Low Noise	10	9	4	800	15	$\pm 3$	$\pm 20$	JG,P	3-59
NE5532A	Low Noise	10	9	4	800	15	$\pm 3$	$\pm 20$	JG,P	3-59
RC4559	High Performance	4	2	6	250	20		$\pm 18$	D,P	3-87
RC4558	High Performance	3.5	1.7	5	500	50		$\pm 18$	D,JG, P	3-89
TL072AC	BIFET, Low Noise	3	13	6	0.2	50	$\pm 3.5$	$\pm 18$	D,JG,P	3-131
TL072BC	BIFET, Low Noise	3	13	3	0.2	50	$\pm 3.5$	$\pm 18$	D,JG,P	3-131
TL072C	BIFET, Low Noise	3	13	10	0.2	25	$\pm 3.5$	$\pm 18$	D,JG,P	3-131
TL082AC	BIFET, General Purpose	3	13	6	0.2	50	$\pm 3.5$	$\pm 18$	JG,P	3-141
TL082BC	BIFET, General Purpose	3	13	3	0.2	50	$\pm 3.5$	$\pm 18$	JG,P	3-141
TL082C	BIFET, General Purpose	3	13	15	0.4	25	$\pm 3.5$	$\pm 18$	JG,P	3-141
TL083AC	BIFET, General Purpose	3	13	6	0.2	50	$\pm 3.5$	$\pm 18$	J,N	3-141
TL083C	BIFET, General Purpose	3	13	15	0.4	25	$\pm 3.5$	$\pm 18$	J,N	3-141
TL287C	BIFET, General Purpose	3	13	0.5	0.2	50	$\pm 3.5$	$\pm 18$	D,JG,P	3-141
TL288C	BIFET, General Purpose	3	13	0.5	0.2	50	$\pm 3.5$	$\pm 18$	D,JG,P	3-141
TLC252AC	LinCMOS, High Bias	2.3	4.5	5	0.001 Typ	10	1	16	D,JG,P	3-161
TLC252BC	LinCMOS, High Bias	2.3	4.5	2	0.001 Typ	10	1	16	D,JG,P	3-161
TLC252C	LinCMOS, High Bias	2.3	4.5	10	0.001 Typ	10	1	16	D,JG,P	3-161
TLC25L2AC	LinCMOS, Low Bias	2.3	4.5	5	0.001 Typ	30	1	16	D,JG,P	3-161
TLC25L2BC	LinCMOS, Low Bias	2.3	4.5	2	0.001 Typ	30	1	16	D,JG,P	3-161
TLC25L2C	LinCMOS, Low Bias	2.3	4.5	10	0.001 Typ	30	1	16	D,JG,P	3-161
TLC25M2AC	LinCMOS, Medium Bias	2.3	4.5	5	0.001 Typ	20	1	16	D,JG,P	3-161
TLC25M2BC	LinCMOS, Medium Bias	2.3	4.5	2	0.001 Typ	20	1	16	D,JG,P	3-161
TLC25M2C	LinCMOS, Medium Bias	2.3	4.5	10	0.001 Typ	20	1	16	D,JG,P	3-161
TL272AC	LinCMOS, High Bias	2.3	4.5	5	0.001 Typ	10	3	16	D,JG,P	3-161
TL272BC	LinCMOS, High Bias	2.3	4.5	2	0.001 Typ	10	3	16	D,JG,P	3-161
TL272C	LinCMOS, High Bias	2.3	4.5	10	0.001 Typ	10	3	16	D,JG,P	3-161
TLC27L2AC	LinCMOS, Low Bias	2.3	4.5	5	0.001 Typ	20	3	16	D,JG,P	3-161
TLC27L2BC	LinCMOS, Low Bias	2.3	4.5	2	0.001 Typ	20	3	16	D,JG,P	3-161
TLC27L2C	LinCMOS, Low Bias	2.3	4.5	10	0.001 Typ	20	3	16	D,JG,P	3-161
TLC27M2AC	LinCMOS, Medium Bias	2.3	4.5	5	0.001 Typ	20	3	16	D,JG,P	3-161
TLC27M2BC	LinCMOS, Medium Bias	2.3	4.5	2	0.001 Typ	20	3	16	D,JG,P	3-161
TLC27M2C	LinCMOS, Medium Bias	2.3	4.5	10	0.001 Typ	20	3	16	D,JG,P	3-161
MC1458	General Purpose	1	0.5	6	500	20	$\pm 1.5$	$\pm 18$	D,JG,P,U	3-49
TL322C	Low Power	1	0.6	10	-500	20	$\pm 1.5$	$\pm 18$	D,JG,P	3-147
TL062AC	BIFET, Low Power	1	3.5	6	0.2	4	$\pm 1.2$	$\pm 18$	D,JG,P	3-89
TL062BC	BIFET, Low Power	1	3.5	3	0.2	4	$\pm 1.2$	$\pm 18$	D,JG,P	3-89
TL062C	BIFET, Low Power	1	3.5	15	0.2	3	$\pm 1.2$	$\pm 18$	D,JG,P	3-89
LM358	High Gain	0.6		7	-250	25	3	30	D,JG,P,U	3-32
LM358A	High Gain	0.6		3	-100	25	3	30	D,JG,P,U	3-32
TL022C	Low Power	0.5	0.5	5	250	60	$\pm 2$	$\pm 18$	JG,P	3-81

## SELECTION GUIDE

internally compensated, quad

military temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	B <sub>1</sub> (MHz) TYP	SR (V/ $\mu$ s) TYP	V <sub>IO</sub> (mV) MAX	I <sub>B</sub> (nA) MAX	A <sub>VD</sub> (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
TL294M	High Frequency	20	50				$\pm 4$	$\pm 18$	J	3-141
RM4136	High Performance	3.5	1.7	4	400	50	$\pm 4$	$\pm 22$	FK,J,W	3-69
TLO74M	BIFET, Low Noise	3	13	9	0.2	35	$\pm 3.5$	$\pm 18$	FK,J,W	3-111
TLO84M	BIFET, General Purpose	3	13	9	0.2	25	$\pm 3.5$	$\pm 18$	FK,J,W	3-121
TLC274AM	LinCMOS, High Bias	2.3	4.5	5	0.001 Typ	10	1	16	FK,J	3-173
TLC274BM	LinCMOS, High Bias	2.3	4.5	2	0.001 Typ	10	1	16	FK,J	3-173
TLC274M	LinCMOS, High Bias	2.3	4.5	10	0.001 Typ	10	1	16	FK,J	3-173
LM148	General Purpose	1	0.5	5	100	50		$\pm 22$	FK,J	3-29
MC3503	General Purpose	1	0.6	5	-500	50	$\pm 1.5$	$\pm 18$	J	3-53
TLO64M	BIFET, Low Power	1	3.5	9	0.2	4	$\pm 1.5$	$\pm 18$	FK,J,W	3-89
TLC27M4AM	LinCMOS, Medium Bias	0.7	0.6	5	0.001 Typ	20	1	16	FK,J	3-173
TLC27M4BM	LinCMOS, Medium Bias	0.7	0.6	2	0.001 Typ	20	1	16	FK,J	3-173
TLC27M4M	LinCMOS, Medium Bias	0.7	0.6	10	0.001 Typ	20	1	16	FK,J	3-173
LM124	General Purpose	0.6	0.5	5	-150	50	3	30	FK,J,W	3-25
TLO44M	Low Power	0.5	0.5	5	100	72	$\pm 2$	$\pm 22$	FK,J,W	3-85
TLC27L4AM	LinCMOS, Low Bias	0.1	0.04	5	0.001 Typ	30	1	16	FK,J	3-173
TLC27L4BM	LinCMOS, Low Bias	0.1	0.04	2	0.001 Typ	30	1	16	FK,J	3-173
TLC27L4M	LinCMOS, Low Bias	0.1	0.04	10	0.001 Typ	30	1	16	FK,J	3-173

automotive temperature range

(values specified for  $T_A = T_A 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	B <sub>1</sub> (MHz) TYP	SR (V/ $\mu$ s) TYP	V <sub>IO</sub> (mV) MAX	I <sub>B</sub> (nA) MAX	A <sub>VD</sub> (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
RV4136	High Performance	3	1.7	6	500	20	$\pm 4.5$	$\pm 32$	D,J,N,W	3-69
LM2900	General Purpose	2.5	0.5		200	1.2	$\pm 4.5$	$\pm 32$	J,N	3-43
TLC274AI	LinCMOS, High Bias	2.3	4.5	5	0.001 Typ	10	1	16	D,J,N	3-173
TLC274BI	LinCMOS, High Bias	2.3	4.5	2	0.001 Typ	10	1	16	D,J,N	3-173
TLC274I	LinCMOS, High Bias	2.3	4.5	10	0.001 Typ	10	1	16	D,J,N	3-173
MC3303	General Purpose	1	0.6	8	-500	20	3	36	D,J,N	3-173
TLC27M4AI	LinCMOS, Medium Bias	0.7	0.6	5	0.001 Typ	20	1	16	D,J,N	3-173
TLC27M4BI	LinCMOS, Medium Bias	0.7	0.6	2	0.001 Typ	20	1	16	D,J,N	3-173
TLC27M4I	LinCMOS, Medium Bias	0.7	0.6	10	0.001 Typ	20	1	16	D,J,N	3-173
LM2902	General Purpose	0.6		7	-250	100 Typ	3	26	D,J,N,W	3-25
TLC27L4AI	LinCMOS, Low Bias	0.1	0.04	5	0.001 Typ	30	1	16	D,J,N	3-173
TLC27L4BI	LinCMOS, Low Bias	0.1	0.04	2	0.001 Typ	30	1	16	D,J,N	3-173
TLC27L4I	LinCMOS, Low Bias	0.1	0.04	10	0.001 Typ	30	1	16	D,J,N	3-173
TLC264AI	LinCMOS, Programmable		12	5	0.001 Typ		2	16	D,J,N	3-185
TLC264BI	LinCMOS, Programmable		12	2	0.001 Typ		2	16	D,J,N	3-185
TLC264I	LinCMOS, Programmable		12	10	0.001 Typ		2	16	D,J,N	3-185

3

Operational Amplifiers



internally compensated, quad

industrial temperature range

(values specified for  $T_A = T_A 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	B <sub>1</sub> (MHz) TYP	SR (V/ $\mu$ s) TYP	V <sub>IO</sub> (mV) MAX	I <sub>B</sub> (nA) MAX	A <sub>VD</sub> (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
TLO74I	BIFET, Low Noise	3	13	6	0.2	50	$\pm 3.5$	$\pm 18$	D,J,N	3-111
TLO84I	BIFET, General Purpose	3	13	6	0.2	50	$\pm 3.5$	$\pm 18$	J,N	3-111
LM248	General Purpose	1	0.5	6	200	25		$\pm 18$	D,J,N	3-29
TLO64I	BIFET, Low Power	1	3.5	6	0.2	4	$\pm 1.5$	$\pm 18$	D,J,N	3-89
LM224	General Purpose	0.6		5	-150	50	3	30	D,J,N,W	3-25

# SELECTION GUIDE

internally compensated, quad

commercial temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	B <sub>1</sub> (MHz) TYP	SR (V/μs) TYP	V <sub>IO</sub> (mV) MAX	I <sub>IB</sub> (nA) MAX	A <sub>VD</sub> (V/mV) MIN	SUPPLY VOLTAGE (V)		PACKAGES	PAGE
							MIN	MAX		
TL294C	High Frequency	20	50				± 4	± 18	J,N	3-141
RC4136	High Performance	3	1.7	6	500	20	± 4	± 18	D,J,N,W	3-69
TL074AC	BIFET, Low Noise	3	13	6	0.2	50	± 3.5	± 18	D,J,N	3-111
TL074BC	BIFET, Low Noise	3	13	3	0.2	50	± 3.5	± 18	D,J,N	3-111
TL074C	BIFET, Low Noise	3	13	10	0.2	25	± 3.5	± 18	D,J,N	3-111
TL075C	BIFET, Low Noise	3	13	13	0.2	25	± 3.5	± 18	N	3-111
TL084AC	BIFET, General Purpose	3	13	6	0.2	50	± 3.5	± 18	J,N	3-121
TL084BC	BIFET, General Purpose	3	13	3	0.2	50	± 3.5	± 18	J,N	3-121
TL084C	BIFET, General Purpose	3	13	15	0.4	25	± 3.5	± 18	J,N	3-121
TL085C	BIFET, General Purpose	3	13	15	0.4	25	± 3.5	± 18	N	3-121
TL136C	High Performance	3	2	6	500	3 Typ	± 4	± 18	D,J,N	3-137
LM3900	General Purpose	2.5	0.5			1.2	± 4.5	± 18	J,N	3-43
TLC254AC	LinCMOS, High Bias	2.3	4.5	5	0.001 Typ	10	1	16	D,J,N	3-173
TLC254BC	LinCMOS, High Bias	2.3	4.5	2	0.001 Typ	10	1	16	D,J,N	3-173
TLC254C	LinCMOS, High Bias	2.3	4.5	10	0.001 Typ	10	1	16	D,J,N	3-173
TLC274AC	LinCMOS, High Bias	2.3	4.5	5	0.001 Typ	10	3	16	D,J,N	3-173
TLC274BC	LinCMOS, High Bias	2.3	4.5	2	0.001 Typ	10	3	16	D,J,N	3-173
TLC274C	LinCMOS, High Bias	2.3	4.5	10	0.001 Typ	10	3	16	D,J,N	3-173
LM348	General Purpose	1	0.5	6	200	25		± 18	D,J,N	3-29
MC3403	General Purpose	1	0.6	10	-500	20	± 1.5	± 18	D,J,N	3-53
TL064AC	BIFET, Low Power	1	3.5	6	0.2	4	± 1.5	± 18	D,J,N	3-89
TL064BC	BIFET, Low Power	1	3.5	3	0.2	4	± 1.5	± 18	D,J,N	3-89
TL064C	BIFET, Low Power	1	3.5	15	0.2	3	± 1.5	± 18	D,J,N	3-89
TLC25M4AC	LinCMOS, Medium Bias	0.7	0.6	5	0.001 Typ	20	1	16	D,J,N	3-173
TLC25M4BC	LinCMOS, Medium Bias	0.7	0.6	2	0.001 Typ	20	1	16	D,J,N	3-173
TLC25M4C	LinCMOS, Medium Bias	0.7	0.6	10	0.001 Typ	20	1	16	D,J,N	3-173
TLC27M4AC	LinCMOS, Medium Bias	0.7	0.6	5	0.001 Typ	20	3	16	D,J,N	3-173
TLC27M4BC	LinCMOS, Medium Bias	0.7	0.6	2	0.001 Typ	20	3	16	D,J,N	3-173
TLC27M4C	LinCMOS, Medium Bias	0.7	0.6	10	0.001 Typ	20	3	16	D,J,N	3-173
LM324	General Purpose	0.6		7	-250	25	3	30	D,J,N,W	3-25
LM324A	General Purpose	0.6		7	-100	25	3	30	D,J,N,W	3-25
TL044C	General Purpose	0.5	0.5	5	250	60	± 2	± 18	J,N,W	3-85
TLC25L4AC	LinCMOS, Low Bias	0.1	0.04	5	0.001 Typ	30	1	16	D,J,N	3-173
TLC25L4BC	LinCMOS, Low Bias	0.1	0.04	2	0.001 Typ	30	1	16	D,J,N	3-173
TLC25L4C	LinCMOS, Low Bias	0.1	0.04	10	0.001 Typ	30	1	16	D,J,N	3-173
TLC27L4AC	LinCMOS, Low Bias	0.1	0.04	5	0.001 Typ	30	3	16	D,J,N	3-173
TLC27L4BC	LinCMOS, Low Bias	0.1	0.04	2	0.001 Typ	30	3	16	D,J,N	3-173
TLC27L4C	LinCMOS, Low Bias	0.1	0.04	10	0.001 Typ	30	3	16	D,J,N	3-173

Operational Amplifiers

**Input Offset Voltage ( $V_{IO}$ )**

The d-c voltage that must be applied between the input terminals to force the quiescent d-c output voltage to zero or other level, if specified.

**Average Temperature Coefficient of Input Offset Voltage ( $\alpha_{VIO}$ )**

The ratio of the change in input offset voltage to the change in free-air temperature. This is an average value for the specified temperature range.

$$\alpha_{VIO} = \left[ \frac{(V_{IO} @ T_{A(1)}) - (V_{IO} @ T_{A(2)})}{T_{A(1)} - T_{A(2)}} \right] \text{ where } T_{A(1)} \text{ and } T_{A(2)} \text{ are the specified temperature extremes.}$$

**Input Offset Current ( $I_{IO}$ )**

The difference between the currents into the two input terminals with the output at zero volts.

**Average Temperature Coefficient of Input Offset Current ( $\alpha_{IIO}$ )**

The ratio of the change in input offset current to the change in free-air temperature. This is an average value for the specified temperature range.

$$\alpha_{IIO} = \left[ \frac{(I_{IO} @ T_{A(1)}) - (I_{IO} @ T_{A(2)})}{T_{A(1)} - T_{A(2)}} \right] \text{ where } T_{A(1)} \text{ and } T_{A(2)} \text{ are the specified temperature extremes.}$$

**Input Bias Current ( $I_{IB}$ )**

The average of the currents into the two input terminals with the output at zero volts.

**Common-Mode Input Voltage ( $V_{IC}$ )**

The average of the two input voltages.

**Common-Mode Input Voltage Range ( $V_{ICR}$ )**

The range of common-mode input voltage that if exceeded will cause the amplifier to cease functioning properly.

**Differential Input Voltage ( $V_{ID}$ )**

The voltage at the noninverting input with respect to the inverting input.

**Maximum Peak Output Voltage Swing ( $V_{OM}$ )**

The maximum positive or negative peak output voltage that can be obtained without waveform clipping when the quiescent d-c output voltage is zero.

**Maximum Peak-to-Peak Output Voltage Swing ( $V_{OPP}$ )**

The maximum peak-to-peak output voltage that can be obtained without waveform clipping when the quiescent d-c output voltage is zero.

**Large-Signal Voltage Amplification ( $A_V$ )**

The ratio of the peak-to-peak output voltage swing to the change in input voltage required to drive the output.

**Differential Voltage Amplification ( $A_{VD}$ )**

The ratio of the change in output voltage to the change in differential input voltage producing it.

## GLOSSARY

### OPERATIONAL AMPLIFIER TERMS AND DEFINITIONS

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#### Maximum-Output-Swing Bandwidth ( $B_{OM}$ )

The range of frequencies within which the maximum output voltage swing is above a specified value.

#### Unity-Gain Bandwidth ( $B_1$ )

The range of frequencies within which the open-loop voltage amplification is greater than unity.

#### Phase Margin ( $\phi_M$ )

The absolute value of the open-loop phase shift between the output and the inverting input at the frequency at which the modulus of the open-loop amplification is unity.

#### Gain Margin ( $A_M$ )

The reciprocal of the open-loop voltage amplification at the lowest frequency at which the open-loop phase shift is such that the output is in phase with the inverting input.

#### Input Resistance ( $r_i$ )

The resistance between the input terminals with either input grounded.

#### Differential Input Resistance ( $r_{id}$ )

The small-signal resistance between the two ungrounded input terminals.

#### Output Resistance ( $r_o$ )

The resistance between the output terminal and ground.

#### Input Capacitance ( $C_i$ )

The capacitance between the input terminals with either input grounded.

#### Common-Mode Input Impedance ( $z_{ic}$ )

The parallel sum of the small-signal impedance between each input terminal and ground.

#### Output Impedance ( $z_o$ )

The small-signal impedance between the output terminal and ground.

#### Common-Mode Rejection Ratio ( $k_{CMR}$ , $CMRR$ )

The ratio of differential voltage amplification to common-mode voltage amplification.

NOTE: This is measured by determining the ratio of a change in input common-mode voltage to the resulting change in input offset voltage.

#### Supply Voltage Sensitivity ( $k_{SVS}$ , $\Delta V_{IO}/\Delta V_{CC}$ )

The absolute value of the ratio of the change in input offset voltage to the change in supply voltages producing it.

NOTES: 1. Unless otherwise noted, both supply voltages are varied symmetrically.

2. This is the reciprocal of supply voltage rejection ratio.

#### Supply Voltage Rejection Ratio ( $k_{SVR}$ , $\Delta V_{CC}/\Delta V_{IO}$ )

The absolute value of the ratio of the change in supply voltages to the change in input offset voltage.

NOTES: 1. Unless otherwise noted, both supply voltages are varied symmetrically.

2. This is the reciprocal of supply voltage sensitivity.

---

**Equivalent Input Noise Voltage ( $V_n$ )**

The voltage of an ideal voltage source (having an internal impedance equal to zero) in series with the input terminals of the device that represents the part of the internally generated noise that can properly be represented by a voltage source.

**Equivalent Input Noise Current ( $I_n$ )**

The current of an ideal current source (having an internal impedance equal to infinity) in parallel with the input terminals of the device that represents the part of the internally generated noise that can properly be represented by a current source.

**Average Noise Figure ( $\bar{F}$ )**

The ratio of (1) the total output noise power within a designated output frequency band when the noise temperature of the input termination(s) is at the reference noise temperature,  $T_0$ , at all frequencies to (2) that part of (1) caused by the noise temperature of the designated signal-input termination within a designated signal-input frequency band.

**Short-Circuit Output Current ( $I_{OS}$ )**

The maximum output current available from the amplifier with the output shorted to ground, to either supply, or to a specified point.

**Supply Current ( $I_{CC}$ )**

The current into the  $V_{CC}$  or  $V_{CC+}$  terminal of an integrated circuit.

**Total Power Dissipation ( $P_D$ )**

The total d-c power supplied to the device less any power delivered from the device to a load.

NOTE: At no load:  $P_D = V_{CC+} \cdot I_{CC+} + V_{CC-} \cdot I_{CC-}$ .

**Crosstalk Attenuation ( $V_{O1}/V_{O2}$ )**

The ratio of the change in output voltage of a driven channel to the resulting change in output voltage of another channel.

**Rise Time ( $t_r$ )**

The time required for an output voltage step to change from 10% to 90% of its final value.

**Total Response Time (Settling Time) ( $t_{TOT}$ )**

The time between a step-function change of the input signal level and the instant at which the magnitude of the output signal reaches for the last time a specified level range ( $\pm \epsilon$ ) containing the final output signal level.

**Overshoot Factor**

The ratio of (1) the largest deviation of the output signal value from its final steady-state value after a step-function change of the input signal, to (2) the absolute value of the difference between the steady-state output signal values before and after the step-function change of the input signal.

**Slew Rate (SR)**

The average time rate of change of the closed-loop amplifier output voltage for a step-signal input.



## Operational Amplifiers

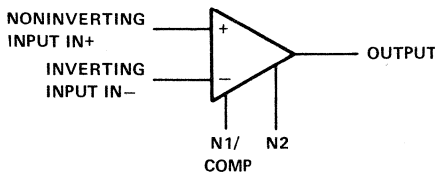
- Low Input Currents
- Low Input Offset Parameters
- Frequency and Transient Response Characteristics Adjustable
- Short-Circuit Protection
- Offset-Voltage Null Capability
- No Latch-Up
- Wide Common-Mode and Differential Voltage Ranges
- Same Pin Assignments as uA709
- Designed to be Interchangeable with National Semiconductor LM101A and LM301A

**description**

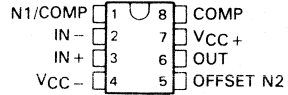
The LM101A, LM201A, and LM301A are high-performance operational amplifiers featuring very low input bias current and input offset voltage and current to improve the accuracy of high-impedance circuits using these devices. The high common-mode input voltage range and the absence of latch-up make these amplifiers ideal for voltage-follower applications. The devices are protected to withstand short-circuits at the output. The external compensation of these amplifiers allows the changing of the frequency response (when the closed-loop gain is greater than unity) for applications requiring wider bandwidth or higher slew rate. A potentiometer may be connected between the offset-null inputs (N1 and N2), as shown in Figure 7, to null out the offset voltage.

The LM101A is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the LM201A is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the LM301A is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

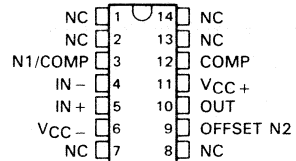
**symbol**



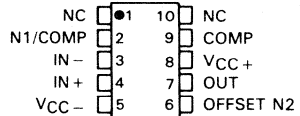
**D, JG, OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



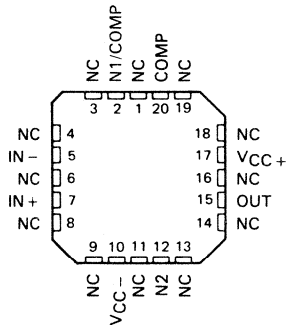
**W FLAT PACKAGE  
(TOP VIEW)**



**LM101A  
U FLAT PACKAGE  
(TOP VIEW)**



**LM101A  
FH OR FK CHIP-CARRIER PACKAGE  
(TOP VIEW)**



NC—No internal connection

# TYPES LM101A, LM201A, LM301A

## HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		LM101A	LM201A	LM301A	UNIT
Supply voltage $V_{CC+}$ (see Note 1)		22	22	18	V
Supply voltage $V_{CC-}$ (see Note 1)		-22	-22	-18	V
Differential input voltage (see Note 2)		$\pm 30$	$\pm 30$	$\pm 30$	V
Input voltage (either input, see Notes 1 and 3)		$\pm 15$	$\pm 15$	$\pm 15$	V
Voltage between either offset null terminal (N1/N2) and $V_{CC-}$		-0.5 to 2	-0.5 to 2	-0.5 to 2	V
Duration of output short-circuit (see Note 4)		unlimited	unlimited	unlimited	
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5)		500	500	500	mW
Operating free-air temperature range		-55 to 125	-25 to 85	0 to 70	°C
Storage temperature range		-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	FH, FK, JG, U, or W package	300	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or P package		260	260	°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply. For the LM101A only, the unlimited duration of the short-circuit applies at (or below) 125°C case temperature or 75°C free-air temperature. For the LM201A only, the unlimited duration of the short-circuit applies at (or below) 85°C case temperature or 75°C free air temperature.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J and JG packages, LM101A chips are alloy-mounted; LM201A and LM301A chips are glass-mounted.

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Operational Amplifiers



# TYPES LM101A, LM201A, LM301A HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $C_C = 30$  pF (see Note 6)

PARAMETER		TEST CONDITIONS†		LM101A, LM201A			LM301A			UNIT	
				MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$	Input offset voltage	$V_O = 0$ V	25 °C	0.6		2	2		7.5	mV	
			Full range				3		10		
$\alpha_{VIO}$	Average temperature coefficient of input offset voltage	$V_O = 0$ V	Full range	3		15	6		30	$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$	Input offset current		25 °C	1.5		10	3		50	nA	
			Full range				20		70		
$\alpha_{IIO}$	Average temperature coefficient of input offset current		$T_A = -55^\circ\text{C}$ to $25^\circ\text{C}$		0.02		0.2			nA/ $^\circ\text{C}$	
			$T_A = 25^\circ\text{C}$ to MAX		0.01		0.1				
			$T_A = 0^\circ\text{C}$ to $25^\circ\text{C}$						0.02		0.6
			$T_A = 25^\circ\text{C}$ to $70^\circ\text{C}$						0.01		0.3
$I_{IB}$	Input bias current		25 °C	30		75	70		250	nA	
			Full range				100		300		
$V_{ICR}$	Common-mode input voltage range	See Note 7	Full range	$\pm 15$			$\pm 12$			V	
$V_{OPP}$	Maximum peak-to-peak output voltage swing	$V_{CC\pm} = \pm 15$ V, $R_L = 10$ k $\Omega$	25 °C	24		28	24		28	V	
			Full range				24				
		$V_{CC\pm} = \pm 15$ V, $R_L = 2$ k $\Omega$	25 °C	20		26	20		26		
			Full range				20				
$A_{VD}$	Large-signal differential voltage amplification	$V_{CC\pm} = \pm 15$ V, $V_O = \pm 10$ V, $R_L \geq 2$ k $\Omega$	25 °C	50		200	25		200	V/mV	
			Full range				15				
$r_i$	Input resistance		25 °C	1.5		4	0.5		2	M $\Omega$	
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min	25 °C	80		98	70		90	dB	
			Full range				70				
kSVR	Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )		25 °C	80		98	70		96	dB	
			Full range				70				
$I_{CC}$	Supply current	No Load, $V_O = 0$ V, See Note 7	25 °C	1.8		3	1.8		3	mA	
			MAX				1.2		2.5		

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for LM101A is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ , for LM201A is  $-25^\circ\text{C}$  to  $85^\circ\text{C}$ , and for LM301A is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

NOTES: 6. Unless otherwise noted,  $V_{CC\pm} = \pm 5$  V to  $\pm 20$  V for LM101A and LM201A, and  $V_{CC\pm} = \pm 5$  V to  $\pm 15$  V for LM301A. All typical values are at  $V_{CC\pm} = \pm 15$  V.

7. For LM101A and LM201A,  $V_{CC\pm} = \pm 20$  V. For LM301A,  $V_{CC\pm} = \pm 15$  V.

3

Operational Amplifiers

# TYPES LM101A, LM201A, LM301A HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS

INPUT OFFSET CURRENT  
vs  
FREE-AIR TEMPERATURE

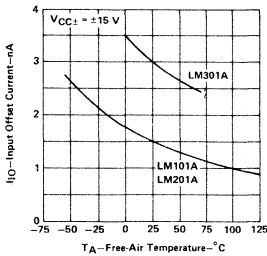


FIGURE 1

INPUT BIAS CURRENT  
vs  
FREE-AIR TEMPERATURE

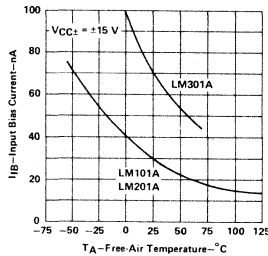


FIGURE 2

MAXIMUM PEAK-TO-PEAK  
OUTPUT VOLTAGE (WITH  
SINGLE-POLE COMPENSATION)  
vs FREQUENCY

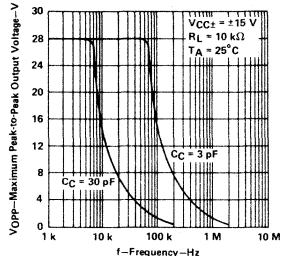


FIGURE 3

OPEN-LOOP LARGE-SIGNAL  
DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
SUPPLY VOLTAGE

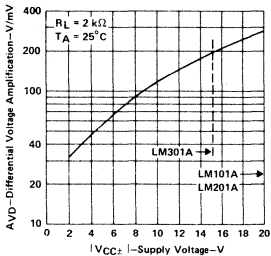


FIGURE 4

OPEN-LOOP LARGE-SIGNAL  
DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
FREQUENCY

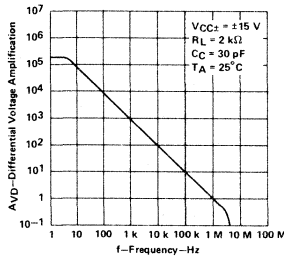


FIGURE 5

VOLTAGE-FOLLOWER  
LARGE-SIGNAL PULSE RESPONSE

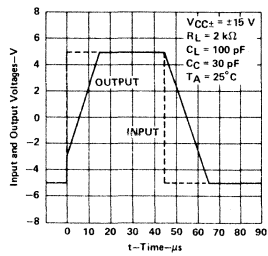


FIGURE 6

## TYPICAL APPLICATION DATA

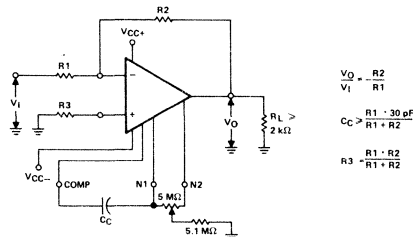


FIGURE 7—INVERTING CIRCUIT WITH ADJUSTABLE GAIN,  
SINGLE-POLE COMPENSATION, AND OFFSET ADJUSTMENT

# LINEAR INTEGRATED CIRCUITS

# TYPES LM107, LM207, LM307 HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

D962, DECEMBER 1970—REVISED AUGUST 1983

- Low Input Currents
- No Frequency Compensation Required
- Low Input Offset Parameters
- Short-Circuit Protection
- No Latch-Up
- Wide Common-Mode and Differential Voltage Ranges

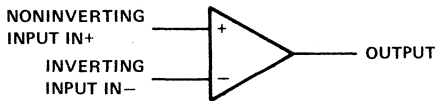
### description

The LM107, LM207, and LM307 are high-performance operational amplifiers featuring very low input bias current and input offset voltage and current to improve the accuracy of high-impedance circuits using these devices.

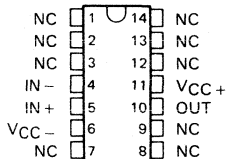
The high common-mode input voltage range and the absence of latch-up make these amplifiers ideal for voltage follower applications. The devices are short-circuit protected and the internal frequency compensation ensures stability without external components.

The LM107 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the LM207 is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the LM307 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

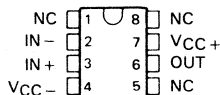
### symbol



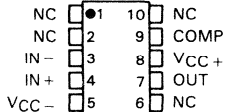
LM107 . . . J OR W PACKAGE  
LM207, LM307 . . . W PACKAGE  
(TOP VIEW)



LM107 . . . JG PACKAGE  
LM207, LM307 . . . D, JG, OR P PACKAGE  
(TOP VIEW)



LM107 . . . U FLAT PACKAGE  
(TOP VIEW)



NC—No internal connection

## TYPES LM107, LM207, LM307 HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

	LM107	LM207	LM307	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	22	22	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-22	-22	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	$\pm 30$	V
Input voltage (either input, see Notes 1 and 3)	$\pm 15$	$\pm 15$	$\pm 15$	V
Duration of output short-circuit (see Note 4)	unlimited	unlimited	unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)	500	500	500	mW
Operating free-air temperature range	-55 to 125	-25 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds JG, U, or W package	300	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds D or P package		260	260	°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply. For the LM107 only, the unlimited duration of the short-circuit applies at (or below) 125°C case temperature or 75°C free-air temperature. For the LM207 only, the unlimited duration of the short-circuit applies at (or below) 85°C case temperature or 75°C free air temperature.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2.

# TYPES LM107, LM207, LM307 HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature (see Note 6)

PARAMETER	TEST CONDITIONS†	LM107, LM207			LM307			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0$	25°C	0.6	2	2	7.5	mV	
		Full range	3			10		
$\alpha_{VIO}$ Average temperature coefficient of input offset voltage	$V_O = 0$	Full range	3	15	6	30	$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$ Input offset current	$V_O = 0$	25°C	1.5	10	3	50	nA	
		Full range	20			70		
$\alpha_{IIO}$ Average temperature coefficient of input offset current		$T_A = -55^\circ\text{C}$ to $25^\circ\text{C}$	0.02	0.2			nA/°C	
		$T_A = 25^\circ\text{C}$ to MAX	0.01	0.1				
		$T_A = 0^\circ\text{C}$ to $25^\circ\text{C}$			0.02	0.6		
		$T_A = 25^\circ\text{C}$ to $70^\circ\text{C}$			0.01	0.3		
$I_{IB}$ Input bias current		25°C	30	75	70	250	nA	
		Full range	100			300		
$V_{ICR}$ Common-mode input voltage range	See Note 7	Full range	$\pm 15$		$\pm 12$		V	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$V_{CC\pm} = \pm 15\text{ V},$ $R_L = 10\text{ k}\Omega$	25°C	24	28	24	28	V	
		Full range	24			24		
		$V_{CC\pm} = \pm 15\text{ V},$ $R_L = 2\text{ k}\Omega$	25°C	20	26	20		26
Full range	20			20				
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC\pm} = \pm 15\text{ V},$ $V_O = \pm 10\text{ V},$ $R_L \geq 2\text{ k}\Omega$	25°C	50	200	25	200	V/mV	
		Full range	25		15			
$r_i$ Input resistance		25°C	1.5	4	0.5	2	M $\Omega$	
$CMRR$ Common-mode rejection ratio	$V_{IC} = V_{ICR\text{ min}}$	25°C	80	98	70	90	dB	
		Full range	80		70			
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )		25°C	80	98	70	96	dB	
		Full range	80			70		
$I_{CC}$ Supply current	No Load, $V_O = 0,$ See Note 7	25°C	1.8	3	1.8	3	mA	
		MAX	1.2	2.5				

†All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for LM107 is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ , for LM207 is  $-25^\circ\text{C}$  to  $85^\circ\text{C}$ , and for LM307 is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

NOTES: 6. Unless otherwise noted  $V_{CC\pm} = \pm 5\text{ V}$  to  $\pm 20\text{ V}$  for LM107 and LM207, and  $V_{CC\pm} = \pm 5\text{ V}$  to  $\pm 15\text{ V}$  for LM307. All typical values are at  $V_{CC\pm} = \pm 15\text{ V}$ .

7. For LM107 and LM207,  $V_{CC\pm} = \pm 20\text{ V}$ . For LM307,  $V_{CC\pm} = \pm 15\text{ V}$ .

3

Operational Amplifiers



## Operational Amplifiers

# LINEAR INTEGRATED CIRCUITS

# TYPES LM124, LM224, LM224A, LM324, LM324A, LM2902 QUADRUPLE OPERATIONAL AMPLIFIERS

D1990, SEPTEMBER 1975—REVISED SEPTEMBER 1983

- **Wide Range of Supply Voltages:**  
Single Supply . . . 3 V to 30 V  
(LM2902 . . . 3 V to 26 V),  
or Dual Supplies
- **Low Supply Current Drain Independent of Supply Voltage . . . 0.7 mA Typ**
- **Common-Mode Input Voltage Range Includes Ground Allowing Direct Sensing near Ground**
- **Low Input Bias and Offset Parameters:**  
Input Offset Voltage . . . 3 mV Typ  
A Versions . . . 2 mV Typ  
Input Offset Current . . . 2 nA Typ  
Input Bias Current . . . 20 nA Typ  
A Versions . . . 15 nA Typ
- **Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . 32 V (26 V for LM2902)**
- **Open-Loop Differential Voltage Amplification . . . 100 V/mV Typ**
- **Internal Frequency Compensation**

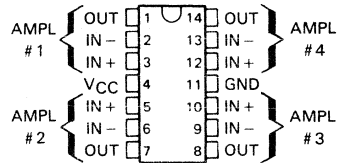
### description

These devices consist of four independent, high-gain frequency-compensated operational amplifiers that were designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies is also possible so long as the difference between the two supplies is 3 volts to 30 volts (for the LM2902, 3 volts to 26 volts), and Pin 4 is at least 1.5 volts more positive than the input common-mode voltage. The low supply current drain is independent of the magnitude of the supply voltage.

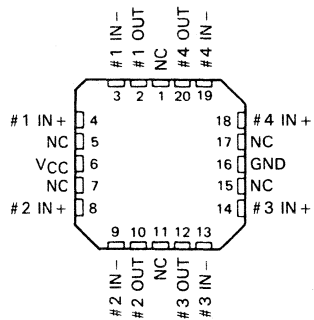
Applications include transducer amplifiers, d-c amplification blocks, and all the conventional operational amplifier circuits that now can be more easily implemented in single-supply-voltage systems. For example, the LM124 can be operated directly off of the standard five-volt supply that is used in digital systems and will easily provide the required interface electronics without requiring additional  $\pm 15$ -volt supplies.

The LM124 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The LM2902 is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , the LM224 and LM224A from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the LM324 and LM324A from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

D, J, OR N DUAL-IN-LINE PACKAGE,  
OR W FLAT PACKAGE  
(TOP VIEW)

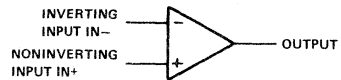


LM124  
FH OR FK CHIP CARRIER PACKAGE  
(TOP VIEW)



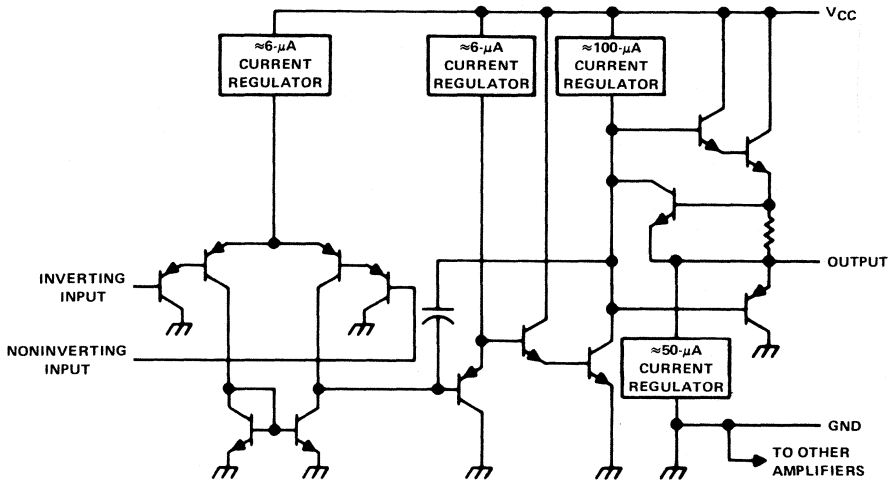
NC—No internal connection

symbol (each amplifier)



# TYPES LM124, LM224, LM224A, LM324, LM324A, LM2902 QUADRUPLE OPERATIONAL AMPLIFIERS

schematic (each amplifier)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		LM124 LM224, LM224A, LM324, LM324A	LM2902	UNIT
Supply voltage, $V_{CC}$ (see Note 1)		32	26	V
Differential voltage (see Note 2)		$\pm 32$	$\pm 26$	V
Input voltage range (either input)		-0.3 to 32	-0.3 to 26	V
Duration of output short-circuit (one amplifier) to ground at (or below) 25°C free-air temperature ( $V_{CC} \leq 15$ V) (see Note 3)		unlimited	unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	D or J package	900	900	mW
	N package	875	875	
Operating free-air temperature range	LM124	-55 to 125	-40 to 85	°C
	LM224, LM224A	-25 to 85		
	LM324, LM324A	0 to 70		
	LM2902			
Storage temperature range		-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	FH, FK, J or W package	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or N package	260	260	°C

- NOTES: 1. All voltage values, except differential voltages and  $V_{CC}$  specified for the measurement of  $I_{OS}$ , are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to dissipation Derating Curves, Section 2. In the J package, LM124 chips are alloy-mounted; LM224, LM324, and LM2902 chips are glass-mounted.



# TYPES LM124, LM224, LM224A, LM324, LM324A, LM2902 QUADRUPLE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature.  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	LM124, LM224			LM324			LM2902			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{CC} = 5\text{ V to MAX.}$ $V_{IC} = V_{ICR\text{ min.}}$ $V_O = 1.4\text{ V}$	25°C	3	5	3	7	3	7	3	7	mV
		Full range		7		9		10		10	
		25°C	2	30	2	50	2	50	2	50	200
$I_{IO}$ Input offset current	$V_O = 1.4\text{ V}$	Full range		100		150		200		200	
		25°C	-20	-150	-20	-250	-20	-250	-20	-250	-500
$I_{IB}$ Input bias current	$V_O = 1.4\text{ V}$	Full range		-300		-500		-500		-500	
		25°C	0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		V
$V_{ICR}$ Common-mode input voltage range	$V_{CC} = 5\text{ V to MAX}$	Full range	0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		
		25°C	0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		
		Full range	$V_{CC}-2$		$V_{CC}-2$		$V_{CC}-2$		$V_{CC}-2$		
$V_{OH}$ High-level output voltage	$R_L = 2\text{ k}\Omega$ $R_L = 10\text{ k}\Omega$ $V_{CC} = \text{MAX.}$ $R_L = 2\text{ k}\Omega$	25°C	$V_{CC}-1.5$		$V_{CC}-1.5$		$V_{CC}-1.5$		$V_{CC}-1.5$		
		Full range	26		26		22		22		
		25°C	27	28	27	28	23	24	23	24	V
$V_{OL}$ Low-level output voltage	$R_L \leq 10\text{ k}\Omega$	Full range	5	20	5	20	5	20	5	100	mV
		25°C	50	100	25	100	25	100	100	100	V/mV
$A_{VD}$ Large signal differential voltage amplification	$V_O = 1\text{ V to }11\text{ V,}$ $R_L \geq 2\text{ k}\Omega$	Full range	25		15		15		15		
		25°C	70	80	65	80	50	80	50	80	dB
$CMRR$ Common-mode rejection ratio	$V_{IC} = V_{ICR\text{ min}}$	Full range	65	100	65	100	50	100	50	100	dB
		25°C	120		120		120		120		
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_O$ )	$f = 1\text{ kHz to }20\text{ kHz}$	Full range	-20	-30	-60		-20	-30	-60		
		25°C	-10		-10		-10		-10		
		Full range	10	20	10	20	10	20	10	20	mA
$I_{IO}$ Output current	$V_{CC} = 15\text{ V,}$ $V_{ID} = -1\text{ V,}$ $V_O = 15\text{ V,}$ $V_{ID} = -1\text{ V,}$ $V_O = 200\text{ mV}$	Full range	5		5		5		5		
		25°C	12	30	12	30	12	30	12	30	$\mu\text{A}$
		Full range	$\pm 40$	$\pm 60$	$\pm 40$	$\pm 60$	$\pm 40$	$\pm 60$	$\pm 40$	$\pm 60$	mA
$I_{OS}$ Short-circuit output current	$V_{CC}$ at 5 V, GND at $-5\text{ V, }V_O = 0$	Full range	0.7	1.2	0.7	1.2	0.7	1.2	0.7	1.2	mA
		25°C	1.1	3	1.1	3	1.1	3	1.1	3	mA
$I_{CC}$ Supply current (four amplifiers)	No load	Full range	1.1	3	1.1	3	1.1	3	1.1	3	mA
		25°C	1.1	3	1.1	3	1.1	3	1.1	3	mA

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. "MAX"  $V_{CC}$  for testing purposes is 26 V for LM2902, 30 V for the others. Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for LM124,  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for LM224,  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for LM324, and  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for LM2902.

**TYPES LM124, LM224, LM224A,  
LM324, LM324A, LM2902  
QUADRUPLE OPERATIONAL AMPLIFIERS**

**3 Operational Amplifiers**

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	LM224A			LM324A			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{CC} = 5\text{ V to }30\text{ V,}$ $V_{IC} = V_{ICR}\text{ min,}$ $V_O = 1.4\text{ V}$	25°C	2	3	2	2	3	mV
		Full range	4	4	5	5		
$I_{IO}$ Input offset current	$V_O = 1.4\text{ V}$	25°C	2	15	2	2	30	nA
		Full range	30	30	75	75		
$I_{IB}$ Input bias current	$V_O = 1.4\text{ V}$	25°C	-15	-80	-15	-15	-100	V
		Full range	-100	-100	-200	-200		
$V_{ICR}$ Common-mode input voltage range	$V_{CC} = 30\text{ V}$	25°C	0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$			V
		Full range	0 to $V_{CC}-2$		0 to $V_{CC}-2$			
$V_{OH}$ High-level output voltage	$R_L = 2\text{ k}\Omega,$ $V_{CC} = 30\text{ V, } R_L = 2\text{ k}\Omega$	25°C	$V_{CC}-1.5$		$V_{CC}-1.5$			V
		Full range	26	26	26	26		
$V_{OL}$ Low-level output voltage	$V_{CC} = 30\text{ V, } R_L = 10\text{ k}\Omega$	25°C	27	28	27	28		mV
		Full range	5	20	5	20		
AVD Large-signal differential voltage amplification	$V_{CC} = 15\text{ V,}$ $V_O = 1\text{ V to }11\text{ V,}$ $R_L \geq 2\text{ k}\Omega$	25°C	50	100	25	100		V/mV
		Full range	25	25	15	15		
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR}\text{ min}$	25°C	70	80	65	80		dB
		Full range	65	100	65	100		
kSVR Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$f = 1\text{ kHz to }20\text{ kHz}$	25°C	120	120	120	120		dB
		Full range	-20	-30	-60	-20	-30	
$V_{O1}/V_{O2}$ Crosstalk attenuation	$V_{CC} = 15\text{ V,}$ $V_{ID} = 1\text{ V,}$ $V_O = 0$	25°C	-10	-10	-10	-10		dB
		Full range	-10	-10	-10	-10		
$I_O$ Output current	$V_{CC} = 15\text{ V,}$ $V_{ID} = -1\text{ V,}$ $V_O = 5\text{ V}$	25°C	10	20	10	20		mA
		Full range	5	5	5	5		
$I_{OS}$ Short-circuit output current	$V_{ID} = -1\text{ V,}$ $V_O = 200\text{ mV}$ $V_{CC} \text{ at } 5\text{ V,}$ $\text{GND at } -5\text{ V, } V_{O} = 0$	25°C	12	30	12	30		$\mu\text{A}$
		Full range	$\pm 40$	$\pm 60$	$\pm 40$	$\pm 60$		
$I_{CC}$ Supply current (four amplifiers)	$V_O = 2.5\text{ V,}$ No load $V_{CC} = 30\text{ V,}$ $V_O = 15\text{ V,}$ No load	25°C	0.7	1.2	0.7	1.2		mA
		Full range	1.1	3	1.1	3		

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range is  $-25^\circ\text{C to }85^\circ\text{C}$  for LM224A and  $0^\circ\text{C to }70^\circ\text{C}$  for LM324A.

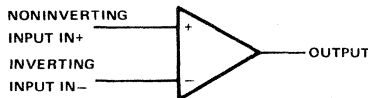
- **uA741 Operating Characteristics**
- **Low Supply Current Drain . . . 0.6 mA Typ (per amplifier)**
- **Low Input Offset Voltage**
- **Low Input Offset Current**
- **Class AB Output Stage**
- **Input/Output Overload Protection**
- **Designed to be Interchangeable with National LM148, LM248, and LM348.**

**description**

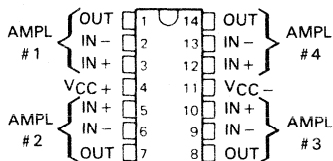
The LM148, LM248, and LM348 are quadruple, independent, high-gain, internally compensated operational amplifiers designed to have operating characteristics similar to the uA741. These amplifiers exhibit low supply current drain, and input bias and offset currents that are much less than those of the uA741.

The LM148 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the LM248 is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the LM348 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

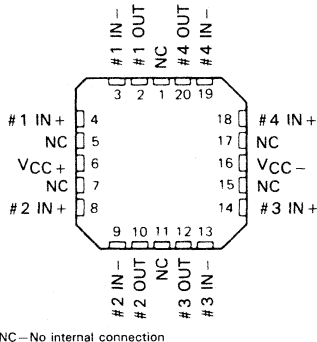
**symbol (each amplifier)**



**LM148 . . . J PACKAGE  
LM248, LM348 . . . D, J, OR N PACKAGE  
(TOP VIEW)**



**LM148 . . . FH OR FK PACKAGE  
(TOP VIEW)**



**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

		LM148	LM248	LM348	UNIT
Supply voltage $V_{CC+}$ (see Note 1)		22	18	18	V
Supply voltage $V_{CC-}$ (see Note 1)		-22	-18	-18	V
Differential input voltage (see Note 2)		44	36	36	V
Input voltage (either input, see Notes 1 and 3)		$\pm 22$	$\pm 18$	$\pm 18$	V
Duration of output short-circuit (see Note 4)		unlimited	unlimited	unlimited	
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5)	D, FH, FK, or J package	900	900	900	mW
	N package		875	875	
Operating free-air temperature range		-55 to 125	-25 to 85	0 to 70	°C
Storage temperature range		-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	FH, FK, or J package	300	300	300	°C
	D or N package		260	260	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds					°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or the value specified in the table, whichever is less.
4. The output may be shorted to ground or either power supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J package, LM148 chips are alloy mounted, LM248 and LM348 chips are glass mounted.

# TYPES LM148, LM248, LM348 QUADRUPLE OPERATIONAL AMPLIFIERS

## Operational Amplifiers

electrical characteristics,  $V_{CC} \pm = \pm 15 \text{ V}$

PARAMETER	TEST CONDITIONS <sup>1</sup>	LM148			LM248			LM348			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage										
	$V_O = 0$	1	5	6	1	6	1	6	1	6	mV
	Full range										
	Full range										
	Full range										
$I_{IO}$	Input offset current	4	25	75	4	50	4	50	4	50	nA
	Full range										
	Full range										
	Full range										
$I_{IB}$	Input bias current	30	100	325	30	200	30	200	30	200	nA
	Full range										
	Full range										
	Full range										
$V_{ICR}$	Common-mode input voltage range	$\pm 12$			$\pm 12$			$\pm 12$			V
	Full range										
	Full range										
	Full range										
$V_{OM}$	Maximum peak output voltage swing	$R_L \geq 10 \text{ k}\Omega$	$\pm 12$	$\pm 13$	$\pm 12$	$\pm 13$	$\pm 12$	$\pm 13$	$\pm 12$	$\pm 13$	V
	Full range										
	Full range										
	Full range										
	Full range										
$A_{VD}$	Large-signal differential voltage amplification	$V_O = \pm 10 \text{ V}$ , $R_L \geq 2 \text{ k}\Omega$	50	160	25	160	25	160	25	160	V/mV
	Full range										
	Full range										
$f_i$	Input resistance	0.8	2.5		0.8	2.5	0.8	2.5	0.8	2.5	M $\Omega$
$B_1$	Unity-gain bandwidth	$A_{VD} = 1$	1		1		1		1		MHz
$\phi_M$	Phase margin	$A_{VD} = 1$	60°		60°		60°		60°		°
$CMRR$	Common-mode rejection ratio	$V_{IC} = V_{ICR \text{ min}}$ , $V_O = 0$	70	90	70	90	70	90	70	90	dB
	Full range										
	Full range										
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{CC} / \Delta V_{IO}$ )	$V_{CC} \pm = \pm 9 \text{ V}$ to $\pm 15 \text{ V}$ , $V_O = 0$	77	96	77	96	77	96	77	96	dB
	Full range										
$I_{OS}$	Short-circuit output current		$\pm 25$		$\pm 25$		$\pm 25$		$\pm 25$		mA
$I_{CC}$	Supply current (four amplifiers)	$V_O = 0$ , No load	2.4	3.6	2.4	4.5	2.4	4.5	2.4	4.5	mA
$V_{01}/V_{02}$	Crosstalk attenuation	$f = 1 \text{ Hz}$ to $20 \text{ kHz}$ ,	120		120		120		120		dB

<sup>1</sup>All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for  $T_A$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for LM148,  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for LM248, and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for LM348.

**TYPES LM148, LM248, LM348  
QUADRUPLE OPERATIONAL AMPLIFIERS**

operating characteristics,  $V_{CC \pm} = \pm 15 \text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain $R_L = 2 \text{ k}\Omega$ , $C_L = 100 \text{ pF}$ , See Figure 1		0.5		$\text{V}/\mu\text{s}$

**PARAMETER MEASUREMENT INFORMATION**

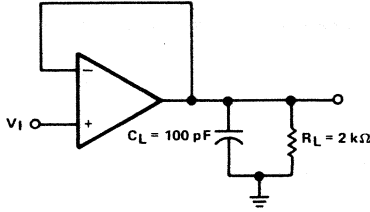


FIGURE 1—UNITY-GAIN AMPLIFIER

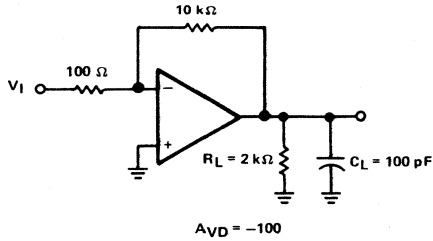
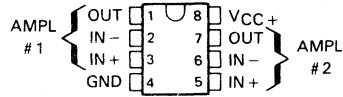


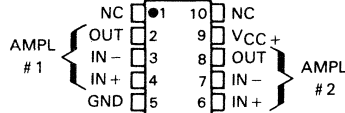
FIGURE 2—INVERTING AMPLIFIER

- **Wide Range of Supply Voltages:**  
Single Supply . . . 3 V to 30 V  
(LM2904 . . . 3 V to 26 V),  
or Dual Supplies
- **Low Supply Current Drain Independent of Supply Voltage . . . 0.7 mA Typ**
- **Common-Mode Input Voltage Range**  
Includes Ground Allowing Direct Sensing  
near Ground
- **Low Input Bias and Offset Parameters:**  
Input Offset Voltage . . . 3 mV Typ  
A Versions . . . 2 mV Typ  
Input Offset Current . . . 2 nA Typ  
Input Bias Current . . . 20 nA Typ  
A Versions . . . 15 nA Typ
- **Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . .  $\pm 32$  V**  
( $\pm 26$  V for LM2904)
- **Open-Loop Differential Voltage Amplification . . . 100 V/mV Typ**
- **Internal Frequency Compensation**

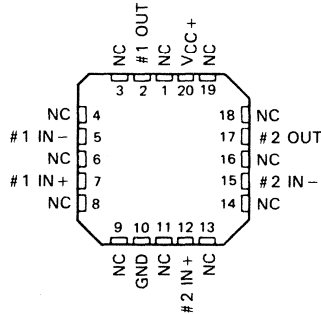
**D, JG, OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



**U FLAT PACKAGE  
(TOP VIEW)**

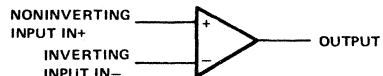


**LM 158  
FH OR FK CHIP CARRIER PACKAGE  
(TOP VIEW)**



NC—No internal connection

**symbol (each amplifier)**



**description**

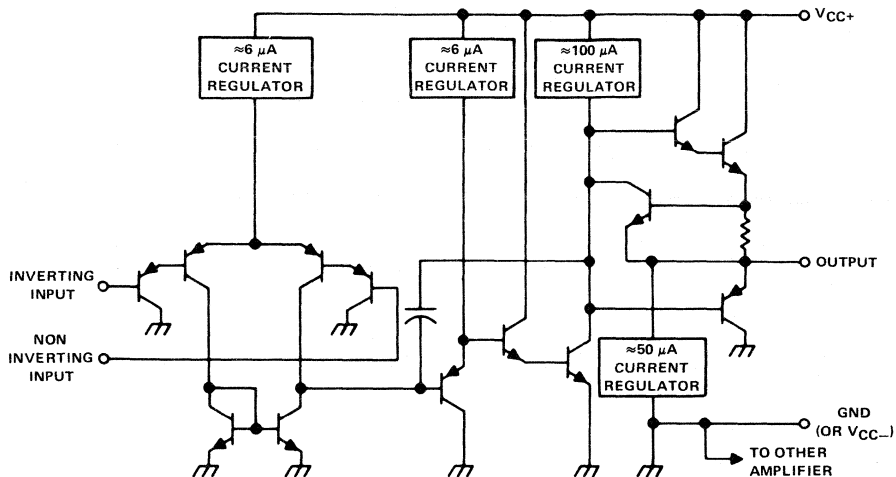
These devices consist of two independent, high-gain, frequency-compensated operational amplifiers that were designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies is also possible so long as the difference between the two supplies is 3 volts to 30 volts (3 volts to 26 volts for the LM2904), and the  $V_{CC}$  pin is at least 1.5 volts more positive than the input common-mode voltage. The low supply current drain is independent of the magnitude of the supply voltage.

Applications include transducer amplifiers, d-c amplification blocks, and all the conventional operational amplifier circuits that now can be more easily implemented in single-supply-voltage systems. For example, these devices can be operated directly off of the standard five-volt supply that is used in digital systems and will easily provide the required interface electronics without requiring additional  $\pm 15$ -volt supplies.

The LM158 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The LM258 and LM258A are characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , the LM358 and LM358A from  $0^{\circ}$  to  $70^{\circ}$ , and the LM2904 from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

# TYPES LM158, LM258, LM358, LM258A, LM358A, LM2904 DUAL OPERATIONAL AMPLIFIERS

schematic (each amplifier)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		LM158, LM258, LM258A LM358, LM358A	LM2904	UNIT
Supply voltage, $V_{CC}$ (see Note 1)		32	26	V
Differential voltage (see Note 2)		$\pm 32$	$\pm 26$	V
Input voltage range (either input)		-0.3 to 32	-0.3 to 26	V
Duration of output short-circuit (one amplifier) to ground at (or below) 25°C free-air temperature ( $V_{CC} \leq 15$ V) (see Note 3)		unlimited	unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	D package	725	725	mW
	JG package (alloy-mounted chip)	1050		
	JG package (glass-mounted chip)	825	825	
	P package	725	725	
	U package	675	675	
Operating free-air temperature range	LM158	-55 to 125		°C
	LM258, LM258A	-25 to 85		
	LM358, LM358A	0 to 70		
	LM2904		-40 to 85	
	Storage temperature range		-65 to 150	
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	FH, FK, JG, or U package	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or P package	260	260	°C

- NOTES: 1. All voltage values, except differential voltages and  $V_{CC}$  specified for the measurement of  $I_{OS}$ , are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the JG package, LM158 chips are alloy-mounted; LM258, LM258A, LM358, LM358A, and LM2904 chips are glass-mounted.

**TYPES LM158, LM258, LM358, LM2904  
DUAL OPERATIONAL AMPLIFIERS**



**Operational Amplifiers**

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	LM158, LM258			LM358			LM2904			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage $V_{CC} = 5\text{ V to MAX,}$ $V_{IC} = V_{ICR\text{ min,}}$ $V_O = 1.4\text{ V}$		3	5	7	3	5	7	3	7	mV
$\alpha_{VIO}$	Average temperature coefficient of input offset voltage		7			7			7		$\mu\text{V}/^\circ\text{C}$
$I_{IO}$	Input offset current $V_O = 1.4\text{ V}$		2	30	100	2	50	150	2	50	nA
$\alpha_{IIO}$	Average temperature coefficient of input offset current		10			10			10		$\text{pA}/^\circ\text{C}$
$I_{IB}$	Input bias current $V_O = 1.4\text{ V}$		-20	-150	-300	-20	-250	-500	-20	-250	nA
$V_{ICR}$	Common-mode input voltage range $V_{CC} = 5\text{ V to MAX}$		0 to $V_{CC} - 1.5$			0 to $V_{CC} - 1.5$			0 to $V_{CC} - 1.5$		V
$V_{OH}$	High-level output voltage $R_L \geq 2\text{ k}\Omega$ $R_L \geq 10\text{ k}\Omega$ $V_{CC} = \text{MAX,}$ $R_L = 2\text{ k}\Omega$		0 to $V_{CC} - 2$			0 to $V_{CC} - 2$			0 to $V_{CC} - 2$		V
$V_{OL}$	Low-level output voltage $R_L \leq 10\text{ k}\Omega$		0 to $V_{CC} - 1.5$			0 to $V_{CC} - 1.5$			0 to $V_{CC} - 1.5$		V
			26			26			22		V
			27	28		27	28		23	24	V
			5	20		5	20		5	100	mV



AVD Large-signal differential voltage amplification	VCC = 15 V, VO = 1 V to 11 V, RL = ≥ 2 kΩ	25°C	50	100	25	100	100	V/mV
		Full range	25		15		15	
CMRR Common-mode rejection ratio	VCC = 5 V to MAX, VIC = VICR min	25°C	70	80	65	80	50	80
kSVR Supply voltage rejection ratio (ΔVCC/ΔVIO)	VCC = 5 V to MAX	25°C	65	100	65	100	50	100
V01/V02 Crosstalk attenuation	f = 1 kHz to 20 kHz	25°C	120		120		120	120
		25°C	-20	-30	-20	-30	-20	-30
IO Output current	VID = 1 V, VO = 0	Full range	-10		-10		-10	mA
		25°C	10	20	10	20	10	20
		Full range	5		5		5	
IOS Short-circuit output current	VID = -1 V, VO = 200 mV	25°C	12	30	12	30	30	μA
		25°C	±40	±60	±40	±60	±40	±60
ICC Supply current (two amplifiers)	VCC = MAX, VO = 0.5 VCC; No load	Full range	0.7	1.2	0.7	1.2	0.7	1.2
		Full range	1	2	1	2	1	2

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. "MAX": VCC for testing purposes is 26 V for LM2904, 30 V for the others. Full range is -55°C to 125°C for LM158, -25°C to 85°C for LM258, 0°C to 70°C for LM358, and -40°C to 85°C for LM2904.

**TYPES LM258A, LM358A  
DUAL OPERATIONAL AMPLIFIERS**

 electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS †	LM258A			LM358A			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{CC} = 5\text{ V}$ to $30\text{ V}$ $V_{IC} = V_{ICR}\text{ min.}$ $V_O = 1.4\text{ V}$		2	3		2	3	mV
	Full range			4			5	
$\epsilon_{VIO}$ Average temperature coefficient of input offset voltage	Full range		7	15		7	20	$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current	$V_O = 1.4\text{ V}$		2	15		2	30	nA
	Full range			30			75	
$\epsilon_{IIO}$ Average temperature coefficient of input offset current	Full range		10	200		10	300	$\text{pA}/^\circ\text{C}$
	$25^\circ\text{C}$		-15	-80		-15	-100	
$I_{IB}$ Input bias current	$V_O = 1.4\text{ V}$			-100			-200	nA
	Full range							
$V_{ICR}$ Common-mode input voltage range	$V_{CC} 30\text{ V}$	$25^\circ\text{C}$	0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$			V
		Full range	0 to $V_{CC}-2$		0 to $V_{CC}-2$			
		$25^\circ\text{C}$	$V_{CC}-1.5$		$V_{CC}-1.5$			
		Full range	26		26			
$V_{OH}$ High-level output voltage	$V_{CC} = 30\text{ V.}$ $R_L = 2\text{ k}\Omega.$	Full range	27	28	27	28	V	
		$V_{CC} = 30\text{ V.}$ $R_L \geq 10\text{ k}\Omega.$						
		$V_{CC} = 30\text{ V.}$ $R_L \leq 10\text{ k}\Omega.$						
$V_{OL}$ Low-level output voltage	Full range	5	20	5	20	mV		

A <sub>V</sub> D	Large-signal differential voltage amplification	V <sub>CC</sub> = 15 V, V <sub>O</sub> = 1 V to 11 V, R <sub>L</sub> = ≥ 2 kΩ	25 °C	50	100	25	100	V/mV	
			Full range	25	80	15			
CMRR	Common-mode rejection ratio		25 °C	70	80	65	80	dB	
			Full range	65	100	65	100	dB	
k <sub>SVR</sub>	Supply voltage rejection ratio (ΔV <sub>CC</sub> /ΔV <sub>O</sub> )		25 °C	120		120		dB	
			Full range	20	30	60	20	30	60
V <sub>e1</sub> /V <sub>O2</sub>	Crosstalk attenuation	f = 1 kHz to 20 kHz	25 °C	20	30	60	20	30	60
			Full range	10			10		
I <sub>O</sub>	Output current	V <sub>CC</sub> = 15 V, V <sub>ID</sub> = 1 V, V <sub>O</sub> = 0	25 °C	10	20	10	20	mA	
			Full range	5			5		
			25 °C	12	30	12	30	μA	
			Full range						
I <sub>OS</sub>	Short-circuit output current	V <sub>CC</sub> at 5 V, GND at -5 V, V <sub>O</sub> = 0	25 °C	±40	±60	±40	±60	mA	
			Full range	0.7	1.2	0.7	1.2		
I <sub>CC</sub>	Supply current (two amplifiers)	V <sub>CC</sub> = 30 V, V <sub>O</sub> = 15 V, No load	Full range	1	2			mA	
			Full range						

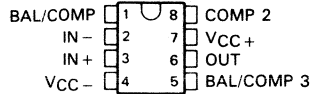
† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range is -25 °C to 85 °C for LM258A and 0 °C to 70 °C for LM358A.



## Operational Amplifiers

- Small-Signal Bandwidth . . . 15 MHz Typ
- Slew Rate . . . 50 V/ $\mu$ s Min
- Bias Current . . . 250 nA Max (LM218)
- Supply Voltage Range . . .  $\pm 5$  V to  $\pm 20$  V
- Internal Frequency Compensation
- Input and Output Overload Protection
- Same Pin Assignments as General-Purpose Operational Amplifiers

D, JG, OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**description**

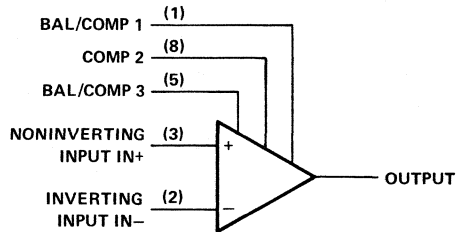
The LM218 and LM318 are precision, high-speed operational amplifiers designed for applications requiring wide bandwidth and high slew rate. They feature a factor-of-ten increase in speed over general purpose devices without sacrificing dc performance.

These operational amplifiers have internal unity-gain frequency compensation. This considerably simplifies their application since no external components are necessary for operation. However, unlike most internally compensated amplifiers, external frequency compensation may be added for optimum performance. For inverting applications, feed-forward compensation will boost the slew rate to over 150 V/ $\mu$ s and almost double the bandwidth. Overcompensation may be used with the amplifier for greater stability when maximum bandwidth is not needed. Further, a single capacitor may be added to reduce the settling time for 0.1% error band to under 1  $\mu$ s.

The high speed and fast settling time of these operational amplifiers make them useful in A/D converters, oscillators, active filters, sample and hold circuits, and general purpose amplifiers.

The LM218 is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the LM318 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

symbol



**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

	LM218	LM318	UNIT
Supply voltage, $V_{CC+}$ (see Note 1)	20	20	V
Supply voltage, $V_{CC-}$ (see Note 1)	-20	-20	V
Input voltage (either input, see Notes 1 and 2)	$\pm 15$	$\pm 15$	V
Differential input current (see Note 3)	$\pm 10$	$\pm 10$	mA
Duration of output short-circuit (see Note 4)	unlimited	unlimited	
Continuous total power dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 5)	500	500	mW
Operating free-air temperature range	$-25$ to $85$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	JG package	300	$^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or P package	260	$^{\circ}\text{C}$

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
3. The inputs are shunted with two opposite-facing base-emitter diodes for over voltage protection. Therefore, excessive current will flow if a differential input voltage in excess of approximately 1 V is applied between the inputs unless some limiting resistance is used.
4. The output may be shorted to ground or either power supply. For the LM218 only, the unlimited duration of the short-circuit applies at (or below)  $85^{\circ}\text{C}$  case temperature or  $75^{\circ}\text{C}$  free-air temperature.
5. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Curves, Section 2. In the JG package, LM218 and LM318 chips are glass-mounted.

# TYPES LM218, LM318 HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature (see Note 6)

PARAMETER	TEST CONDITIONS†	LM218			LM318			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0$	25°C	2	4	4	10	mV	
		Full range		6		15		
$I_{IO}$ Input offset current	$V_O = 0$	25°C	6	50	30	200	nA	
		Full range		100		300		
$I_{IB}$ Input bias current	$V_O = 0$	25°C	120	250	150	250	nA	
		Full range		500		750		
$V_{ICR}$ Common-mode input voltage range	$V_{CC\pm} = \pm 15$ V	Full range	$\pm 11.5$		$\pm 11.5$		V	
$V_{OM}$ Maximum peak output voltage swing	$V_{CC\pm} = \pm 15$ V, $R_L = 2$ k $\Omega$	Full range	$\pm 12$	$\pm 13$	$\pm 12$	$\pm 13$	V	
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC\pm} = \pm 15$ V, $V_O = \pm 10$ V, $R_L \geq 2$ k $\Omega$	25°C	50	200	25	200	V/mV	
		Full range	25		20			
$B_1$ Unity-gain bandwidth	$V_{CC\pm} = \pm 15$ V	25°C		15		15	MHz	
$r_i$ Input resistance		25°C	1	3	0.5	3	M $\Omega$	
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min	Full range	80	100	70	100	dB	
kSVR Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )		Full range	70	80	65	80	dB	
$I_{CC}$ Supply current	No load, $V_O = 0$	25°C		5	8	5	10	mA
		Full range		4.5	7			

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for LM218 is  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  and for LM318 is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

NOTE 6: Unless otherwise noted,  $V_{CC} = \pm 5$  V to  $\pm 20$  V. All typical values are at  $V_{CC\pm} = \pm 15$  V.

operating characteristics,  $V_{CC+} = 15$  V,  $V_{CC-} = -15$  V,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR Slew rate at unity gain	$\Delta V_I = 10$ V, $C_L = 10$ pF, See Figure 1	50	70		V/ $\mu\text{s}$

parameter measurement information

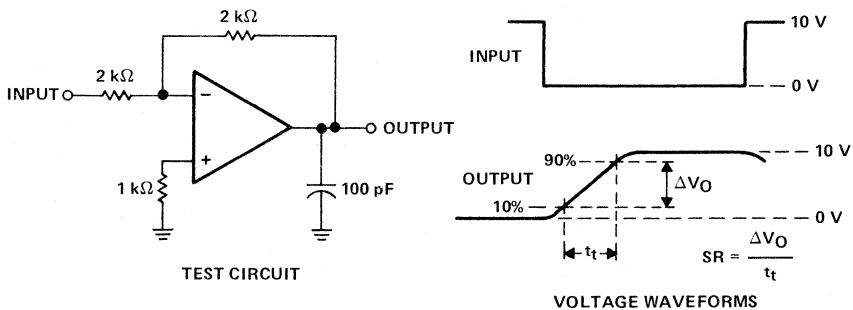
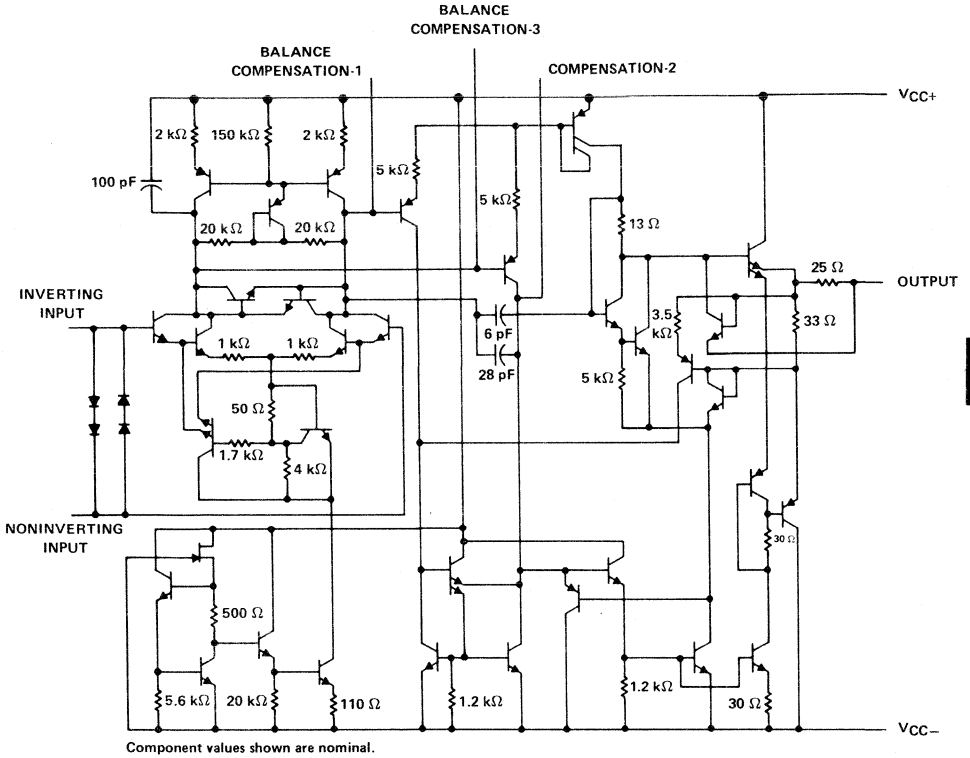


FIGURE 1—SLEW RATE

**TYPES LM218, LM318  
HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS**

schematic



**3**  
Operational Amplifiers

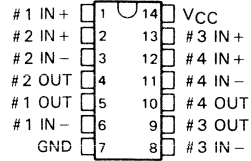


## Operational Amplifiers



- Wide Range of Supply Voltages, Single or Dual Supplies
- Wide Bandwidth
- Large Output Voltage Swing
- Output Short-Circuit Protection
- Internal Frequency Compensation
- Low Input Bias Current
- Designed to be Interchangeable with National Semiconductor LM2900 and LM3900. Respectively

J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)

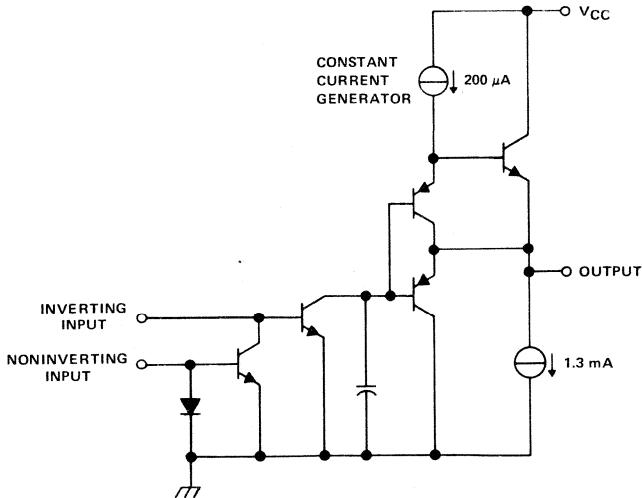


**description**

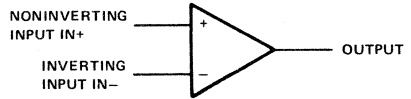
These devices consist of four independent, high-gain frequency-compensated Norton operational amplifiers that were designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies is also possible. The low supply current drain is essentially independent of the magnitude of the supply voltage. These devices provide wide bandwidth and large output voltage swing.

The LM2900 is characterized for operation from -40°C to 85°C, and the LM3900 is characterized for operation from 0°C to 70°C.

**schematic (each amplifier)**



**symbol (each amplifier)**



# TYPES LM2900, LM3900

## QUADRUPLE OPERATIONAL AMPLIFIERS

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		LM2900	LM3900	UNIT
Supply voltage, $V_{CC}$ (see Note 1)		32	32	V
Input current		20	20	mA
Duration of output short circuit (one amplifier) to ground at (or below) 25 °C free-air temperature (see Note 2)		unlimited	unlimited	
Continuous total dissipation at (or below) 25 °C free-air temperature (see Note 3)	J Package	1025	1025	mW
	N Package	875	875	
Operating free-air temperature range		-40 to 85	0 to 70	°C
Storage temperature range		-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J Package	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	N Package	260	260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 3. For operation above 25 °C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J package, LM2900 and LM3900 chips are glass-mounted.

### recommended operating conditions

	LM2900		LM3900		UNIT
	MIN	MAX	MIN	MAX	
Input current (see Note 4)		-1		-1	mA
Operating free-air temperature, $T_A$	-40	85	0	70	°C

- NOTE 4: Clamp transistors are included that prevent the input voltages from swinging below ground more than approximately -0.3 volt. The negative input currents that may result from large signal overdrive with capacitive input coupling must be limited externally to values of approximately -1 mA. Negative input currents in excess of -4 mA will cause the output voltage to drop to a low voltage. These values apply for any one of the input terminals. If more than one of the input terminals are simultaneously driven negative, maximum currents are reduced. Common-mode current biasing can be used to prevent negative input voltages.

3 Operational Amplifiers

# TYPES LM2900, LM3900 QUADRUPLE OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC} = 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		LM2900			LM3900			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$I_{IB}$ Input bias current (inverting input)	$I_{I+} = 0$	$T_A = 25^\circ\text{C}$ $T_A = \text{full range}$	30	200		30	200	nA	
$\frac{I_{I-}}{I_{I+}}$ Mirror gain	$I_{I+} = 20\ \mu\text{A}$ to $200\ \mu\text{A}$ , $T_A = \text{full range}$ , See Note 5		0.9	1.1	0.9	1.1	$\mu\text{A}/\mu\text{A}$		
Change in mirror gain			2	5	2	15	%		
Mirror current	$V_{I+} = V_{I-}$ , See Note 5	$T_A = \text{full range}$ ,	10	500	10	500	$\mu\text{A}$		
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 10\text{ V}$ , $f = 100\text{ Hz}$	$R_L = 10\text{ k}\Omega$ ,	1.2	2.8	1.2	2.8	V/mV		
$r_i$ Input resistance (inverting input)			1		1		$\text{M}\Omega$		
$r_o$ Output resistance			8		8		$\text{k}\Omega$		
$B_1$ Unity-gain bandwidth (inverting input)			2.5		2.5		MHz		
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )			70		70		dB		
$V_{OH}$ High-level output voltage	$I_{I+} = 0$ , $I_{I-} = 0$	$R_L = 2\text{ k}\Omega$ $V_{CC} = 30\text{ V}$ , No load	13.5		13.5		V		
$V_{OL}$ Low-level output voltage	$I_{I+} = 0$ , $R_L = 2\text{ k}\Omega$	$I_{I-} = 10\ \mu\text{A}$ ,	0.09	0.2	0.09	0.2	V		
$I_{OHS}$ Short-circuit output current (output internally high)	$I_{I+} = 0$ , $V_O = 0$	$I_{I-} = 0$ ,	-6	-18	-6	-10	mA		
Pull-down current			0.5	1.3	0.5	1.3	mA		
$I_{OL}$ Low-level output current†	$I_{I-} = 5\ \mu\text{A}$ , Supply current	$V_{OL} = 1\text{ V}$	5		5		mA		
$I_{CC}$ (four amplifiers)	No load		6.2	10	6.2	10	mA		

† All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified. Full range for  $T_A$  is  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for LM2900, and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for LM3900.

‡ The output current-sink capability can be increased for large-signal conditions by overdriving the inverting input.

NOTE 5: These parameters are measured with the output balanced midway between  $V_{CC}$  and ground.

operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
SR Slew rate at unity gain	Low-to-high output	$V_O = 10\text{ V}$ , $C_L = 100\text{ pF}$ , $R_L = 2\text{ k}\Omega$	0.5			$\text{V}/\mu\text{s}$
	High-to-low output		20			

3

Operational Amplifiers

# TYPES LM2900, LM3900 QUADRUPLE OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

INPUT BIAS CURRENT (INVERTING INPUT)  
vs  
FREE-AIR TEMPERATURE

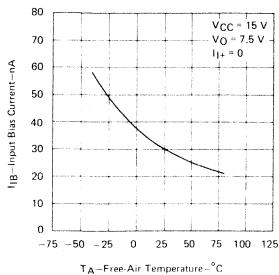


FIGURE 1

MIRROR GAIN  
vs  
FREE-AIR TEMPERATURE

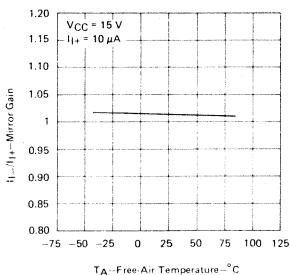


FIGURE 2

SUPPLY VOLTAGE REJECTION RATIO  
vs  
FREQUENCY

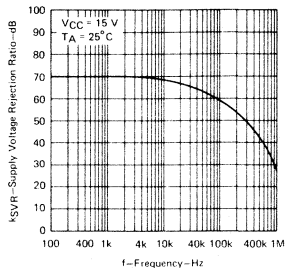


FIGURE 3

LARGE SIGNAL  
DIFFERENTIAL VOLTAGE AMPLIFICATION  
vs  
FREQUENCY

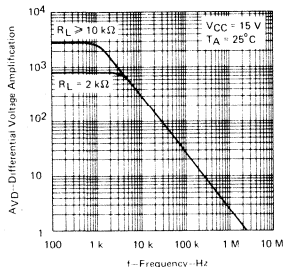


FIGURE 4

LARGE-SIGNAL  
DIFFERENTIAL VOLTAGE AMPLIFICATION  
vs  
SUPPLY VOLTAGE

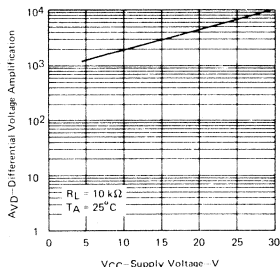


FIGURE 5

LARGE SIGNAL  
DIFFERENTIAL VOLTAGE AMPLIFICATION  
vs  
FREE AIR TEMPERATURE

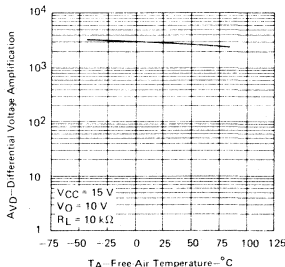


FIGURE 6

PEAK-TO-PEAK OUTPUT VOLTAGE  
vs  
FREQUENCY

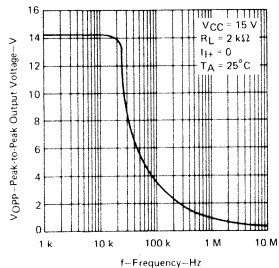


FIGURE 7

LM2900  
SHORT CIRCUIT OUTPUT CURRENT  
(OUTPUT INTERNALLY HIGH)  
vs  
SUPPLY VOLTAGE

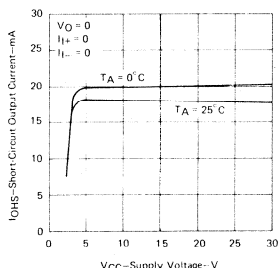


FIGURE 8

LOW-LEVEL OUTPUT CURRENT  
vs  
SUPPLY VOLTAGE

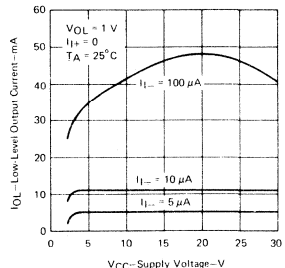
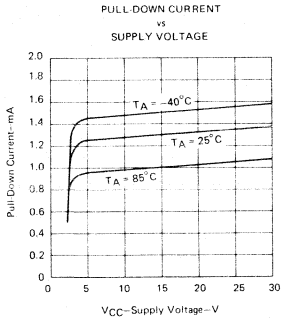


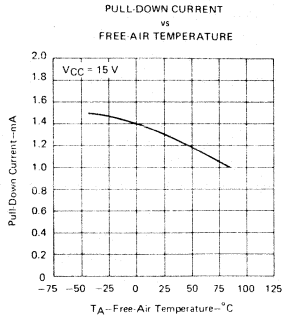
FIGURE 9

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

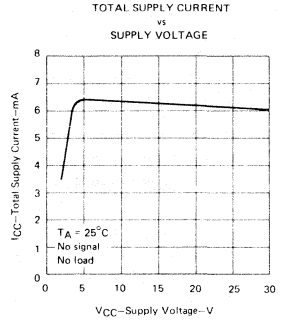
**TYPICAL CHARACTERISTICS†**



**FIGURE 10**



**FIGURE 11**



**FIGURE 12**

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

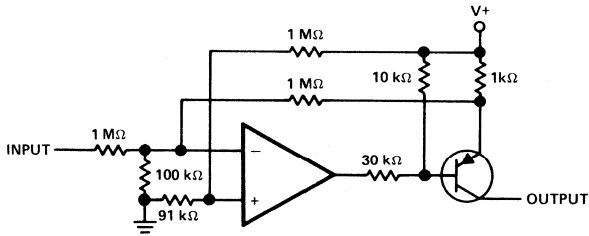
# TYPES LM2900, LM3900 QUADRUPLE OPERATIONAL AMPLIFIERS

## TYPICAL APPLICATION DATA

Norton (or current-differencing) amplifiers can be used in most standard general-purpose op-amp applications. Performance as a dc amplifier in a single-power-supply mode is not as precise as a standard integrated-circuit operational amplifier operating from dual supplies. Operation of the amplifier can best be understood by noting that input currents are differenced at the inverting input terminal and this current then flows through the external feedback resistor to produce the output voltage. Common-mode current biasing is generally useful to allow operating with signal levels near (or even below) ground.

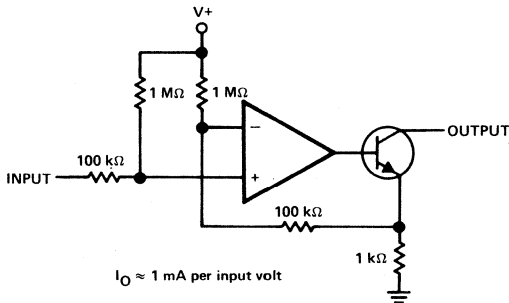
Internal transistors clamp negative input voltages at approximately  $-0.3$  volt but the magnitude of current flow has to be limited by the external input network. For operation at high temperature, this limit should be approximately  $-100$  microamperes.

Noise immunity of a Norton amplifier is less than that of standard bipolar amplifiers. Circuit layout is more critical since coupling from the output to the noninverting input can cause oscillations. Care must also be exercised when driving either input from a low-impedance source. A limiting resistor should be placed in series with the input lead to limit the peak input current. Current up to 20 milliamperes will not damage the device but the current mirror on the noninverting input will saturate and cause a loss of mirror gain at higher current levels, especially at high operating temperatures.



$$I_O \approx 1 \text{ mA per input volt}$$

FIGURE 13—VOLTAGE-CONTROLLED CURRENT SOURCE



$$I_O \approx 1 \text{ mA per input volt}$$

FIGURE 14—VOLTAGE-CONTROLLED CURRENT SINK

- Short-Circuit Protection
- Wide Common-Mode and Differential Voltage Ranges
- No Frequency Compensation Required
- Low Power Consumption
- No Latch-up
- Designed to be Interchangeable with Motorola MC1558/MC1458 and Signetics S5558/N5558

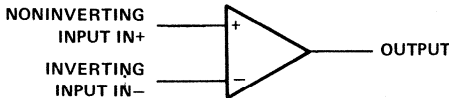
**description**

The MC1558 and MC1458 are dual general-purpose operational amplifiers with each half electrically similar to  $\mu$ A741 except that offset null capability is not provided.

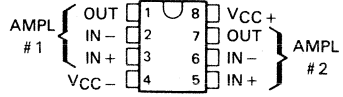
The high common-mode input voltage range and the absence of latch-up make these amplifiers ideal for voltage-follower applications. The devices are short-circuit protected and the internal frequency compensation ensures stability without external components.

The MC1558 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the MC1458 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

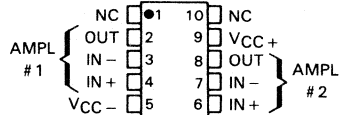
**symbol (each amplifier)**



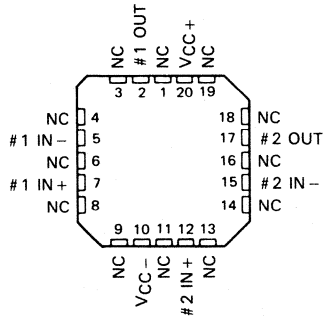
MC1558 . . . JG PACKAGE  
MC1458 . . . D, JG, OR P PACKAGE  
(TOP VIEW)



MC1558, MC1458 . . . U FLAT PACKAGE  
(TOP VIEW)



MC1558 . . . FH OR FK PACKAGE  
(TOP VIEW)

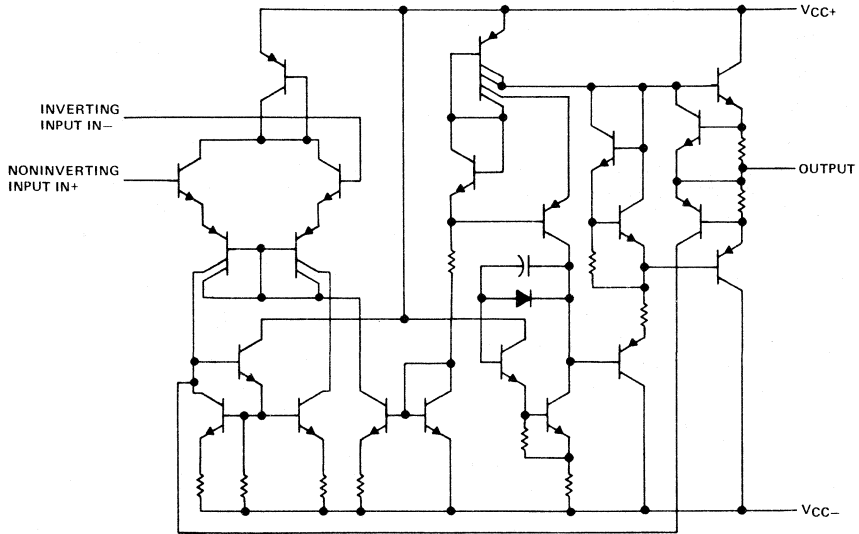


NC—No internal connection

# TYPES MC1558, MC1458

## DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

schematic (each amplifier)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		MC1558	MC1458	UNIT	
Supply voltage $V_{CC+}$ (see Note 1)		22	18	V	
Supply voltage $V_{CC-}$ (see Note 1)		-22	-18	V	
Differential input voltage (see Note 2)		$\pm 30$	$\pm 30$	V	
Input voltage at either input (see Notes 1 and 3)		$\pm 15$	$\pm 15$	V	
Duration of output short-circuit (see Note 4)		unlimited	unlimited		
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)	Each amplifier	500	500	mW	
	Total package	D, FH, FK, JG, or P package	680		
		U package	675		
Operating free-air temperature range		-55 to 125	0 to 70	°C	
Storage temperature range		-65 to 150	-65 to 150	°C	
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds		FH, FK, JG or U package		300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds		D or P package		260	°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply. For the MC1558 only, the unlimited duration of the short-circuit applies at (or below) 125°C case temperature or 70°C free-air temperature.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the JG package, MC1558 chips are alloy mounted, MC1458 chips are glass mounted.



# TYPES MC1558, MC1458 DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$

PARAMETER	TEST CONDITIONS†	MC1558			MC1458			UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$V_O = 0$	25 °C	1	5		1	6	mV	
		Full range		6		7.5			
$I_{IO}$ Input offset current	$V_O = 0$	25 °C	20	200		20	200	nA	
		Full range		500		300			
$I_{IB}$ Input bias current	$V_O = 0$	25 °C	80	500		80	500	nA	
		Full range		1500		800			
$V_{ICR}$ Common-mode input voltage range		25 °C	±12	±13		±12	±13	V	
		Full range	±12			±12			
$V_{OM}$ Maximum peak output voltage swing	$R_L = 10\text{ k}\Omega$	25 °C	±12	±14		±12	±14	V	
	$R_L \geq 10\text{ k}\Omega$	Full range	±12			±12			
	$R_L = 2\text{ k}\Omega$	25 °C	±10	±13		±10	±13		
	$R_L \geq 2\text{ k}\Omega$	Full range	±10			±10			
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 2\text{ k}\Omega$ , $V_O \geq \pm 10\text{ V}$	25 °C	50	200		20	200	V/mV	
		Full range	25			15			
$B_{OM}$ Maximum-output-swing bandwidth (closed-loop)	$R_L = 2\text{ k}\Omega$ , $V_O \geq \pm 10\text{ V}$ , $A_{VD} = 1$ , $THD \leq 5\%$	25 °C		14			14	kHz	
$B_1$ Unity-gain bandwidth		25 °C		1			1	MHz	
$\phi_m$ Phase margin	$A_{VD} = 1$	25 °C		65°			65°		
$A_m$ Gain margin		25 °C		11			11	dB	
$r_i$ Input resistance		25 °C	0.3	2		0.3	2	M $\Omega$	
$r_o$ Output resistance	$V_O = 0$ , See Note 6	25 °C		75			75	$\Omega$	
$C_i$ Input capacitance		25 °C		1.4			1.4	pF	
$z_{ic}$ Common-mode input impedance	$f = 20\text{ Hz}$	25 °C		200			200	M $\Omega$	
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR}\text{ min}$ , $V_O = 0$	25 °C	70	90		70	90	dB	
		Full Range	70			70			
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$V_{CC} = \pm 9\text{ V to } \pm 15\text{ V}$ , $V_O = 0$	25 °C	30	150		30	150	$\mu\text{V/V}$	
		Full range		150		150			
$V_n$ Equivalent input noise voltage (closed-loop)	$A_{VD} = 100$ , $R_S = 0$ , $f = 1\text{ kHz}$ , $BW = 1\text{ Hz}$	25 °C		45			45	nV/ $\sqrt{\text{Hz}}$	
$I_{OS}$ Short-circuit output current		25 °C		±25	±40		±25	±40	mA
$I_{CC}$ Supply current (both amplifiers)	No load, $V_O = 0$	25 °C	3.4	5		3.4	5.6	mA	
		Full range		6.6			6.6		
$P_D$ Total power dissipation (both amplifiers)	No load, $V_O = 0$	25 °C	100	150		100	170	mW	
		Full range		200			200		
$V_{O1}/V_{O2}$ Crosstalk attenuation		25 °C		120			120	dB	

† All characteristics are specified under open-loop operating conditions with zero common-mode input voltage unless otherwise specified. Full range for MC1558 is -55 °C to 125 °C and for MC1458 is 0 °C to 70 °C.

NOTE 6: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.



Operational Amplifiers

# TYPES MC1558, MC1458 DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MC1558			MC1458			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$ Rise time	$V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$ ,	0.3			0.3			$\mu\text{s}$
	$C_L = 100\text{ pF}$ , See Figure 1	5%			5%			
SR Slew rate at unity gain	$V_I = 10\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1	0.5			0.5			$\text{V}/\mu\text{s}$

## PARAMETER MEASUREMENT INFORMATION

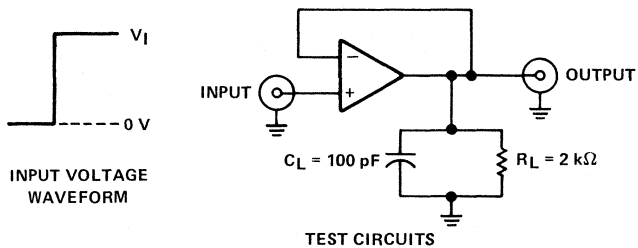
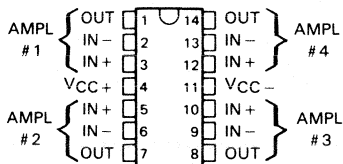


FIGURE 1—RISE TIME, OVERSHOOT, AND SLEW RATE

- Wide Range of Supply Voltages  
Single Supply . . . 3 V to 36 V  
or Dual Supplies
- Class AB Output Stage
- True Differential Input Stage
- Low Input Bias Current
- Internal Frequency Compensation
- Short-Circuit Protection
- Designed to be Interchangeable with Motorola  
MC3503, MC3303, MC3403

MC3503 . . . J PACKAGE  
MC3303, MC3403 . . . D, J, OR N PACKAGE  
(TOP VIEW)

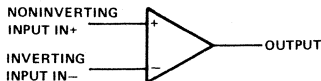


**description**

The MC3503, MC3303, and the MC3403 are quadrupe operational amplifiers similar in performance to the uA741 but with several distinct advantages. They are designed to operate from a single supply over a range of voltages from 3 volts to 36 volts. Operation from split supplies is also possible provided the difference between the two supplies is 3 volts to 36 volts. The common-mode input range includes the negative supply. Output range is from the negative supply to  $V_{CC} - 1.5$  V. Quiescent supply currents are less than one-half those of the uA741.

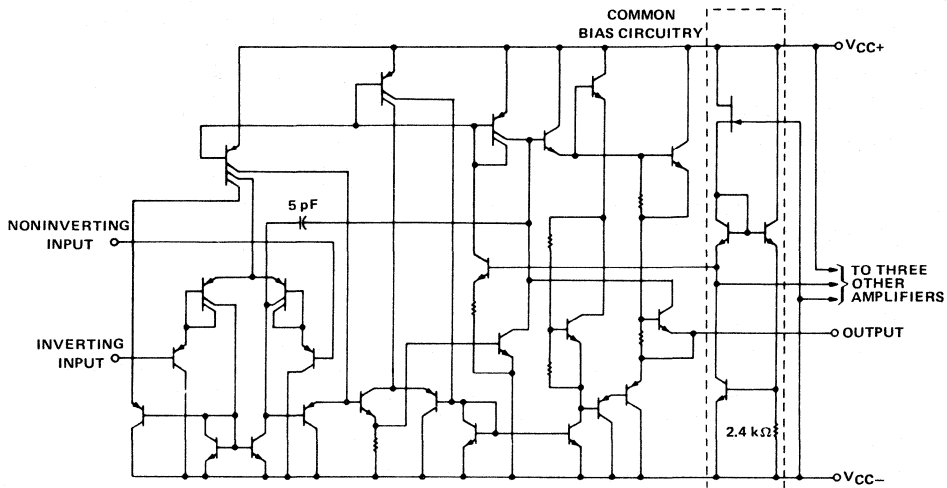
The MC3503 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The MC3303 is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the MC3403 is characterized for operation from  $0^{\circ}$  to  $70^{\circ}$ .

**symbol (each amplifier)**



# TYPES MC3503, MC3303, MC3403 QUADRUPLE LOW-POWER OPERATIONAL AMPLIFIERS

schematic (each amplifier)



All component values shown are nominal

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	MC3503	MC3303	MC3403	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	18	18	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-18	-18	-18	V
Supply voltage $V_{CC+}$ with respect to $V_{CC-}$	36	36	36	V
Differential input voltage (see Note 2)	$\pm 36$	$\pm 36$	$\pm 36$	V
Input voltage (see Notes 1 and 3)	$\pm 18$	$\pm 18$	$\pm 18$	V
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 4)	D package	960	960	mW
	J package	1375	1025	
	N package		875	
Operating free-air temperature range	-55 to 125	-40 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J package	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or N package		260	°C

- NOTES: 1. These voltage values are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting terminal.  
 3. Neither input must ever be more positive than  $V_{CC+}$  or more negative than  $V_{CC-}$ .  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J package, MC3503 chips are alloy mounted, MC3303 and MC3403 chips are glass mounted.

# TYPES MC3503, MC3303, MC3403 QUADRUPLE LOW-POWER OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature;  $V_{CC+} = 14\text{ V}$ ,  $V_{CC-} = 0\text{ V}$  for MC3303;  
 $V_{CC\pm} = \pm 15\text{ V}$  for MC3403 and MC3503

PARAMETER	TEST CONDITIONS †	MC3503			MC3303			MC3403			UNIT		
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX			
$V_{IO}$ Input offset voltage	See Note 5	25 °C	2	5	2	8	2	10			mV		
		Full range	6			10			12				
$\alpha_{VIO}$ Temperature coefficient of input offset voltage	See Note 5	Full range	10			10			10			$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$ Input offset current	See Note 5	25 °C	30	50	30	75	30	50			nA		
		Full range	200			250			200				
$\alpha_{IIO}$ Temperature coefficient of input offset current	See Note 5	Full range	50			50			50			$\text{pA}/^\circ\text{C}$	
$I_{IB}$ Input bias current	See Note 5	25 °C	-0.2	-0.5	-0.2	-0.5	-0.2	-0.5			$\mu\text{A}$		
		Full range	-1.5			-1			-0.8				
$V_{ICR}$ Common-mode input voltage range ‡		25 °C	$V_{CC-}$ to $V_{CC-}$	$V_{CC-}$ to $V_{CC-}$	$V_{CC-}$ to $V_{CC-}$	$V_{CC-}$ to $V_{CC-}$	$V_{CC-}$ to $V_{CC-}$	$V_{CC-}$ to $V_{CC-}$	$V_{CC-}$ to $V_{CC-}$		V		
			13	13.5	12	12.5	13	13.5					
$V_{OM}$ Peak output voltage swing	$R_L = 10\text{ k}\Omega$ $R_L = 2\text{ k}\Omega$ $R_L = 2\text{ k}\Omega$	25 °C	$\pm 12$	$\pm 13.5$	12	12.5	$\pm 12$	$\pm 13.5$			V		
		25 °C	$\pm 10$	$\pm 13$	10	12	$\pm 10$	$\pm 13$					
		Full range	$\pm 10$			10			$\pm 10$				
$A_{VD}$ Large-signal differential voltage amplification	$V_O = \pm 10\text{ V}$ , $R_L = 2\text{ k}\Omega$	25 °C	50	200	20	200	20	200			V/mV		
		Full range	25			15			15				
$B_{OM}$ Maximum-output-swing bandwidth	$V_{OPP} = 20\text{ V}$ , $A_{VD} = 1$ , $\text{THD} \leq 5\%$ , $R_L = 2\text{ k}\Omega$	25 °C	9			9			9			kHz	
$B_1$ Unity-gain bandwidth	$V_O = 50\text{ mV}$ , $R_L = 10\text{ k}\Omega$	25 °C	1			1			1			MHz	
$\phi_m$ Phase margin	$C_L = 200\text{ pF}$ , $R_L = 2\text{ k}\Omega$	25 °C	60°			60°			60°				
$r_i$ Input resistance	$f = 20\text{ Hz}$	25 °C	0.3	1	0.3	1	0.3	1			M $\Omega$		
$r_o$ Output resistance	$f = 20\text{ Hz}$	25 °C	75			75			75			$\Omega$	
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR\text{ min}}$	25 °C	70	90	70	90	70	90			dB		
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$V_{CC} = \pm 2.5$ to $\pm 15\text{ V}$	25 °C	30			150			30			$\mu\text{V}/\text{V}$	
$I_{OS}$ Short-circuit output current §		25 °C	$\pm 10$	$\pm 30$	$\pm 45$	$\pm 10$	$\pm 30$	$\pm 45$	$\pm 10$	$\pm 30$	$\pm 45$	mA	
$I_{CC}$ Total supply current	No load, See Note 5	25 °C	2.8			4			2.8			7	mA

† All characteristics are measured under open-loop conditions with zero common-mode voltage unless other specified. Full range for  $T_A$  - 55 °C to 125 °C for MC3503, -40 °C to 85 °C for MC3303, and 0 °C to 70 °C for MC3403.

‡ The  $V_{ICR}$  limits are directly linked volt-for-volt to supply voltage, viz the positive limit is 2 volts less than  $V_{CC+}$ .

§ Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

NOTE 5:  $V_{IO}$ ,  $I_{IO}$ ,  $I_{IB}$ , and  $I_{CC}$  are defined at  $V_O = 0$  for MC3403 and MC3503, and  $V_O = 7\text{ V}$  for MC3303.

# TYPES MC3503, MC3303, MC3403 QUADRUPLE LOW-POWER OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>1</sup>	MC3503			MC3303			MC3403			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage $V_O = 2.5\text{ V}$		2	5			10		2	10	mV
$I_{IO}$	Input offset current $V_O = 2.5\text{ V}$		30	50			75		30	50	nA
$I_{IB}$	Input bias current $V_O = 2.5\text{ V}$		-0.2	-0.5			-0.5		-0.2	-0.5	pA
$V_{OM}$	Peak output voltage swing <sup>‡</sup>	$R_L = 10\text{ k}\Omega$	3.3	3.5	3.3	3.5		3.3	3.5		V
		$R_L = 10\text{ k}\Omega$ , $V_{CC+} = 5\text{ V}$ to $30\text{ V}$	$V_{CC+} - 1.7$			$V_{CC+} - 1.7$			$V_{CC+} - 1.7$		
$A_{VD}$	Large-signal differential voltage amplification $V_O = 1.7\text{ V}$ to $3.3\text{ V}$ , $R_L = 2\text{ k}\Omega$	20	200		20	200		20	200		V/mV
$k_{SVS}$	Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC\pm}$ ) $V_{CC} = \pm 15\text{ V}$ to $\pm 2.5\text{ V}$			150			150			150	$\mu\text{V/V}$
$I_{CC}$	Supply current No load, $V_O = 2.5\text{ V}$		2.5	4		2.5	7		2.5	7	mA
$V_{O1}/V_{O2}$	Crosstalk attenuation $f = 1\text{ kHz}$ to $20\text{ kHz}$		120			120			120		dB

<sup>1</sup>All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

<sup>‡</sup>Output will swing essentially to ground.

operating characteristics,  $V_{CC+} = 14\text{ V}$ ,  $V_{CC-} = 0\text{ V}$  for MC3303;  $V_{CC\pm} = \pm 15\text{ V}$  for MC3403 and MC3503;  $T_A = 25^\circ\text{C}$ ,  $A_{VD} = 1$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain $V_I = \pm 10\text{ V}$ , See Figure 1		0.6		$\text{V}/\mu\text{s}$
$t_r$	Rise time $\Delta V_O = 50\text{ mV}$ , $C_L = 100\text{ pF}$ , $R_L = 10\text{ k}\Omega$		0.35		$\mu\text{s}$
$t_f$	Fall time See Figure 1		0.35		$\mu\text{s}$
Overshoot factor			20%		
Crossover distortion	$V_{pp} = 30\text{ mV}$ , $V_{OPP} = 2\text{ V}$ , $f = 10\text{ kHz}$		1%		

## PARAMETER MEASUREMENT INFORMATION

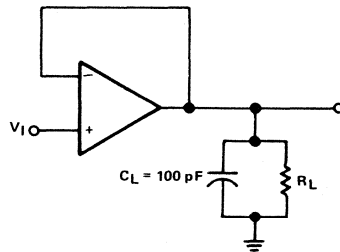


FIGURE 1—UNITY-GAIN AMPLIFIER

# TYPES MC3503, MC3303, MC3403 QUADRUPLE LOW-POWER OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

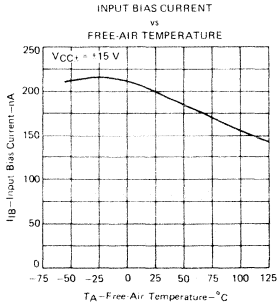


FIGURE 2

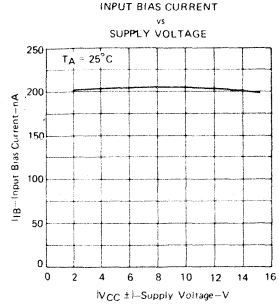


FIGURE 3

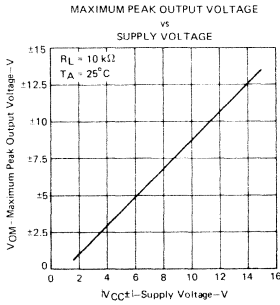


FIGURE 4

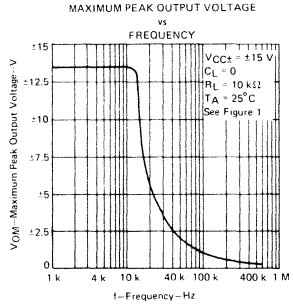


FIGURE 5

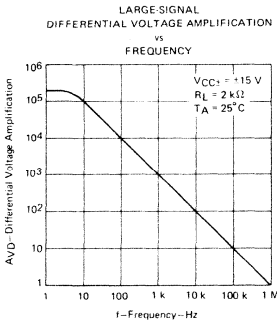


FIGURE 6

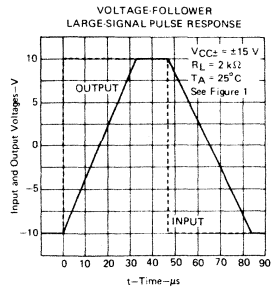


FIGURE 7

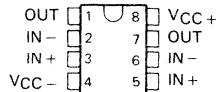
†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

**3**  
**Operational Amplifiers**



- Equivalent Input Noise Voltage . . . . . 5 nV/ $\sqrt{\text{Hz}}$  Typ at 1 kHz
- Unity-Gain Bandwidth . . . . . 10 MHz Typ
- Common-Mode Rejection Ratio . . . . . 100 dB Typ
- High DC Voltage Gain . . . . . 100 V/mV Typ
- Peak-to-Peak Output Voltage Swing . . . . . 32 V Typ with  $V_{CC\pm} = \pm 18 \text{ V}$  and  $R_L = 600 \Omega$
- High Slew Rate . . . . . 9 V/ $\mu\text{s}$  Typ
- Wide Supply Voltage Range . . . . .  $\pm 3 \text{ V}$  to  $\pm 20 \text{ V}$
- Designed to be Interchangeable with Signetics NE5532 and NE5532A

NE5532, NE5532A . . . JG OR P  
DUAL IN-LINE PACKAGE  
(TOP VIEW)

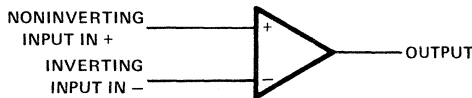


**description**

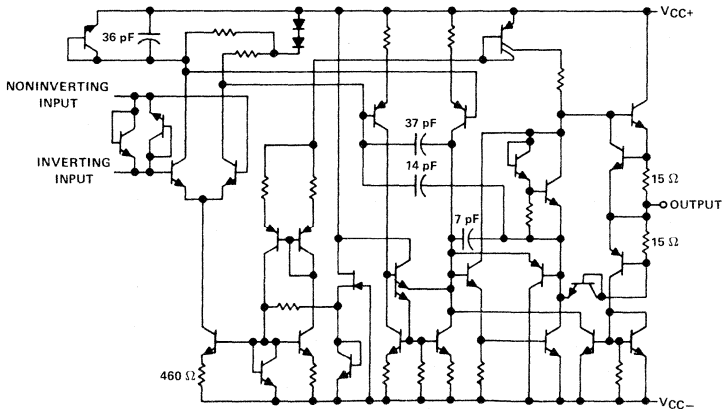
The NE5532 and NE5532A are monolithic high-performance operational amplifiers combining excellent dc and ac characteristics. They feature very low noise, high output drive capability, high unity-gain and maximum-output-swing bandwidths, low distortion, high slew rate, input-protection diodes, and output short-circuit protection. These operational amplifiers are internally compensated for unity gain operation. The NE5532A has guaranteed maximum limits for equivalent input noise voltage.

The NE5532 and NE5532A are characterized for operation from 0°C to 70°C.

**symbol (each amplifier)**



**schematic (each amplifier)**



All component values shown are nominal.

# TYPES NE5532, NE5532A

## DUAL LOW-NOISE OPERATIONAL AMPLIFIERS

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC+}$ (see Note 1) . . . . .	22 V
Supply voltage, $V_{CC-}$ (see Note 1) . . . . .	- 22 V
Input voltage, either input (see Notes 1 and 2) . . . . .	$V_{CC} \pm$
Input current (see Note 3) . . . . .	$\pm 10$ mA
Duration of output short-circuit (see Note 4) . . . . .	unlimited
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5):	
JG package . . . . .	825 mW
P package . . . . .	725 mW
Operating free-air temperature range: NE5532, NE5532A . . . . .	0°C to 70°C
Storage temperature range . . . . .	- 65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package . . . . .	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: P package . . . . .	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. The magnitude of the input voltage must never exceed the magnitude of the supply voltage.
3. Excessive input current will flow if a differential input voltage in excess of approximately 0.6 V is applied between the inputs unless some limiting resistance is used.
4. The output may be shorted to ground or either power supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.
5. For operation above 25°C free-air temperature, refer to the Dissipation Derating Curves in Section 2. In the JG package, chips are glass-mounted.

# TYPES NE5532, NE5532A DUAL LOW-NOISE OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		NE5532, NE5532A			UNIT
			MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0$	$T_A = 25^\circ\text{C}$ $T_A = 0^\circ\text{C to } 70^\circ\text{C}$	0.5 4 5			mV
$I_{IO}$ Input offset current	$T_A = 25^\circ\text{C}$ $T_A = 0^\circ\text{C to } 70^\circ\text{C}$		10 150 200			nA
$I_{IB}$ Input bias current	$T_A = 25^\circ\text{C}$ $T_A = 0^\circ\text{C to } 70^\circ\text{C}$		200 800 1000			nA
$V_{ICR}$ Common-mode input voltage range			$\pm 12$	$\pm 13$		V
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L \geq 600\ \Omega$	$V_{CC\pm} = \pm 15\text{ V}$ $V_{CC\pm} = \pm 18\text{ V}$	24 30	26 32		V
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 600\ \Omega$ , $V_O = \pm 10\text{ V}$ $R_L \geq 2\text{ k}\Omega$ , $V_O = \pm 10\text{ V}$	$T_A = 25^\circ\text{C}$ $T_A = 0^\circ\text{C to } 70^\circ\text{C}$	15 50 10			V/mV
		$T_A = 25^\circ\text{C}$	25 100			
		$T_A = 0^\circ\text{C to } 70^\circ\text{C}$	15			
$A_{vd}$ Small-signal differential voltage amplification	$f = 10\text{ kHz}$		2.2			V/mV
$B_{OM}$ Maximum output-swing bandwidth	$R_L = 600\ \Omega$ , $R_L = 600\ \Omega$	$V_O = \pm 10\text{ V}$ $V_{CC\pm} = \pm 18\text{ V}, V_O = \pm 14\text{ V}$	140 100			kHz
	$R_L = 600\ \Omega$	$C_L = 100\text{ pF}$	10			
$B_1$ Unity-gain bandwidth	$R_L = 600\ \Omega$ , $C_L = 100\text{ pF}$		10			MHz
$r_i$ Input resistance			30	300		k $\Omega$
$z_o$ Output impedance	$A_{VD} = 30\text{ dB}$ , $R_L = 600\ \Omega$ , $f = 10\text{ kHz}$		0.3			$\Omega$
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR\text{ min}}$		70	100		dB
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ )	$V_{CC\pm} = \pm 9\text{ V to } \pm 15\text{ V}$ , $V_O = 0$		80	100		dB
$I_{OS}$ Output short-circuit current			38			mA
$I_{CC}$ Total supply current	No load,	$V_O = 0$	8 16			mA
$V_{O1}/V_{O2}$ Crosstalk attenuation	$V_{O1} = 10\text{ V peak}$ , $f = 1\text{ kHz}$		110			dB

†All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

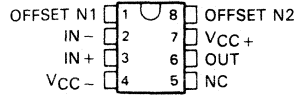
PARAMETER	TEST CONDITIONS	NE5532			NE5532A			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
SR Slew rate at unity gain		9						V/ $\mu\text{s}$
Overshoot factor	$V_I = 100\text{ mV}$ , $R_L = 600\ \Omega$ , $A_{VD} = 1$ , $C_L = 100\text{ pF}$	10%			10%			
$V_n$ Equivalent input noise voltage	$f = 30\text{ Hz}$	8			8	10		nV/ $\sqrt{\text{Hz}}$
	$f = 1\text{ kHz}$	5			5	6		
$I_n$ Equivalent input noise current	$f = 30\text{ Hz}$	2.7			2.7			pA/ $\sqrt{\text{Hz}}$
	$f = 1\text{ kHz}$	0.7			0.7			

3  
Operational Amplifiers

**3** Operational Amplifiers

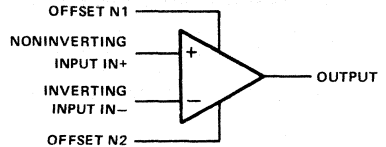
- Ultra-Low Offset Voltage . . . 30  $\mu\text{V}$  Typ (OP-07E)
- Ultra-Low Offset Voltage Temperature Coefficient . . . 0.3  $\mu\text{V}/^\circ\text{C}$  Typ (OP-07E)
- Ultra-Low Noise
- No External Components Required
- Replaces Chopper Amplifiers at a Lower Cost
- Single-Chip Monolithic Fabrication
- Wide Input Voltage Range  
0 to  $\pm 14$  V Typ
- Wide Supply Voltage Range  
 $\pm 3$  V to  $\pm 18$  V
- Essentially Equivalent to Fairchild  $\mu\text{A}714$  Operational Amplifiers
- Direct Replacement for PMI OP-07C, OP-07D, OP-07E

JG OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



NC—No internal connection

symbol

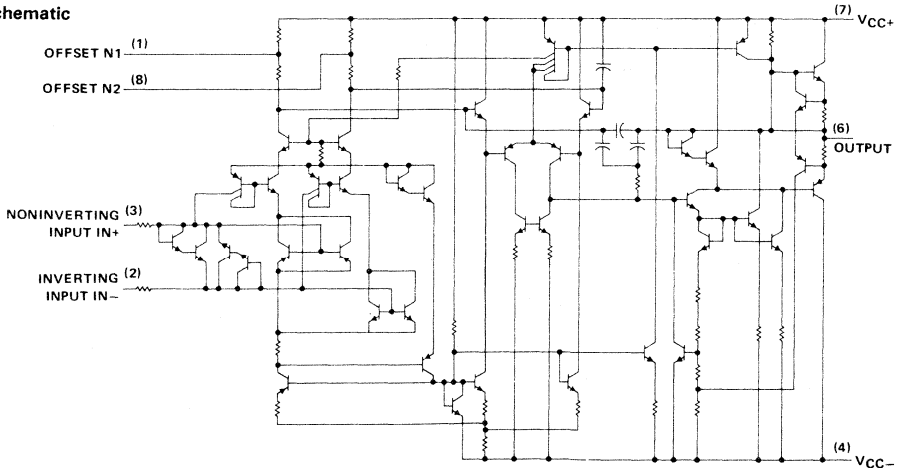


**description**

These devices represent a breakthrough in operational amplifier performance. Low offset and long-term stability are achieved by means of a low-noise, chopperless, bipolar-input-transistor amplifier circuit. For most applications, no external components are required for offset nulling and frequency compensation. The true differential input, with a wide input voltage range and outstanding common-mode rejection, provides maximum flexibility and performance in high-noise environments and in noninverting applications. Low bias currents and extremely high input impedances are maintained over the entire temperature range. The OP-07 is unsurpassed for low-noise, high-accuracy amplification of very-low-level signals.

These devices are characterized for operation from 0°C to 70°C.

**schematic**



# TYPES OP-07C, OP-07D, OP-07E

## ULTRA-LOW-OFFSET VOLTAGE OPERATIONAL AMPLIFIERS

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage $V_{CC+}$ (see Note 1)	22 V
Supply voltage $V_{CC-}$	-22 V
Differential input voltage (see Note 2)	$\pm 30$ V
Input voltage (either input, see Note 3)	$\pm 22$ V
Duration of output short circuit (see Note 4)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)	500 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: P package	260°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves in Section 2. In the JG package, these chips are glass-mounted.

# TYPES OP-07C, OP-07D, OP-07E ULTRA-LOW-OFFSET VOLTAGE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC} = \pm 15\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>1</sup>	OP-7C			OP-7D			OP-7E			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0$ , $R_S = 50\ \Omega$	25°C	60	150	80	150	30	75			$\mu\text{V}$
Temperature coefficient of input offset voltage	$V_O = 0$ , $R_S = 50\ \Omega$	0°C to 70°C	85	250	85	250	45	130			$\mu\text{V}/^\circ\text{C}$
$\alpha_{VIO}$ Long-term drift of input offset voltage	See Note 6	0°C to 70°C	0.5	1.8	0.7	2.5	0.3	1.3			$\mu\text{V}/^\circ\text{C}$
Input offset voltage			0.4		0.5		0.3				$\mu\text{V}/\text{mo}$
Offset adjustment range	$R_S = 20\ \text{k}\Omega$ . See Figure 1	25°C	$\pm 4$		$\pm 4$		$\pm 4$				mV
Input offset current		25°C	0.8	6	0.8	6	0.5	3.8			nA
Temperature coefficient of input offset current		0°C to 70°C	1.6	8	1.6	8	0.9	5.3			$\text{pA}/^\circ\text{C}$
$I_{IB}$ Input bias current		0°C to 70°C	12	50	12	50	8	35			$\text{pA}/^\circ\text{C}$
Temperature coefficient of input bias current		25°C	$\pm 1.8$	$\pm 7$	$\pm 2$	$\pm 12$	$\pm 1.2$	$\pm 4$			nA
Common-mode input voltage range		0°C to 70°C	$\pm 2.2$	$\pm 9$	$\pm 3$	$\pm 14$	$\pm 1.5$	$\pm 5.5$			$\text{pA}/^\circ\text{C}$
$V_{ICR}$ Common-mode input voltage range		0°C to 70°C	18	50	18	50	13	35			$\text{pA}/^\circ\text{C}$
$V_{OM}$ Peak output voltage	$R_L \geq 10\ \text{k}\Omega$ $R_L \geq 2\ \text{k}\Omega$ $R_L \geq 1\ \text{k}\Omega$ $R_L \geq 2\ \text{k}\Omega$	25°C	$\pm 13$	$\pm 14$	$\pm 13$	$\pm 14$	$\pm 13$	$\pm 14$			V
Large-signal differential voltage amplification	$V_{CC\pm} = \pm 3\text{ V}$ , $V_O = \pm 0.5\text{ V}$ , $R_L \geq 500\ \text{k}\Omega$	0°C to 70°C	$\pm 13$	$\pm 13.5$	$\pm 13$	$\pm 13.5$	$\pm 13$	$\pm 13.5$			V
$A_{VD}$ Unity gain bandwidth	$V_O = \pm 10\text{ V}$ , $R_L = 2\ \text{k}\Omega$	25°C	$\pm 12$	$\pm 13$	$\pm 12$	$\pm 13$	$\pm 12.5$	$\pm 13$			V
$B_1$ Input resistance		25°C	$\pm 11.5$	$\pm 12.8$	$\pm 11.5$	$\pm 12.8$	$\pm 12$	$\pm 12.8$			V
Common-mode rejection ratio		0°C to 70°C	$\pm 12$		$\pm 12$		$\pm 10.5$	$\pm 12$			V
Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$V_{IC} = \pm 13\text{ V}$ , $R_S = 50\ \Omega$	25°C	$\pm 11$	$\pm 12.6$	$\pm 11$	$\pm 12.6$	$\pm 12$	$\pm 12.6$			V
Power dissipation	$V_{CC\pm} = \pm 3\text{ V}$ , $V_O = 0$ , No load	25°C	100	400	400	400	150	400			V/mV
		25°C	120	400	120	400	200	500			V/mV
		0°C to 70°C	100	400	100	400	180	450			MHz
		25°C	0.4	0.6	0.4	0.6	0.4	0.6			MHz
		25°C	8	33	7	31	15	50			dB
		0°C to 70°C	97	120	94	106	103	123			dB
		25°C	7	32	7	32	5	20			A/VV
		0°C to 70°C	10	51	10	51	7	32			A/VV
		25°C	80	150	80	150	75	120			mW
		25°C	4	8	4	8	4	6			mW

<sup>1</sup>All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise noted.  
NOTE 6: Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the averaged trend line of drift versus time over extended periods after the first thirty days of operation.

# TYPES OP-07C, OP-07D, OP-07E

## ULTRA-LOW-OFFSET VOLTAGE OPERATIONAL AMPLIFIERS

operating characteristics at specified free-air temperature,  $V_{CC\pm} = \pm 15\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	OP-7C		OP-7D		OP-7E		UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX		MIN
$V_n$ Equivalent input noise voltage	$T_A = 25^\circ\text{C}$	$f = 10\text{ Hz}$	10.5	20	10.5	20	10.3	18	$\text{nV}/\sqrt{\text{Hz}}$
		$f = 100\text{ Hz}$	10.2	13.5	10.3	13.5	10.0	13	
		$f = 1\text{ kHz}$	9.8	11.5	9.8	11.5	9.6	11	
$V_{NPP}$ Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }10\text{ Hz},$ $T_A = 25^\circ\text{C}$	0.38	0.65	0.38	0.65	0.35	0.6	$\mu\text{V}$	
$I_n$ Equivalent input noise current	$T_A = 25^\circ\text{C}$	$f = 10\text{ Hz}$	0.35	0.9	0.35	0.9	0.32	0.8	$\text{pA}/\sqrt{\text{Hz}}$
		$f = 100\text{ Hz}$	0.15	0.27	0.15	0.27	0.14	0.23	
		$f = 1\text{ kHz}$	0.13	0.18	0.13	0.18	0.12	0.17	
$I_{NPP}$ Peak-to-peak equivalent input noise current	$f = 0.1\text{ Hz to }10\text{ Hz},$ $T_A = 25^\circ\text{C}$	15	35	15	35	14	30	$\text{pA}$	
SR Slew rate	$R_L \geq 2\text{ k}\Omega, T_A = 25^\circ\text{C}$	0.1	0.3	0.1	0.3	0.1	0.3	$\text{V}/\mu\text{s}$	

†All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

### TYPICAL APPLICATION DATA

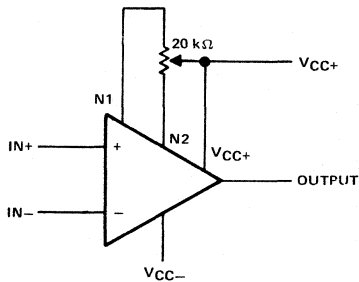


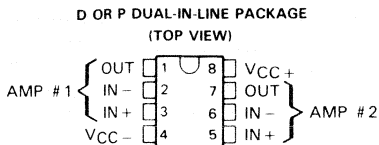
FIGURE 1—INPUT OFFSET VOLTAGE NULL CIRCUIT

3

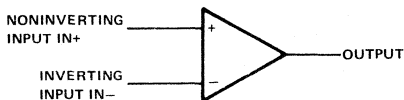
Operational Amplifiers



- Matched Gain and Offset Between Amplifiers
- Unity-Gain Bandwidth . . . 3 MHz Min
- Slew Rate . . . 1.5 V/ns Min
- Low Equivalent Input Noise Voltage  
. . . 2  $\mu\text{V}/\sqrt{\text{Hz}}$  Max (20 Hz to 20 kHz)
- No Frequency Compensation Required
- No Latch Up
- Wide Common-Mode Voltage Range
- Low Power Consumption
- Designed to be Interchangeable with Raytheon RC4559



symbol (each amplifier)



**description**

The RC4559 is a dual high-performance operational amplifier. The high common-mode input voltage and the absence of latch-up make this amplifier ideal for low-noise signal applications such as audio preamplifiers and signal conditioners. This amplifier features a guaranteed dynamic performance and output drive capability that far exceeds that of the general-purpose type amplifiers.

The RC4559 is characterized for operation from 0°C to 70°C.

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage $V_{CC+}$ (see Note 1)	18 V
Supply voltage $V_{CC-}$ (see Note 1)	-18 V
Differential input voltage (see Note 2)	$\pm 30$ V
Input voltage (any input, see Notes 1 and 3)	$\pm 15$ V
Duration of output short-circuit to ground, one amplifier at a time (see Note 4)	unlimited
Continuous total dissipation	500 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 125°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the zero reference level (ground) of the supply voltages where the zero reference level is the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

# TYPE RC4559

## DUAL HIGH-PERFORMANCE OPERATIONAL AMPLIFIER

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
$V_{IO}$	Input offset voltage	$V_O = 0$	25°C	2	6	mV	
			0°C to 70°C	7.5			
$I_{IO}$	Input offset current	$V_O = 0$	25°C	5	100	nA	
			0°C to 70°C	200			
$I_{IB}$	Input bias current	$V_O = 0$	25°C	40	250	nA	
			0°C to 70°C	500			
$V_I$	Input voltage range		25°C	±12	±13	V	
$V_{OM}$	Maximum peak output voltage swing	$R_L \geq 3\text{ k}\Omega$	25°C	±12	±13	V	
		$R_L = 600\ \Omega$	25°C	±9.5	±10		
		$R_L \geq 2\text{ k}\Omega$	0°C to 70°C	±10			
$A_{VD}$	Large-signal differential voltage amplification	$V_O = \pm 10\text{ V}$ , $R_L = 2\text{ k}\Omega$	25°C	20	300	V/mV	
			0°C to 70°C	15			
$B_{OM}$	Maximum output-swing bandwidth	$V_{OPP} = 20\text{ V}$ , $R_L = 2\text{ k}\Omega$	25°C	24	32	kHz	
$B_1$	Unity-gain bandwidth		25°C	3	4	MHz	
$r_i$	Input resistance		25°C	0.3	1	M $\Omega$	
$CMRR$	Common-mode rejection ratio	$V_O = 0$	25°C	80	100	dB	
$k_{SVS}$	Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$V_O = 0$	25°C	10	75	$\mu\text{V/V}$	
$V_n$	Equivalent input noise voltage (closed-loop)	$A_{VD} = 100$ , $R_S = 1\text{ k}\Omega$ , $f = 20\text{ Hz to } 20\text{ kHz}$	25°C	1.4	2	$\mu\text{V}$	
$I_n$	Equivalent input noise current	$f = 20\text{ Hz to } 20\text{ kHz}$	25°C	25		pA	
$I_{CC}$	Supply current (both amplifiers)	No load, No signal	25°C	3.3	5.6	mA	
			0°C	4	6.6		
			70°C	3	5		
$V_{O1}/V_{O2}$	Crosstalk attenuation	$A_{VD} = 100$ , $R_S = 1\text{ k}\Omega$ , $f = 10\text{ kHz}$	25°C	90		dB	
			25°C	90			

†All characteristics are specified under open-loop operation, unless otherwise noted.

matching characteristics at  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{IO}$	Input offset voltage	$V_O = 0$		±0.2		mV
$I_{IO}$	Input offset current	$V_O = 0$		±7.5		nA
$I_{IB}$	Input bias current	$V_O = 0$		±15		nA
$A_{VD}$	Large-signal differential voltage amplification	$V_O = \pm 10\text{ V}$ , $R_L = 2\text{ k}\Omega$		±1		dB

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_r$	Rise time	$V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$ ,		80		$\mu\text{s}$
	Overshoot	$C_L = 100\text{ pF}$		18%		
SR	Slew rate at unity gain	$V_I = 10\text{ V}$ , $C_L = 100\text{ pF}$	1.5	2		V/ $\mu\text{s}$

- Continuous-Short-Circuit Protection
- Wide Common-Mode and Differential Voltage Ranges
- No Frequency Compensation Required
- Low Power Consumption
- No Latch-Up
- Unity Gain Bandwidth 3 MHz Typical
- Gain and Phase Match Between Amplifiers
- Designed to be Interchangeable with Raytheon RM4136, RV4136, and RC4136
- Low Noise . . . 8 nV/ $\sqrt{\text{Hz}}$  Typ at 1 kHz

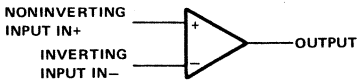
**description**

The RM4136, RV4136, and RC4136 are quad high-performance operational amplifiers with each amplifier electrically similar to uA741 except that offset null capability is not provided.

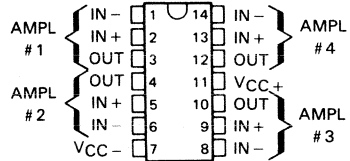
The high common-mode input voltage range and the absence of latch-up make these amplifiers ideal for voltage-follower applications. The devices are short-circuit protected and the internal frequency compensation ensures stability without external components.

The RM4136 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the RV4136 is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the RC4136 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

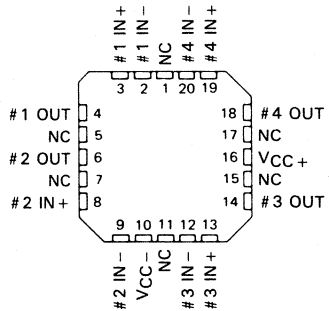
**symbol (each amplifier)**



**D, J, OR N DUAL-IN-LINE  
OR W FLAT PACKAGE  
(TOP VIEW)**



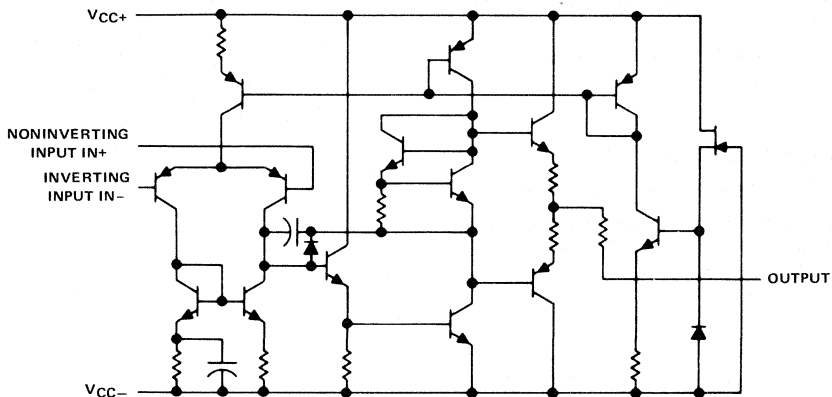
**RM4136  
FH OR FK CHIP CARRIER PACKAGE  
(TOP VIEW)**



NC—No internal connection

# TYPES RM4136, RV4136, RC4136 QUAD HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

schematic (each amplifier)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		RM4136	RV4136	RC4136	UNIT
Supply voltage $V_{CC+}$ (see Note 1)		22	18	18	V
Supply voltage $V_{CC-}$ (see Note 1)		-22	-18	-18	V
Differential input voltage (see Note 2)		$\pm 30$	$\pm 30$	$\pm 30$	V
Input voltage (any input, see Notes 1 and 3)		$\pm 15$	$\pm 15$	$\pm 15$	V
Duration of output short-circuit to ground, one amplifier at a time (see Note 4)		unlimited	unlimited	unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)		800	800	800	mW
Operating free-air temperature range		-55 to 125	-40 to 85	0 to 70	°C
Storage temperature range		-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	FH, FK, J, or W package	300	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or N package		260	260	

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.
5. For operation above 25°C free-air temperature, refer to Dissipation Defating Curves, Section 2. In the J package, RM4136 chips are alloy-mounted; RV4136 and RC4136 chips are glass-mounted.

# TYPES RM4136, RV4136, RC4136 QUAD HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

**electrical characteristics at specified free-air temperature,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$**

PARAMETER	TEST CONDITIONS †	RM4136			RV4136			RC4136			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0$	25°C	0.5	4	0.5	6	0.5	6	mV		
		Full range		6	7.5	7.5					
$I_{IO}$ Input offset current	$V_O = 0$	25°C	5	150	5	200	5	200	nA		
		Full range		500	500	300					
$I_{IB}$ Input bias current	$V_O = 0$	25°C	140	400	140	500	140	500	nA		
		Full range		1500	1500	800					
$V_i$ Input voltage range	25°C	±12	±14	±12	±14	±12	±14	V			
$V_{OM}$ Maximum peak output voltage swing	$R_L = 10\text{ k}\Omega$	25°C	±12	±14	±12	±14	±12	±14	V		
	$R_L = 2\text{ k}\Omega$	25°C	±10	±13	±10	±13	±10	±13			
	$R_L \geq 2\text{ k}\Omega$	Full range	±10		±10		±10				
$A_{VD}$ Large-signal differential voltage amplification	$V_O = \pm 10\text{ V}$ , $R_L \geq 2\text{ k}\Omega$	25°C	50	350	20	300	20	300	V/mV		
		Full range	25		15		15				
$B_1$ Unity-gain bandwidth	25°C	3.5		3		3		MHz			
$r_i$ Input resistance	25°C	0.3	5	0.3	5	0.3	5	M $\Omega$			
CMRR Common-mode rejection ratio	$V_O = 0$ , $R_S = 50\text{ }\Omega$	25°C	70	90	70	90	70	90	dB		
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$V_{CC} = \pm 9\text{ V}$ to $\pm 15\text{ V}$ , $V_O = 0$	25°C	30	150	30	150	30	150	$\mu\text{V/V}$		
$V_n$ Equivalent input noise voltage (closed-loop)	$A_{VD} = 100$ , BW = 1 Hz, f = 1 kHz, $R_S = 100\text{ }\Omega$	25°C	8		8		8		$n\text{V}/\sqrt{\text{Hz}}$		
$I_{CC}$ Supply current (All four amplifiers)	$V_O = 0$ , No load	25°C	5	11.3	5	11.3	5	11.3	mA		
		MIN $T_A$	6	13.3	6	13.7	6	13.7			
		MAX $T_A$	4.5	10	4.5	10	4.5	10			
$P_D$ Total power dissipation (All four amplifiers)	$V_O = 0$ , No load	25°C	150	340	150	340	150	340	mW		
		MIN $T_A$	180	400	180	400	180	400			
		MAX $T_A$	135	300	135	300	135	300			
$V_{O1}/V_{O2}$ Crosstalk attenuation	$A_{VD} = 100$ , f = 10 kHz, $R_S = 1\text{ k}\Omega$	25°C	105		105		105		dB		

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for RM4136,  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for RV4136, and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for RC4136.

**operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$**

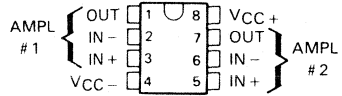
PARAMETER	TEST CONDITIONS	RM4136			RV4136, RC4136			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$ Rise Time	$V_i = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$		0.13		0.13			$\mu\text{s}$
		Overshoot factor		5%		5%		
SR Slew rate at unity gain	$V_i = 10\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$		1.7		1.7		V/ $\mu\text{s}$	

**Operational Amplifiers**

## **3** Operational Amplifiers

- Continuous-Short-Circuit Protection
- Wide Common-Mode and Differential Voltage Ranges
- No Frequency Compensation Required
- Low Power Consumption
- No Latch-up
- Unity Gain Bandwidth 3 MHz Typical
- Gain and Phase Match Between Amplifiers
- Low Noise . . . 8 nV/ $\sqrt{\text{Hz}}$  Typ at 1 kHz
- Designed to be Interchangeable with Raytheon RM4558, RV4558, and RC4558

D, JG, OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



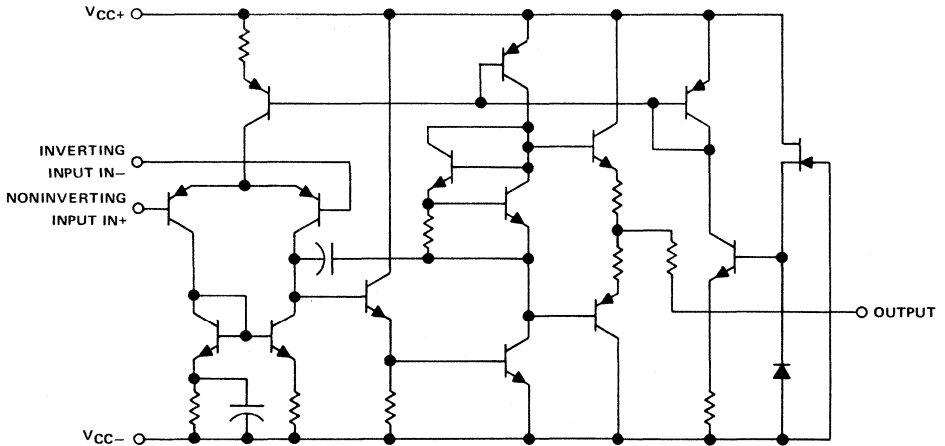
**description**

The RM4558, RV4558, and RC4558 are dual general-purpose operational amplifiers with each half electrically similar to uA741 except that offset null capability is not provided.

The high common-mode input voltage range and the absence of latch-up make these amplifiers ideal for voltage-follower applications. The devices are short-circuit protected and the internal frequency compensation ensures stability without external components.

The RM4558 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the RV4558 is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ ; and the RC4558 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**schematic (each amplifier)**



# TYPES RM4558, RV4558, RC4558

## DUAL HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	RM4558	RV4558	RC4558	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	22	18	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-22	-18	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	$\pm 30$	V
Input voltage (any input, see Notes 1 and 3)	$\pm 15$	$\pm 15$	$\pm 15$	V
Duration of output short-circuit to ground, one amplifier at a time (see Note 4)	unlimited	unlimited	unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)	680	680	680	mW
Operating free-air temperature range	55 to 125	40 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	JG package	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or P package	260	260	°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the JG packages, RM4558 chips are alloy mounted; RV4558 and RC4558 chips are glass mounted.

3

Operational Amplifiers



**TYPES RM4558, RV4558, RC4558**  
**DUAL HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS**

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$

PARAMETER	TEST CONDITIONS <sup>†</sup>	RM4558			RV4558			RC4558			UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$	Input offset voltage $V_O = 0$		0.5	5	6	0.5	5	6	0.5	6	mV	
$I_{IO}$	Input offset current $V_O = 0$	Full range			7.5			7.5				
		25°C	5	200	5	200	5	200	5	200	nA	
$I_{IB}$	Input bias current $V_O = 0$	Full range			500			500				
		25°C	140	500	140	500	150	500	150	500	nA	
$V_{ICR}$	Common-mode input voltage range	Full range			1500			1500				
		25°C	$\pm 12$	$\pm 14$	$\pm 12$	$\pm 14$	$\pm 12$	$\pm 14$	$\pm 12$	$\pm 14$	V	
VOM	Maximum output voltage swing	25°C	$R_L = 10\text{ k}\Omega$	$\pm 12$	$\pm 14$	$\pm 12$	$\pm 14$	$\pm 12$	$\pm 14$	$\pm 12$	$\pm 14$	V
		25°C	$R_L = 2\text{ k}\Omega$	$\pm 10$	$\pm 13$	$\pm 10$	$\pm 13$	$\pm 10$	$\pm 13$	$\pm 10$	$\pm 13$	
		Full range	$R_L \geq 2\text{ k}\Omega$	$\pm 10$		$\pm 10$		$\pm 10$		$\pm 10$		
AVD	Large-signal differential voltage amplification	25°C	$R_L \geq 2\text{ k}\Omega$	50	350	20	300	20	300	20	300	V/mV
		Full range	$V_O = \pm 10\text{ V}$	25		15		15		15		
$B_1$	Unity-gain bandwidth	25°C		2	3.5		3		3		MHz	
$r_i$	Input resistance	25°C		0.3	5		0.3	5		0.3	5	M $\Omega$
CMRR	Common-mode rejection ratio	25°C		70	90		70	90		70	90	dB
kSVS	Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	25°C		30	150		30	150		30	150	$\mu\text{V/V}$
		$V_{CC} = \pm 15\text{ V}$ to $\pm 9\text{ V}$										
$V_n$	Equivalent input noise voltage (closed-loop)	25°C	$A_{VD} = 100$ , $R_S = 100\ \Omega$ , $f = 1\text{ kHz}$ , $BW = 1\text{ Hz}$			8			8			$\text{nV}/\sqrt{\text{Hz}}$
		No load, $V_O = 0$		2.5	5.6	2.5	5.6	2.5	5.6	2.5	5.6	
$I_{CC}$	Supply current (Both amplifiers)	MIN TA		3	6.6		3	6.6		3	6.6	mA
		MAX TA		2	5		2.3	5		2.3	5	
PD	Total power dissipation (Both amplifiers)	25°C		75	170		75	170		75	170	mW
		MIN TA		90	200		90	200		90	200	
$V_O/V_{O2}$	Crosstalk attenuation	MAX TA		60	150		70	150		70	150	dB
		25°C		85		85		85		85		
	Open loop			105		105		105		105		
	$A_{VD} = 100$											

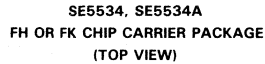
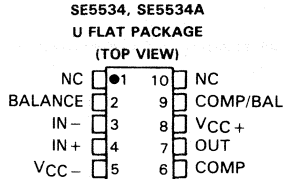
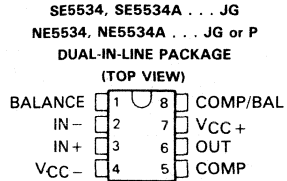
<sup>†</sup> All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for RM4558,  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for RV4558, and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for RC4558.

**TYPES RM4558, RV4558, RC4558  
DUAL HIGH-PERFORMANCE OPERATIONAL AMPLIFIERS**

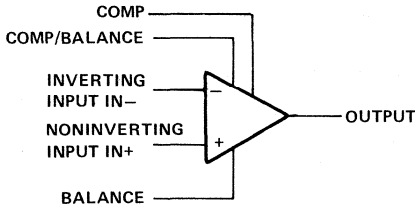
operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	RM4558			RV4558			RC4558			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$ Rise time	$V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$	0.13			0.13			0.13			ns
Overshoot	$C_L = 100\text{ pF}$	5%			5%			5%			
SR Slew rate at unity gain	$V_I = 10\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$	1.3	1.7		1.3	1.7		1.3	1.7		$\text{V}/\mu\text{s}$

- Equivalent Input Noise Voltage  
3.5 nV/ $\sqrt{\text{Hz}}$  Typ
- Unity-Gain Bandwidth . . . . . 10 MHz Typ
- Common-Mode Rejection Ratio  
100 dB Typ
- High DC Voltage Gain . . . . . 100 V/mV Typ
- Peak-to-Peak Output Voltage Swing  
32 V Typ with  $V_{CC\pm} = \pm 18$  V and  
 $R_L = 600 \Omega$
- High Slew Rate . . . . . 13 V/ $\mu\text{s}$  Typ
- Wide Supply Voltage Range  
 $\pm 3$  V to  $\pm 20$  V
- Low Harmonic Distortion
- Designed to be Interchangeable with Signetics  
SE5534, SE5534A, NE5534, and NE5534A



symbol



**description**

The SE5534, SE5534A, NE5534, and NE5534A are monolithic high-performance operational amplifiers combining excellent dc and ac characteristics. Some of the features include very low noise, high output drive capability, high unity-gain and maximum-output-swing bandwidths, low distortion, and high slew rate.

These operational amplifiers are internally compensated for a gain equal to or greater than three. Optimization of the frequency response for various applications can be obtained by use of an external compensation capacitor between COMP and COMP/BAL. The devices feature input-protection diodes, output short-circuit protection, and offset-voltage nulling capability.

The SE5534A and NE5534A have guaranteed maximums on equivalent input noise voltage.

The SE5534 and SE5534A are characterized for operation over the full military temperature range of  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ ; the NE5534 and NE5534A are characterized for operation from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

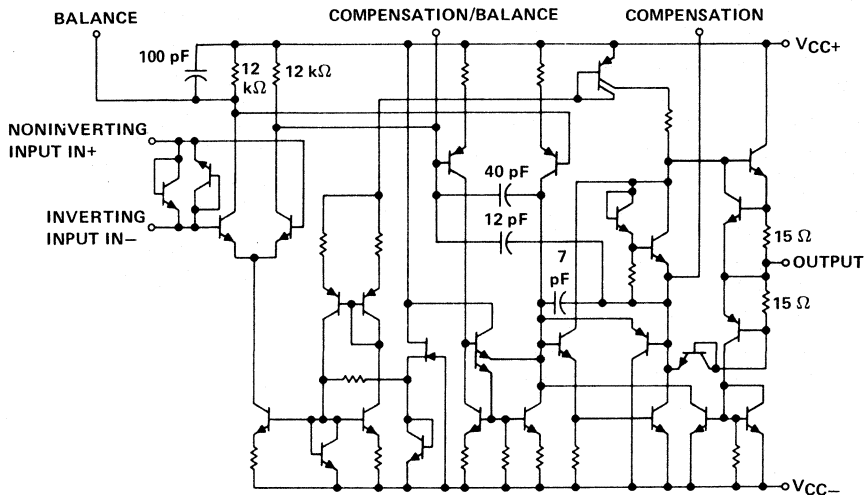
**Operational Amplifiers**

NC—No internal connection

# TYPES SE5534, SE5534A, NE5534, NE5534A

## LOW-NOISE OPERATIONAL AMPLIFIERS

schematic



All component values shown are nominal.

### absolute maximum ratings over operating free-air temperature (unless otherwise noted)

Supply voltage, $V_{CC+}$ (see Note 1)	22 V
Supply voltage, $V_{CC-}$ (see Note 1)	-22 V
Input voltage either input (see Notes 1 and 2)	$V_{CC+}$
Input current (see Note 3)	$\pm 10$ mA
Duration of output short-circuit (see Note 4)	unlimited
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5)	
FH package (see Note 6)	1200 mW
FK package (see Note 6)	1375 mW
SE5534, SE5534A in JG package	1050 mW
NE5534, NE5534A in JG package	825 mW
P package	725 mW
U package	675 mW
Operating free-air temperature range: SE5534, SE5534A	-55°C to 125°C
NE5534, NE5534A	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: FH, FK, JG, or U package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: P package	260°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .

2. The magnitude of the input voltage must never exceed the magnitude of the supply voltage.

3. Excessive current will flow if a differential input voltage in excess of approximately 0.6 V is applied between the inputs unless some limiting resistance is used.

4. The output may be shorted to ground or either power supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.

5. For operation above 25°C free-air temperature, refer to the Dissipation Derating Curves, Section 2. In the JG package, SE5534 and SE5534A chips are alloy-mounted; NE5534 and NE5534A chips are glass-mounted.

6. For FH and FK packages, power rating and derating factor will vary with actual mounting technique used. The values stated here are believed to be conservative.

# TYPES SE5534, SE5534A, NE5534, NE5534A LOW-NOISE OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC} \pm = \pm 15 \text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		SE5534, SE5534A			NE5534, NE5534A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0$ , $R_S = 50 \Omega$	$T_A = 25^\circ\text{C}$	0.5	2		0.5	4	mV	
		$T_A = \text{full range}$		3			5		
$I_{IO}$ Input offset current	$V_O = 0$	$T_A = 25^\circ\text{C}$	10	200		20	300	nA	
		$T_A = \text{full range}$		500			400		
$I_{IB}$ Input bias current	$V_O = 0$	$T_A = 25^\circ\text{C}$	400	800		500	1500	nA	
		$T_A = \text{full range}$		1500			2000		
$V_{ICR}$ Common-mode input voltage range			$\pm 12$	$\pm 13$		$\pm 12$	$\pm 13$	V	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L \geq 600 \Omega$	$V_{CC\pm} = \pm 15 \text{ V}$	24	26		24	26	V	
		$V_{CC\pm} = \pm 18 \text{ V}$	30	32		30	32		
$A_{VD}$ Large-signal differential voltage amplification	$V_O = \pm 10 \text{ V}$ , $R_L \geq 600 \Omega$	$T_A = 25^\circ\text{C}$	50	100		25	100	V/mV	
		$T_A = \text{full range}$	25			15			
$A_{vd}$ Small-signal differential voltage amplification	$f = 10 \text{ kHz}$	$C_C = 0$		6			6	V/mV	
		$C_C = 22 \text{ pF}$		2.2			2.2		
$B_{OM}$ Maximum-output-swing bandwidth	$V_O = \pm 10 \text{ V}$ , $C_C = 0$			200			200	kHz	
		$V_O = \pm 10 \text{ V}$ , $C_C = 22 \text{ pF}$		95			95		
		$V_{CC\pm} = \pm 18 \text{ V}$ , $V_O = \pm 14 \text{ V}$ , $R_L = 600 \Omega$ , $C_C = 22 \text{ pF}$		70			70		
$B_1$ Unity-gain bandwidth	$C_C = 22 \text{ pF}$ , $C_L = 100 \text{ pF}$		10			10	MHz		
$r_i$ Input resistance			50	100		30	100	k $\Omega$	
$z_o$ Output impedance	$A_{VD} = 30 \text{ dB}$ , $C_C = 22 \text{ pF}$ , $f = 10 \text{ kHz}$	$R_L = 600 \Omega$	0.3			0.3		$\Omega$	
CMRR Common-mode rejection ratio	$V_O = 0$ , $R_S = 50 \Omega$	$V_{IC} = V_{ICR \text{ min.}}$	80	100		70	100	dB	
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{CC\pm} = \pm 9 \text{ V}$ to $\pm 15 \text{ V}$ , $V_O = 0$ , $R_S = 50 \Omega$		86	100		80	100	dB	
$I_{OS}$ Output short-circuit current			38			38		mA	
$I_{CC}$ Supply current	No load, $V_O = 0$	$T_A = 25^\circ\text{C}$	4	6.5		4	8	mA	
		$T_A = \text{full range}$		9					

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for  $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$  for SE5534 and SE5534A and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for NE5534 and NE5534A.

operating characteristics,  $V_{CC} \pm = \pm 15 \text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS		SE5534, NE5534			SE5534A, NE5534A			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
SR Slew rate at unity gain	$C_C = 0$ $C_C = 22 \text{ pF}$		13			13		V/ $\mu\text{s}$	
			6			6			
$t_r$ Rise time	$V_I = 50 \text{ mV}$ , $A_{VD} = 1$ , $R_L = 600 \Omega$ , $C_C = 22 \text{ pF}$ , $C_L = 100 \text{ pF}$		20			20		ns	
		overshoot factor	20%			20%			
$t_r$ Rise time	$V_I = 50 \text{ mV}$ , $A_{VD} = 1$ , $R_L = 600 \Omega$ , $C_C = 47 \text{ pF}$ , $C_L = 500 \text{ pF}$		50			50		ns	
		overshoot factor	35%			35%			
$V_n$ Equivalent input noise voltage	$f = 30 \text{ Hz}$ $f = 1 \text{ kHz}$		7			5.5	7	nV/ $\sqrt{\text{Hz}}$	
			4			3.5	4.5		
$I_n$ Equivalent input noise current	$f = 30 \text{ Hz}$ $f = 1 \text{ kHz}$		2.5			1.5		pA/ $\sqrt{\text{Hz}}$	
			0.6			0.4			
F Average noise figure	$R_S = 5 \text{ k}\Omega$ , $f = 10 \text{ Hz}$ to $20 \text{ kHz}$					0.9		dB	

# TYPES SE5534, SE5534A, NE5534, NE5534A

## LOW-NOISE OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS†

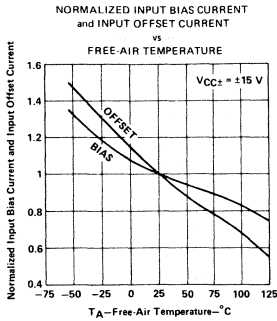


FIGURE 1

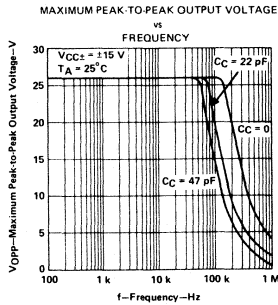


FIGURE 2

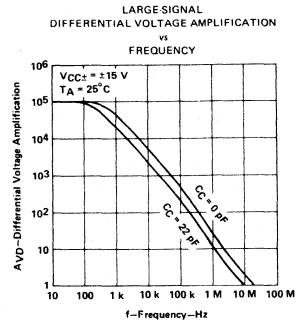


FIGURE 3

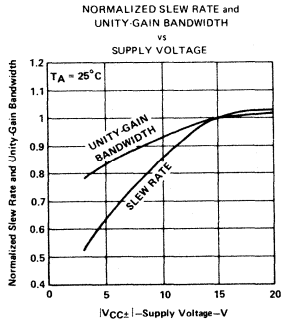


FIGURE 4

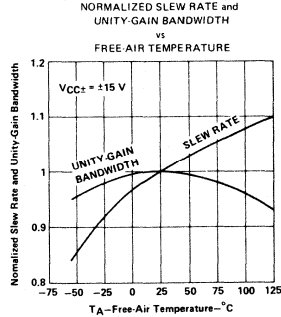


FIGURE 5

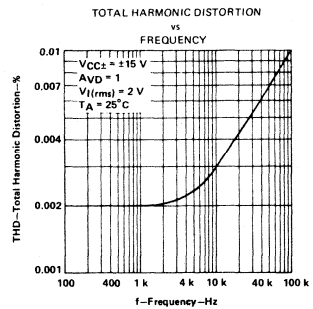


FIGURE 6

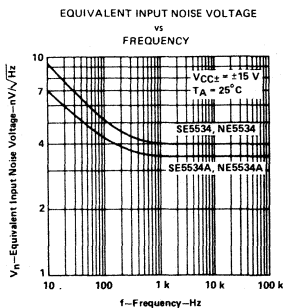


FIGURE 7

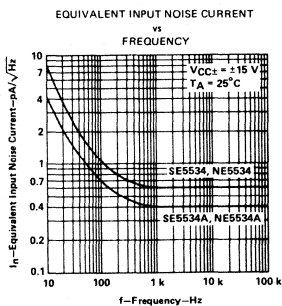


FIGURE 8

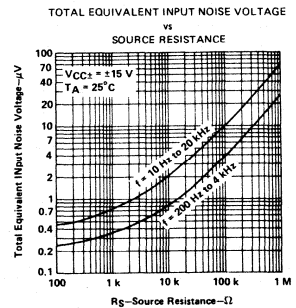


FIGURE 9

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

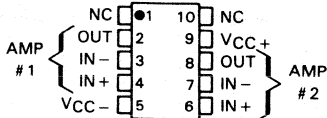
- Very Low Power Consumption
- Power Dissipation with  $\pm 2$ -V Supplies . . . 170  $\mu$ W Typ
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- Low Input Offset Voltage
- Internal Frequency Compensation
- Latch-Up-Free Operation
- Popular Dual Op-Amp Pin-Out

**description**

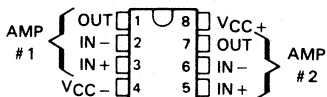
The TL022 is a dual low-power operational amplifier designed to replace higher power devices in many applications without sacrificing system performance. High input impedance, low supply currents, and low equivalent input noise voltage over a wide range of operating supply voltages result in an extremely versatile operational amplifier for use in a variety of analog applications including battery-operated circuits. Internal frequency compensation, absence of latch-up, high slew rate, and output short-circuit protection assure ease of use.

The TL022M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL022C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**TL022M . . . U FLAT PACKAGE  
(TOP VIEW)**

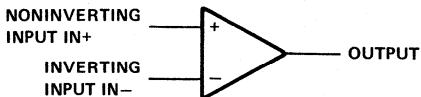


**TL022C . . . JG OR P  
DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



NC—No internal connection

**symbol (each amplifier)**



**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

		TL022M	TL022C	UNIT	
Supply voltage $V_{CC+}$ (see Note 1)		22	18	V	
Supply voltage $V_{CC-}$ (see Note 1)		-22	-18	V	
Differential input voltage (see Note 2)		$\pm 30$	$\pm 30$	V	
Input voltage (any input, see Notes 1 and 3)		$\pm 15$	$\pm 15$	V	
Duration of output short-circuit (see Note 4)		unlimited	unlimited		
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature range (see Note 5)	Each amplifier	500	500	mW	
	Total package	JG or P package	680		680
		U package	675		675
Operating free-air temperature range		$-55$ to $125$	$0$ to $70$	$^{\circ}\text{C}$	
Storage temperature range		$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$	
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds		JG or U package	300	$^{\circ}\text{C}$	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds		P package	260	$^{\circ}\text{C}$	

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply. For the TL022M only, the unlimited duration of the short-circuit applies at (or below)  $125^{\circ}\text{C}$  case temperature or  $75^{\circ}\text{C}$  free-air temperature.
5. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Curves in Section 2. In the JG package, TL022M chips are alloy-mounted; TL022C chips are glass-mounted.

# TYPES TL022M, TL022C

## DUAL LOW-POWER OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$

PARAMETER	TEST CONDITIONS†	TL022M			TL022C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0$ , $R_S = 50\ \Omega$	25°C	1	5	1	5		mV
		Full range			6	7.5		
$I_{IO}$ Input offset current	$V_O = 0$	25°C	5	40	15	80		nA
		Full range			100	200		
$I_{IB}$ Input bias current	$V_O = 0$	25°C	50	100	100	250		nA
		Full range			250	400		
$V_{ICR}$ Common-mode input voltage range		25°C	±12	±13	±12	±13		V
		Full range	±12		±12			
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L = 10\text{ k}\Omega$	25°C	20	26	20	26		V
	$R_L \geq 10\text{ k}\Omega$	Full range	20		20			
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 10\text{ k}\Omega$ , $V_O = \pm 10\text{ V}$	25°C	72	86	60	80		dB
		Full range	72		60			
$B_1$ Unity-gain bandwidth		25°C		0.5		0.5		MHz
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR}\text{ min.}$ , $R_S = 50\ \Omega$	25°C	60	72	60	72		dB
		Full range	60		60			
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$V_{CC} = \pm 9\text{ V to } \pm 15\text{ V}$ , $R_S = 50\ \Omega$	25°C	30	150	30	200		$\mu\text{V/V}$
		Full range			150	200		
$V_n$ Equivalent input noise voltage	$A_{VD} = 20\text{ dB}$ , $B = 1\text{ Hz}$ , $f = 1\text{ kHz}$	25°C		50		50		$\text{nV}/\sqrt{\text{Hz}}$
$I_{OS}$ Short-circuit output current		25°C		±6		±6		mA
$I_{CC}$ Supply current (both amplifiers)	No load, $V_O = 0$	25°C	130	200	130	250		$\mu\text{A}$
		Full range			200	250		
$P_D$ Total dissipation (both amplifiers)	No load, $V_O = 0$	25°C	3.9	6	3.9	7.5		mW
		Full range			6	7.5		

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for TL022M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for TL022C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL022M			TL022C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$ Rise time	$V_I = 20\text{ mV}$ , $R_L = 10\text{ k}\Omega$		0.3			0.3		$\mu\text{s}$
Overshoot factor	$C_L = 100\text{ pF}$ , See Figure 1		5%			5%		
SR Slew rate at unity gain	$V_I = 10\text{ V}$ , $C_L = 100\text{ pF}$ , See Figure 1		0.5			0.5		$\text{V}/\mu\text{s}$



# TYPES TL022M, TL022C DUAL LOW-POWER OPERATIONAL AMPLIFIERS

## PARAMETER MEASUREMENT INFORMATION

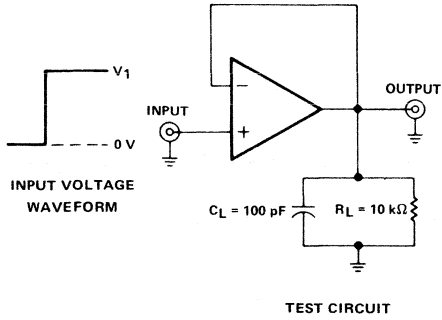


FIGURE 1—RISE TIME, OVERSHOOT FACTOR, AND SLEW RATE

## TYPICAL CHARACTERISTICS

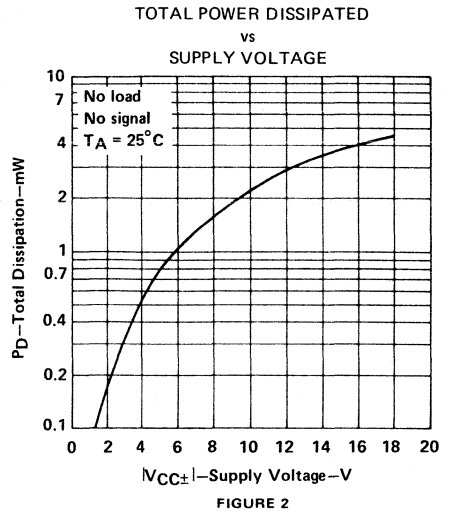
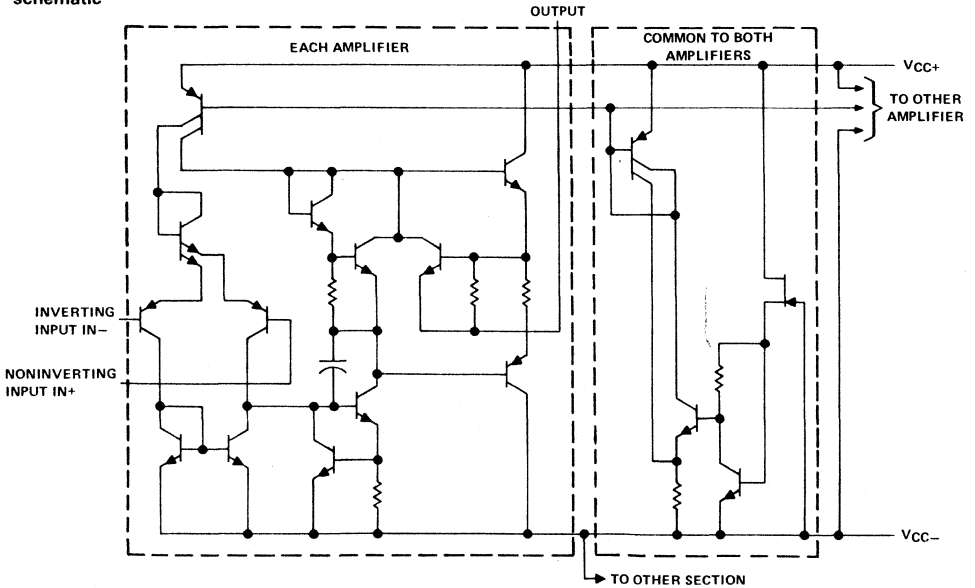


FIGURE 2

## schematic





**NOT RECOMMENDED  
FOR NEW DESIGN**  
For new design, see TL064

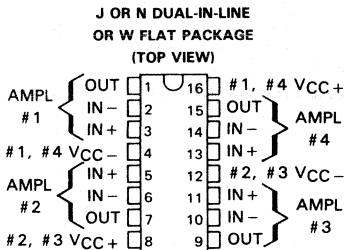
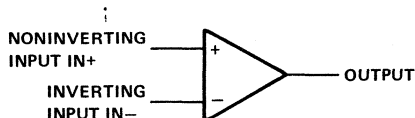
- Very Low Power Consumption
- Typical Power Dissipation with  $\pm 2$ -V Supplies . . . 340  $\mu$ W
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- Low Input Offset Voltage
- Internal Frequency Compensation
- Latch-Up-Free Operation
- Power Applied in Pairs

**description**

The TL044 is a quad low-power operational amplifier designed to replace higher-power devices in many applications without sacrificing system performance. High input impedance, low supply currents, and low equivalent input noise voltage over a wide range of operating supply voltages result in an extremely versatile operational amplifier for use in a variety of analog applications including battery-operated circuits. Internal frequency compensation, absence of latch-up, high slew rate, and output short-circuit protection assure ease of use. Power may be applied separately to Section A (amplifiers 1 and 4) or Section B (amplifiers 2 and 3) while the other pair remains unpowered.

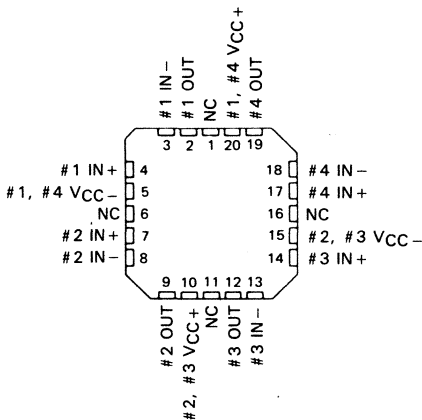
The TL044M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL044C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**symbol (each amplifier)**



Pins 4 and 12 are internally connected together in the N package only.

**TL044M . . . FH OR FK PACKAGE  
(TOP VIEW)**



NC—No internal connection

**Operational Amplifiers**

# TYPES TL044M, TL044C

## QUAD LOW-POWER OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		TL044M	TL044C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)		22	18	V
Supply voltage $V_{CC-}$ (see Note 1)		-22	-18	V
Differential input voltage (see Note 2)		$\pm 30$	$\pm 30$	V
Input voltage (any input, see Notes 1 and 3)		$\pm 15$	$\pm 15$	V
Duration of output short-circuit (see Note 4)		unlimited	unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature range (see Note 5)	Each amplifier	500	500	mW
	Total package	680	680	
Operating free-air temperature range		-55 to 125	0 to 70	°C
Storage temperature range		-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	FH, FK, J, or W package	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	N package		260	°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply. For the TL044M only, the unlimited duration of the short-circuit applies at (or below) 125°C case temperature or 85°C free-air temperature.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves in Section 2. In the J package, TL044M chips are alloy-mounted; TL044C chips are glass-mounted.

3

Operational Amplifiers

# TYPES TL044M, TL044C QUAD LOW-POWER OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$

PARAMETER	TEST CONDITIONS†	TL044M			TL044C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0$ , $R_S = 50\ \Omega$	25°C	1	5	1	5	mV	
		Full range		6		7.5		
$I_{IO}$ Input offset current	$V_O = 0$	25°C	5	40	15	80	nA	
		Full range		100		200		
$I_{IB}$ Input bias current	$V_O = 0$	25°C	50	100	100	250	nA	
		Full range		250		400		
$V_{ICR}$ Common-mode input voltage range		25°C	±12	±13	±12	±13	V	
		Full range	±12		±12			
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L = 10\ \text{k}\Omega$ $R_L \geq 10\ \text{k}\Omega$	25°C	20	26	20	26	V	
		Full range	20		20			
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 10\ \text{k}\Omega$ , $V_O = \pm 10\ \text{V}$	25°C	72	86	60	80	dB	
		Full range	72		60			
$B_1$ Unity-gain bandwidth		25°C		0.5		0.5	MHz	
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR\ min}$ , $V_O = 0$ , $R_S = 50\ \Omega$	25°C	60	72	60	72	dB	
		Full range	60		60			
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$V_{CC} = \pm 9\ \text{V}$ to $\pm 15\ \text{V}$ , $V_O = 0$ , $R_S = 50\ \Omega$	25°C		30	150	30	200	$\mu\text{V}/\text{V}$
		Full range			150		200	
$V_n$ Equivalent input noise voltage	$A_{VD} = 20\ \text{dB}$ , $B = 1\ \text{Hz}$ , $f = 1\ \text{kHz}$	25°C		50		50	$\text{nV}/\sqrt{\text{Hz}}$	
$I_{OS}$ Short-circuit output current		25°C		±6		±6	mA	
$I_{CC}$ Supply current (four amplifiers)	No load, $V_O = 0$	25°C	250	400	250	500	$\mu\text{A}$	
		Full range		400		500		
$P_D$ Total dissipation (four amplifiers)	No load, $V_O = 0$	25°C	7.5	12	7.5	15	mW	
		Full range		12		15		

† All characteristics are measured under open-loop conditions with zero common-mode input voltage, unless otherwise specified. Full range for TL044M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for TL044C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

operating characteristics,  $V_{CC+} = 15\ \text{V}$ ,  $V_{CC-} = -15\ \text{V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL044M			TL044C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$ Rise time	$V_I = 20\ \text{mV}$ , $C_L = 10\ \text{k}\Omega$		0.3			0.3	$\mu\text{s}$	
Overshoot factor	$C_L = 100\ \text{pF}$ , See Figure 1		5%			5%		
SR Slew rate at unity gain	$V_I = 10\ \text{V}$ , $C_L = 100\ \text{pF}$ , See Figure 1		0.5			0.5	$\text{V}/\mu\text{s}$	

3

Operational Amplifiers

## 3 Operational Amplifiers

**20 DEVICES COVER MILITARY, INDUSTRIAL, AND COMMERCIAL  
TEMPERATURE RANGES**

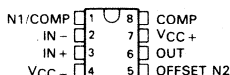
- Very Low Power Consumption
- Typical Supply Current . . . 200  $\mu$ A (per Amplifier)
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- High Input Impedance . . . JFET-Input Stage
- Internal Frequency Compensation (Except TL060)
- Latch-Up Free Operation
- High Slew Rate . . . . . 3.5 V/ $\mu$ s Typ

**description**

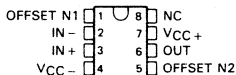
The JFET-input operational amplifiers of the TL061 series are designed as low-power versions of the TL081 series amplifiers. They feature high input impedance, wide bandwidth, high slew rate, and low input offset and bias currents. The TL061 series features the same terminal assignments as the TLO71 and TLO81 series. Each of these JFET-input operational amplifiers incorporates well-matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit.

Device types with an "M" suffix are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , those with an "I" suffix are characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and those with a "C" suffix are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

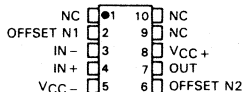
**TL060, TL060A, TL060B**  
D, JG, OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



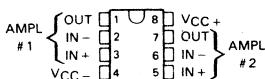
**TL061, TL061A, TL061B**  
D, JG, OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



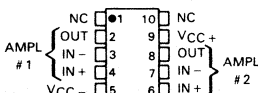
**TL061**  
U FLAT PACKAGE  
(TOP VIEW)



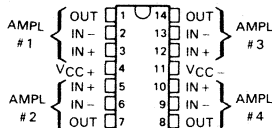
**TL062, TL062A, TL062B**  
D, JG, OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



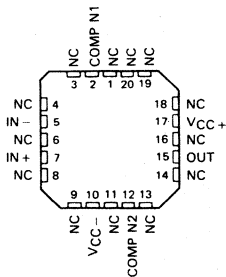
**TL062**  
U FLAT PACKAGE  
(TOP VIEW)



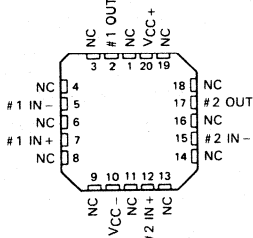
**TL064 . . . D, J, N, OR W PACKAGE  
TL064A, TL064B . . . D, J, OR N PACKAGE**  
(TOP VIEW)



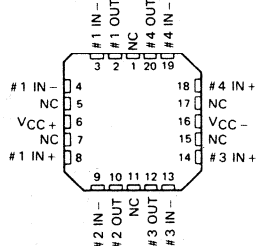
**TL061**  
FH OR FK CHIP-CARRIER PACKAGE  
(TOP VIEW)



**TL062**  
FH OR FK CHIP-CARRIER PACKAGE  
(TOP VIEW)



**TL064**  
FH OR FK CHIP-CARRIER PACKAGE  
(TOP VIEW)

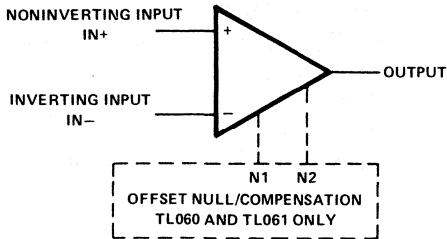


NC—No internal connection

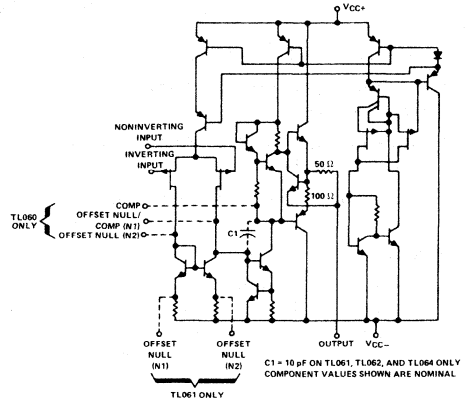
# TYPES TL060, TL060A, TL060B, TL061, TL061A, TL061B, TL062, TL062A, TL062B, TL064, TL064A, TL064B

## LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

symbol (each amplifier)



schematic (each amplifier)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TL06_M	TL06_I	TL06_C TL06_AC TL06_BC	UNIT	
Supply voltage, $V_{CC+}$ (see Note 1)	18	18	18	V	
Supply voltage, $V_{CC-}$ (see Note 1)	-18	-18	-18	V	
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	$\pm 30$	V	
Input voltage (see Notes 1 and 3)	$\pm 15$	$\pm 15$	$\pm 15$	V	
Duration of output short circuit (see Note 4)	unlimited	unlimited	unlimited		
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)	D package	680	680	mW	
	FH or FK package	680	680		
	J, JG, N, P, or W package	680	680		
	U package	675			
Operating free-air temperature range	-55 to 125	-25 to 85	0 to 70	°C	
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C	
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J, JG, U, FH, FK, or W package			300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D, N, or P package			260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.  
 4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.  
 5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J and JG packages, TL06\_M chips are alloy-mounted; TL06\_I, TL06\_C, TL06\_AC, and TL06\_BC chips are glass-mounted.

### DEVICE TYPES, SUFFIX VERSIONS, AND PACKAGES

	TL060	TL061	TL062	TL064
TL06_M	JG	FH, FK, JG, U	FH, FK, JG, U	FH, FK, J, W
TL06_I	D, JG, P	D, JG, P	D, JG, P	D, J, N
TL06_C	D, JG, P	D, JG, P	D, JG, P	D, J, N
TL06_AC	D, JG, P	D, JG, P	D, JG, P	D, J, N
TL06_BC	D, JG, P	D, JG, P	D, JG, P	D, J, N



# TYPES TL060M, TL061M, TL062M, TL064M LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC \pm} = \pm 15 \text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	TL060M TL061M TL062M			TL064M			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage $V_O = 0$ , $R_S = 50 \Omega$	$T_A = 25^\circ\text{C}$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$			3 6 9			mV
$\alpha_{VIO}$	Temperature coefficient of input offset voltage $V_O = 0$ , $R_S = 50 \Omega$ , $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	10			10			$\mu\text{V}/^\circ\text{C}$
$I_{IO}$	Input offset current <sup>‡</sup> $V_O = 0$	$T_A = 25^\circ\text{C}$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$			5 100 20			pA nA
$I_{IB}$	Input bias current $V_O = 0$	$T_A = 25^\circ\text{C}$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$			30 200 50			pA nA
$V_{ICR}$	Common-mode input voltage range $T_A = 25^\circ\text{C}$	$\pm 11.5 \pm 12$			$\pm 11.5 \pm 12$			V
$V_{OM}$	Maximum peak output voltage swing $R_L = 10 \text{ k}\Omega$ , $T_A = 25^\circ\text{C}$ $R_L \geq 10 \text{ k}\Omega$ , $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	$\pm 10 \pm 13.5$ $\pm 10$			$\pm 10 \pm 13.5$ $\pm 10$			V
$A_{VD}$	Large-signal differential voltage amplification $V_O = \pm 10 \text{ V}$ , $R_L \geq 10 \text{ k}\Omega$	$T_A = 25^\circ\text{C}$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$			4 6 4			V/mV
$B_1$	Unity-gain bandwidth $R_L = 10 \text{ k}\Omega$ , $T_A = 25^\circ\text{C}$	1			1			MHz
$r_i$	Input resistance $T_A = 25^\circ\text{C}$	$10^{12}$			$10^{12}$			$\Omega$
CMRR	Common-mode rejection ratio $V_{IC} = V_{ICR \text{ min}}$ , $V_O = 0$ , $R_S = 50 \Omega$ , $T_A = 25^\circ\text{C}$	80 86			80 86			dB
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{CC \pm} / \Delta V_{IO}$ ) $V_{CC} = \pm 15 \text{ V to } \pm 9 \text{ V}$ , $V_O = 0$ , $R_S = 50 \Omega$ , $T_A = 25^\circ\text{C}$	80 95			80 95			dB
$P_D$	Total power dissipation (each amplifier) No load, $V_O = 0$ , $T_A = 25^\circ\text{C}$	6 7.5			6 7.5			mW
$I_{CC}$	Supply current (each amplifier) No load, $V_O = 0$ , $T_A = 25^\circ\text{C}$	200 250			200 250			$\mu\text{A}$
$V_{O1}/V_{O2}$	Crosstalk attenuation $A_{VD} = 100$ , $T_A = 25^\circ\text{C}$	120			120			dB

<sup>†</sup>All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified.

<sup>‡</sup>Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 17. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

3

Operational Amplifiers

**TYPES TL060, TL060A, TL060B, TL061, TL061A, TL061B, TL062, TL062A, TL062B, TL064, TL064A, TL064B, LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

electrical characteristics,  $V_{CC} \pm = \pm 15\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		TL0600			TL060C			TL060AC			TL060BC			UNIT	
	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP		MAX
$V_{IO}$	Input offset voltage		$V_O = 0,$ $R_S = 50\ \Omega$	3	6	6	3	15	3	6	6	3	6	3	mV	
$e_{VIO}$	Temperature coefficient of input offset voltage		$V_O = 0,$ $T_A = \text{full range}$	9			20			7.5			5			
$I_{IO}$	Input offset current‡		$T_A = \text{full range}$	10			10			10			10		$\mu\text{V}/^\circ\text{C}$	
$I_{IB}$	Input bias current‡		$V_O = 0$	5	100	5	200	5	200	5	100	5	100	5	pA	
$V_{ICR}$	Common-mode input voltage range		$T_A = 25^\circ\text{C}$	30	200	30	200	30	200	30	200	30	200	30	pA	
$V_{OM}$	Maximum peak output voltage swing		$T_A = 25^\circ\text{C}$	20			10			7			7		nA	
$A_{VD}$	Large-signal differential voltage amplification		$T_A = 25^\circ\text{C}$	$\pm 11.5$	$\pm 12$	$\pm 11$	$\pm 12$	$\pm 11.5$	$\pm 12$	$\pm 11.5$	$\pm 12$	$\pm 11.5$	$\pm 12$	$\pm 11.5$	$\pm 12$	V
$B_1$	Unity-gain bandwidth		$R_L = 10\ \text{k}\Omega,$ $T_A = 25^\circ\text{C}$	1			1			1			1		MHz	
$f_i$	Input resistance		$T_A = 25^\circ\text{C}$	10 <sup>12</sup>			10 <sup>12</sup>			10 <sup>12</sup>			10 <sup>12</sup>		$\Omega$	
CMRR	Common-mode rejection ratio		$V_{IC} = V_{ICR\ \text{min}}, V_O = 0,$ $R_S = 50\ \Omega,$ $T_A = 25^\circ\text{C}$	80	86	70	86	80	86	80	86	80	86	80	86	dB
*SVR	Supply voltage rejection ratio ( $\Delta V_{CC} \pm / \Delta V_{IO}$ )		$V_{CC} = \pm 15\text{ V to } \pm 9\text{ V}, V_O = 0,$ $R_S = 50\ \Omega,$ $T_A = 25^\circ\text{C}$	80	95	70	95	80	95	80	95	80	95	80	95	dB
$P_D$	Total power dissipation (each amplifier)		No load, $V_O = 0,$ $T_A = 25^\circ\text{C}$	6	7.5	6	7.5	6	7.5	6	7.5	6	7.5	6	7.5	mW
$I_{CC}$	Supply current (each amplifier)		No load, $V_O = 0,$ $T_A = 25^\circ\text{C}$	200	250	200	250	200	250	200	250	200	250	200	250	$\mu\text{A}$
$V_{O1}/V_{O2}$	Crosstalk attenuation		$A_{VD} = 100,$ $T_A = 25^\circ\text{C}$	120			120			120			120		dB	

†All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified. Full range for  $T_A$  is  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for TL060\_1 and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TL060\_3, TL060\_AC, and TL060\_BC.

‡Input bias currents of a JFET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 17. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

# TYPES TL060, TL060A, TL060B, TL061, TL061A, TL061B, TL062, TL062A, TL062B, TL064, TL064A, TL064B LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR Slew rate at unity gain	$V_I = 10\text{ V}$ , $C_L = 100\text{ pF}$ , $R_L = 10\text{ k}\Omega$ , See Figure 1	2	3.5		$\text{V}/\mu\text{s}$
$t_r$ Rise time	$V_I = 20\text{ mV}$ , $R_L = 10\text{ k}\Omega$		0.2		$\mu\text{s}$
Overshoot factor	$C_L = 100\text{ pF}$ , See Figure 1		10%		
$V_n$ Equivalent input noise voltage	$R_S = 100\ \Omega$ , $f = 1\text{ kHz}$		42		$\text{nV}/\sqrt{\text{Hz}}$

## PARAMETER MEASUREMENT INFORMATION

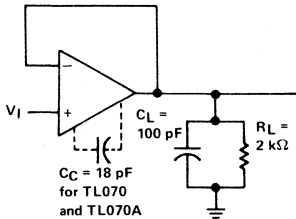


FIGURE 1—UNITY-GAIN AMPLIFIER

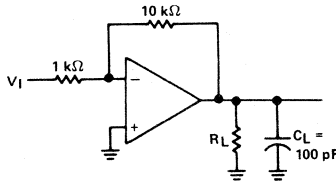


FIGURE 2—GAIN-OF-10  
INVERTING AMPLIFIER

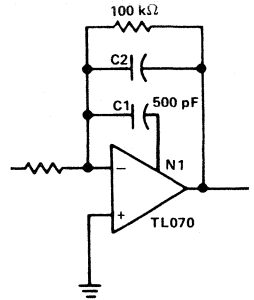
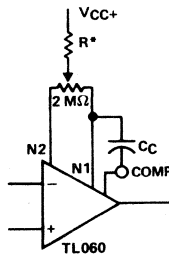


FIGURE 3—FEED-FORWARD  
COMPENSATION

## INPUT OFFSET VOLTAGE NULL CIRCUITS



\*For best results use  $R = 20\text{ M}\Omega$  for  $V_{CC\pm} = \pm 15\text{ V}$  to  $R = 5\text{ M}\Omega$  for  $V_{CC\pm} = \pm 3\text{ V}$ .

FIGURE 4

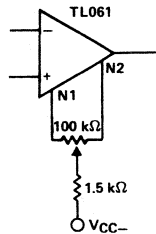


FIGURE 5

# TYPES TL060, TL060A, TL060B, TL061, TL061A, TL061B, TL062, TL062A, TL062B, TL064, TL064A, TL064B

## LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS†

MAXIMUM PEAK OUTPUT VOLTAGE  
vs  
SUPPLY VOLTAGE

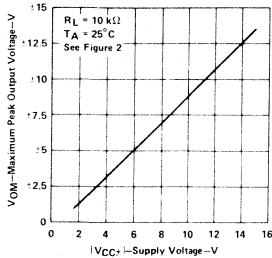


FIGURE 6

MAXIMUM PEAK OUTPUT VOLTAGE  
vs  
FREE-AIR TEMPERATURE

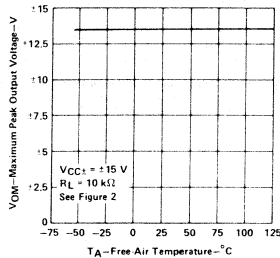


FIGURE 7

MAXIMUM PEAK OUTPUT VOLTAGE  
vs  
LOAD RESISTANCE

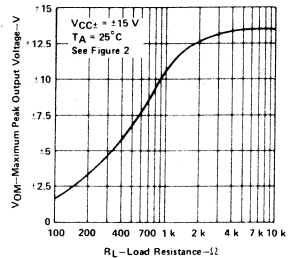


FIGURE 8

MAXIMUM PEAK OUTPUT VOLTAGE  
vs  
FREQUENCY

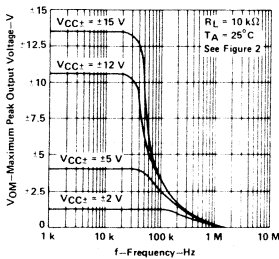


FIGURE 9

DIFFERENTIAL VOLTAGE AMPLIFICATION  
vs  
FREE-AIR TEMPERATURE

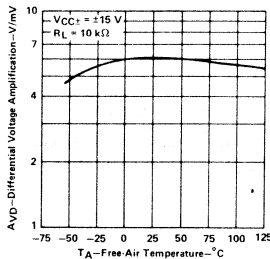


FIGURE 10

LARGE-SIGNAL  
DIFFERENTIAL VOLTAGE AMPLIFICATION  
and PHASE SHIFT  
vs  
FREQUENCY

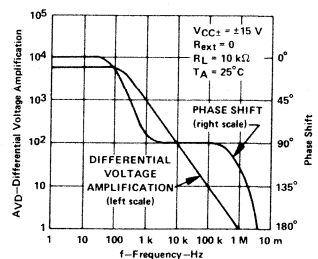


FIGURE 11

SUPPLY CURRENT PER AMPLIFIER  
vs  
SUPPLY VOLTAGE

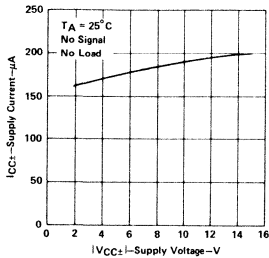


FIGURE 12

SUPPLY CURRENT PER AMPLIFIER  
vs  
FREE-AIR TEMPERATURE

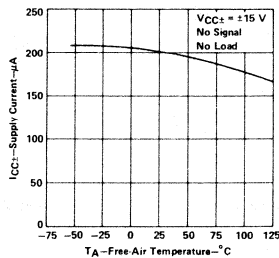


FIGURE 13

TOTAL POWER DISSIPATED  
vs  
FREE-AIR TEMPERATURE

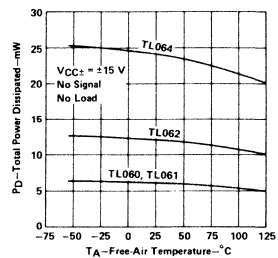


FIGURE 14

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 10-pF compensation capacitor is used with TL060 and TL060A.

3  
Operational Amplifiers

# TYPES TL060, TL060A, TL060B, TL061, TL061A, TL061B, TL062, TL062A, TL062B, TL064, TL064A, TL064B LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

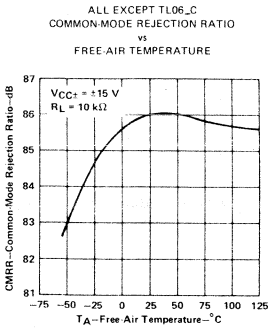


FIGURE 15

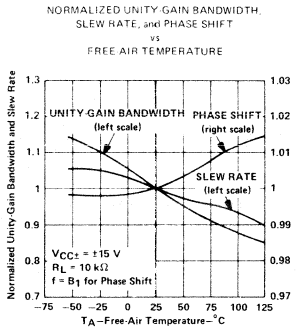


FIGURE 16

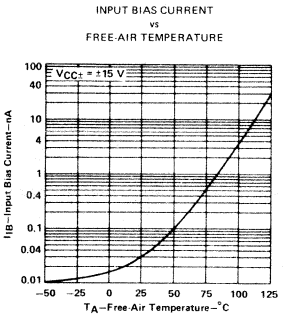


FIGURE 17

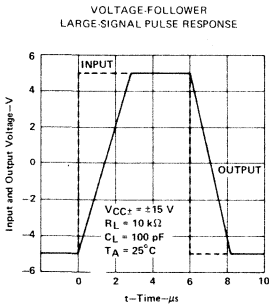


FIGURE 18

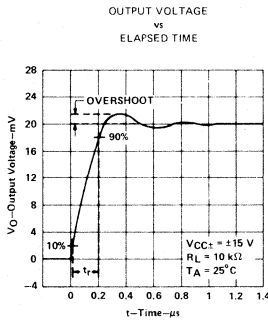


FIGURE 19

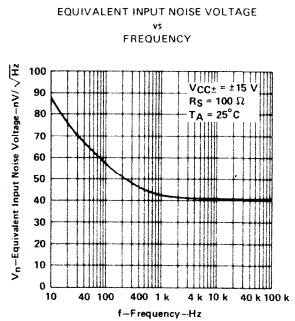


FIGURE 20

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 10-pF compensation capacitor is used with TL060 and TL060A.

## TYPICAL APPLICATION DATA

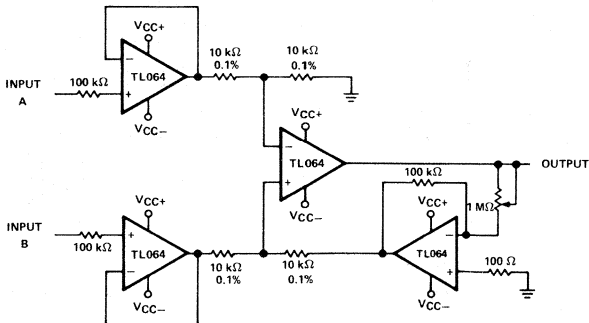


FIGURE 21—INSTRUMENTATION AMPLIFIER

**TYPES TL060, TL060A, TL060B, TL061, TL061A, TL061B,  
TL062, TL062A, TL062B, TL064, TL064A, TL064B  
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

**TYPICAL APPLICATION DATA**

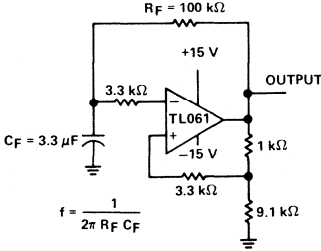


FIGURE 22—0.5-Hz SQUARE-WAVE OSCILLATOR

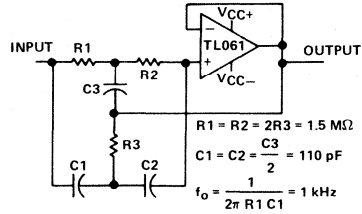


FIGURE 23—HIGH-Q NOTCH FILTER

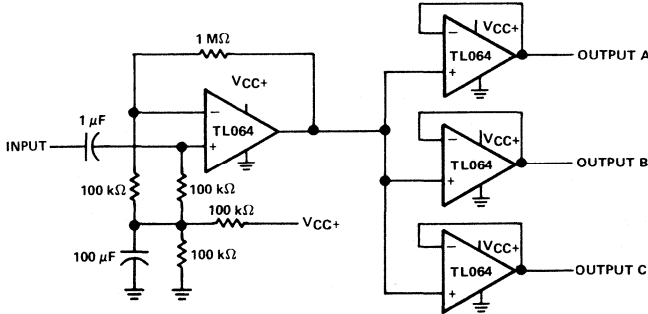


FIGURE 24—AUDIO DISTRIBUTION AMPLIFIER

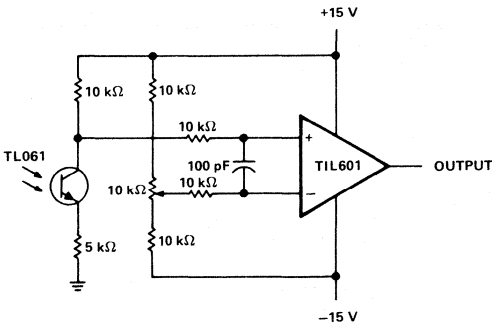


FIGURE 25—LOW-LEVEL LIGHT DETECTOR PREAMPLIFIER

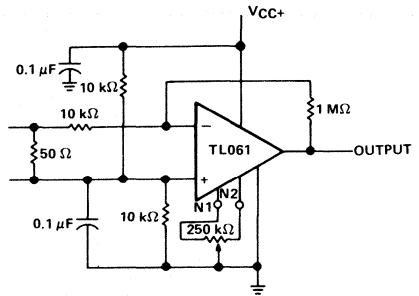


FIGURE 26—AC AMPLIFIER

**TYPES TL060, TL060A, TL060B, TL061, TL061A, TL061B,  
TL062, TL062A, TL062B, TL064, TL064A, TL064B  
LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

**TYPICAL APPLICATION DATA**

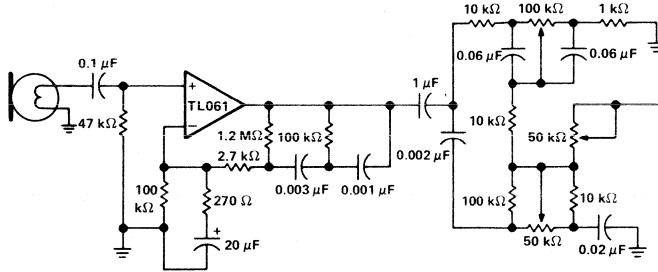


FIGURE 27—MICROPHONE PREAMPLIFIER WITH TONE CONTROL

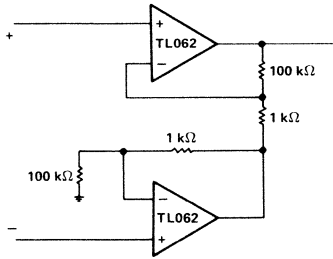


FIGURE 28—INSTRUMENTATION AMPLIFIER

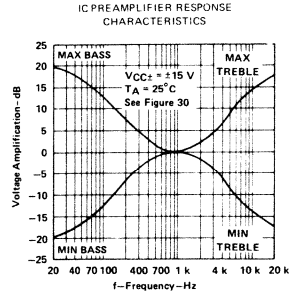


FIGURE 29

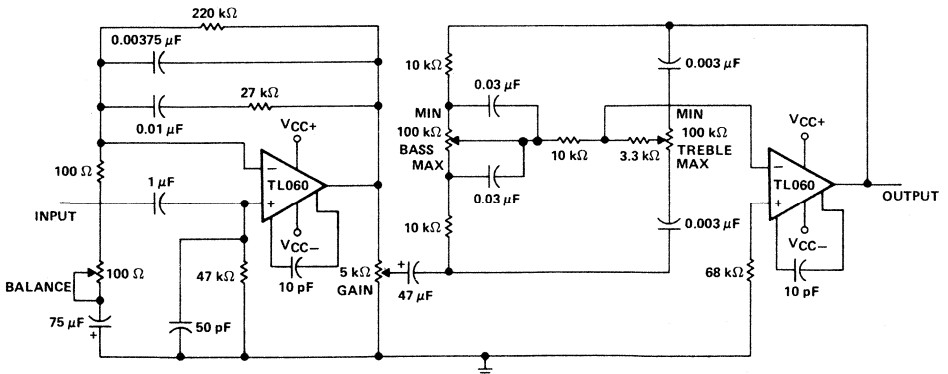


FIGURE 30—IC PREAMPLIFIER





**5 DEVICES COVER COMMERCIAL,  
INDUSTRIAL, AND MILITARY  
TEMPERATURE RANGES**

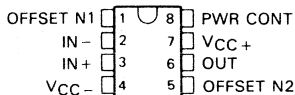
- Very Low, Adjustable ("Programmable") Power Consumption
- Adjustable Supply Current . . . 5  $\mu$ A to 200  $\mu$ A
- Very Low Input Bias and Offset Currents
- Wide Supply Range . . .  $\pm 1.2$  V to  $\pm 18$  V
- Wide Common-Mode and Differential Voltage Range
- Output Short-Circuit Protection
- High Input Impedance . . . JFET-Input Stage
- Unity-Gain Bandwidth . . . 1 MHz Typ (100 kHz at 25  $\mu$ W)
- High Slew Rate . . . 3.5 V/ $\mu$ s Typ
- Internal Frequency Compensation
- Latch-Up-Free Operation

**description**

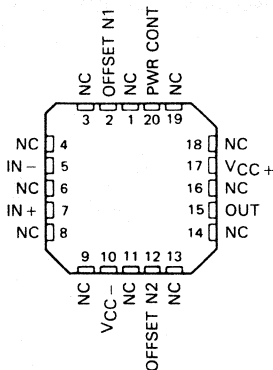
The TL066, TL066A, and TL066B are JFET-input operational amplifiers similar to the TL061 with the additional feature of being power-adjustable. They feature very low input offset and bias currents, high input impedance, wide bandwidth, and high slew rate. The power-control feature permits the amplifiers to be adjusted to require as little as 25 microwatts of power. This type of amplifier, which provides for changing several characteristics by varying one external element, is sometimes referred to as being "programmable." The JFET-input stage combined with the adjustable-low-power feature results in superior bandwidth and slew rate performance compared to low-power bipolar-input devices.

The TL066M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL066I is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ ; the TL066C, TL066AC, and TL066BC are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

TL066M . . . JG PACKAGE  
TL066I, TL066C, TL066AC, TL066BC . . . D, JG, OR P PACKAGE  
(TOP VIEW)

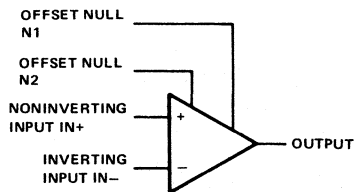


TL066M . . . FH OR FK PACKAGE  
(TOP VIEW)



NC—No internal connection

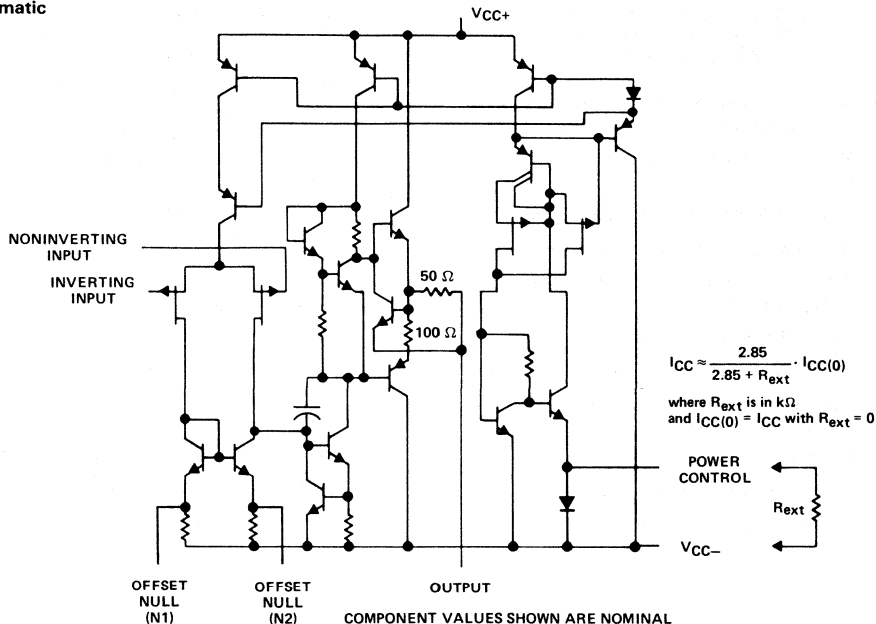
**symbol**



# TYPES TL066M, TL066I, TL066C, TL066AC, TL066BC

## ADJUSTABLE LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

schematic



absolute maximum ratings over operating free-air temperature (unless otherwise noted)

	TL066M	TL066I	TL066C TL066AC TL066BC	UNIT
Supply voltage, $V_{CC+}$ (see Note 1)	18	18	18	V
Supply voltage, $V_{CC-}$ (see Note 1)	-18	-18	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	$\pm 30$	V
Input voltage (see Notes 1 and 3)	$\pm 15$	$\pm 15$	$\pm 15$	V
Voltage between power-control terminal and $V_{CC-}$	$\pm 0.5$	$\pm 0.5$	$\pm 0.5$	V
Duration of output short circuit (see Note 4)	unlimited	unlimited	unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)	680	680	680	mW
Operating free-air temperature range	-55 to 125	-25 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	FH, FK, or JG package	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or P package	260	260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.  
 4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.  
 5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves in Section 2. In the JG package, the TL066I, TL066C, TL066AC, and TL066BC chips are glass-mounted; the TL066M chips are alloy-mounted.

# TYPES TL066M, TL066I, TL066C ADJUSTABLE LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC} = \pm 15\text{ V}$

PARAMETER	TEST CONDITIONS <sup>†</sup>	TL066M			TL066I			TL066C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0$ , $T_A = 25^\circ\text{C}$		3	6		3	6		3	15	mV
	$V_O = 0$ , $T_A = \text{full range}$			9			9			20	
	$V_O = 0$ , $T_A = \text{full range}$		10			10			10		
$\alpha_{VIO}$ Temperature coefficient of input offset voltage	$T_A = 25^\circ\text{C}$		5	100		5	100		5	200	pA
	$T_A = \text{full range}$			20			10			5	
$I_{IO}$ Input offset current <sup>‡</sup>	$V_O = 0$ , $T_A = 25^\circ\text{C}$		30	200		30	200		30	400	pA
$I_{IB}$ Input bias current <sup>‡</sup>	$V_O = 0$ , $T_A = \text{full range}$			50			20			10	nA
$V_{ICR}$ Common-mode input voltage range	$T_A = 25^\circ\text{C}$		$\pm 11.5$			$\pm 11.5$			$\pm 11$		V
	Maximum peak output voltage swing	$T_A = 25^\circ\text{C}$ , $R_L \geq 10\text{ k}\Omega$		$\pm 10 \pm 13.5$		$\pm 10 \pm 13.5$		$\pm 10 \pm 13.5$		$\pm 10 \pm 13.5$	
$V_{OM}$ Large-signal differential voltage amplification	$R_L \geq 10\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$		4	6		4	6		3	6	V/mV
	$R_L \geq 10\text{ k}\Omega$ , $T_A = \text{full range}$		4			4			3		
	$T_A = 25^\circ\text{C}$ , $R_L = 10\text{ k}\Omega$		1			1			1		
$B_1$ Unity-gain bandwidth	$T_A = 25^\circ\text{C}$		1012			1012			10 <sup>12</sup>		MHz
$r_i$ Input resistance	$T_A = 25^\circ\text{C}$ , $f = 1\text{ kHz}$		220			220			220		$\Omega$
$r_o$ Output resistance	$V_{IC} = V_{ICR}\text{ min}$ , $V_O = 0$ , $R_S = 50\ \Omega$ , $T_A = 25^\circ\text{C}$		80	86		80	86		70	76	dB
CMRR Common-mode rejection ratio	$V_{CC} = \pm 9\text{ V to } \pm 15\text{ V}$ , $V_O = 0$ , $R_S = 50\ \Omega$ , $T_A = 25^\circ\text{C}$		80	95		80	95		70	95	dB
KSVR Supply voltage rejection ratio ( $\Delta V_{CC} \pm / \Delta V_{IO}$ )	$V_O = 0$ , $T_A = 25^\circ\text{C}$		6	7.5		6	7.5		6	7.5	mW
PD Total power dissipation	$V_O = 0$ , $T_A = 25^\circ\text{C}$		200	250		200	250		200	250	$\mu\text{A}$
$I_{CC}$ Supply current	$V_O = 0$ , $T_A = 25^\circ\text{C}$		200	250		200	250		200	250	$\mu\text{A}$

<sup>†</sup> All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range of  $T_A$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for TL066M;  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for TL066I; and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TL066C. The electrical parameters are measured with the power-control terminal (pin 8) connected to  $V_{CC}$ .

<sup>‡</sup> Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature-sensitive. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as is possible.

# TYPES TL066AC, TL066BC ADJUSTABLE LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC} = \pm 15 \text{ V}$

PARAMETER	TEST CONDITIONS <sup>†</sup>	TL066AC			TL066BC			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0$ , $T_A = 25^\circ\text{C}$ , $R_S = 50 \Omega$		3	6		2	3	mV
	$V_O = 0$ , $T_A = \text{full range}$ , $R_S = 50 \Omega$			7.5			5	
$\alpha_{VIO}$ Temperature coefficient of input offset voltage	$V_O = 0$ , $T_A = \text{full range}$ , $R_S = 50 \Omega$		10			10		$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current <sup>‡</sup>	$V_O = 0$ , $T_A = 25^\circ\text{C}$		5	100		5	100	pA
	$V_O = 0$ , $T_A = \text{full range}$			3			3	nA
$I_{IB}$ Input bias current <sup>‡</sup>	$V_O = 0$ , $T_A = 25^\circ\text{C}$		30	200		30	200	pA
	$V_O = 0$ , $T_A = \text{full range}$			7			7	nA
$V_{ICR}$ Common-mode input voltage range	$T_A = 25^\circ\text{C}$		$\pm 11.5$			$\pm 11.5$		V
$V_{OM}$ Maximum peak output voltage swing	$T_A = 25^\circ\text{C}$ , $R_L \geq 10 \text{ k}\Omega$		$\pm 10$	$\pm 13.5$		$\pm 10$	$\pm 13.5$	V
	$T_A = \text{full range}$ , $R_L \geq 10 \text{ k}\Omega$		$\pm 10$	$\pm 13.5$		$\pm 10$	$\pm 13.5$	
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 10 \text{ k}\Omega$ , $T_A = 25^\circ\text{C}$ , $V_O = \pm 10 \text{ V}$		4	6		4	6	V/mV
	$R_L \geq 10 \text{ k}\Omega$ , $T_A = \text{full range}$ , $V_O = \pm 10 \text{ V}$		4			4		
$B_1$ Unity-gain bandwidth	$T_A = 25^\circ\text{C}$ , $R_L = 10 \text{ k}\Omega$			1			1	MHz
$r_i$ Input resistance	$T_A = 25^\circ\text{C}$		$10^{12}$			$10^{12}$		$\Omega$
$r_o$ Output resistance	$T_A = 25^\circ\text{C}$ , $f = 1 \text{ kHz}$			220			220	$\Omega$
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR \text{ min}}$ , $R_S = 50 \Omega$ , $V_O = 0$ , $T_A = 25^\circ\text{C}$		80	86		80	86	dB
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC} \pm \Delta V_{IO}$ )	$V_{CC} = \pm 9 \text{ V}$ to $\pm 15 \text{ V}$ , $R_S = 50 \Omega$ , $V_O = 0$ , $T_A = 25^\circ\text{C}$		80	95		80	95	dB
$P_D$ Total power dissipation	No load, $T_A = 25^\circ\text{C}$ , $V_O = 0$		6	7.5		6	7.5	mW
$I_{CC}$ Supply current	No load, $T_A = 25^\circ\text{C}$ , $V_O = 0$		200	250		200	250	$\mu\text{A}$

<sup>†</sup>All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range of  $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$  for TL066M;  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for TL066I; and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TL066C, TL066AC, and TL066BC. The electrical parameters are measured with the power-control terminal (pin 8) connected to  $V_{CC-}$ .

<sup>‡</sup>Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature-sensitive. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as is possible.

# TYPES TL066M, TL066I, TL066C, TL066AC, TL066BC ADJUSTABLE LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_{ext} = 0$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	$V_I = 10\text{ V}$ , $R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1	2	3.5		$\text{V}/\mu\text{s}$
$t_r$	Rise time	$V_I = 20\text{ mV}$ , $R_L = 10\text{ k}\Omega$		0.2		$\mu\text{s}$
	Overshoot factor	$C_L = 100\text{ pF}$ , See Figure 1		10%		
$V_n$	Equivalent input noise voltage	$R_S = 100\ \Omega$ , $f = 1\text{ kHz}$		42		$\text{nV}/\sqrt{\text{Hz}}$

## PARAMETER MEASUREMENT INFORMATION

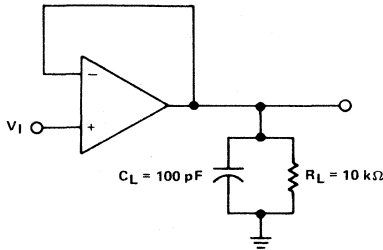


FIGURE 1—UNITY-GAIN AMPLIFIER

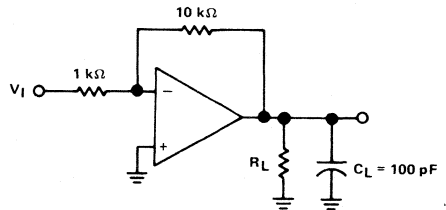


FIGURE 2—GAIN-OF-10 INVERTING AMPLIFIER

## INPUT OFFSET VOLTAGE NULL CIRCUIT

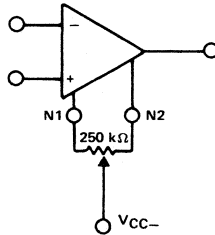


FIGURE 3

# TYPES TL066M, TL066I, TL066C, TL066AC, TL066BC ADJUSTABLE LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

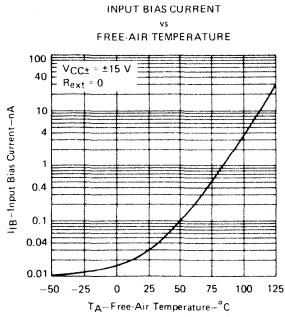


FIGURE 4

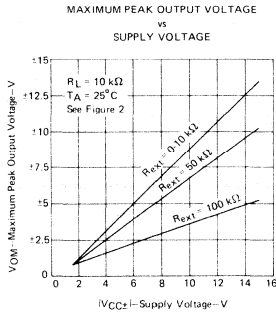


FIGURE 5

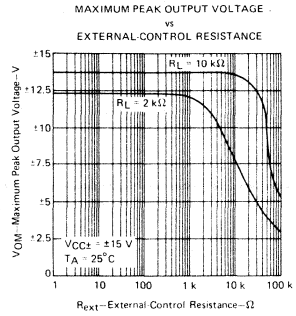


FIGURE 6

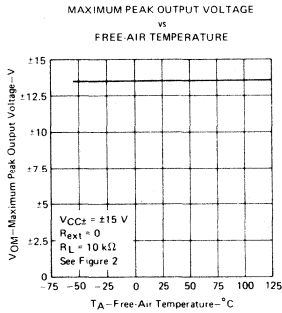


FIGURE 7

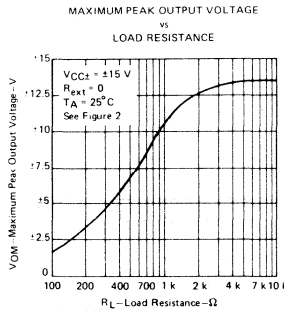


FIGURE 8

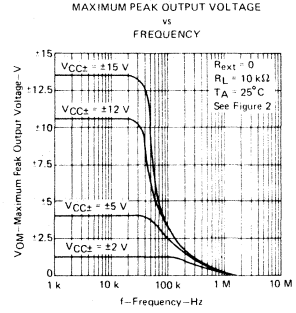


FIGURE 9

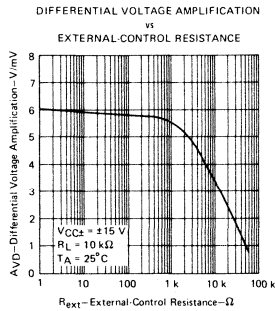


FIGURE 10

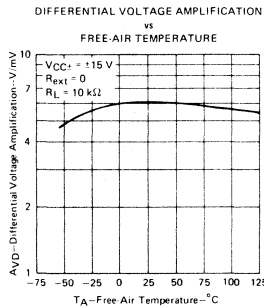


FIGURE 11

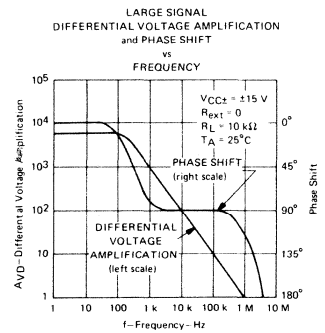


FIGURE 12

†Data at high and low temperatures are applicable only within the rated free-air temperature ranges of the various devices.

3  
Operational Amplifiers

# TYPES TL066M, TL066I, TL066C, TL066AC, TL066BC ADJUSTABLE LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

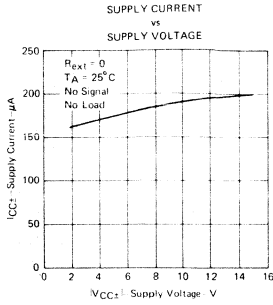


FIGURE 13

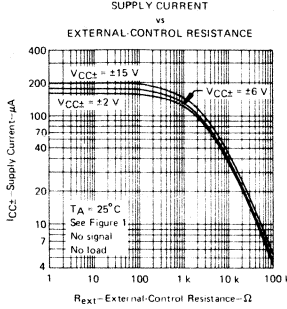


FIGURE 14

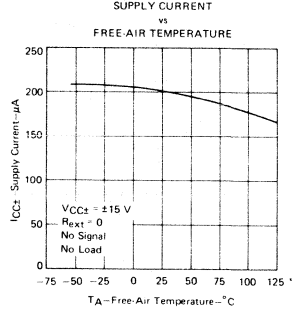


FIGURE 15

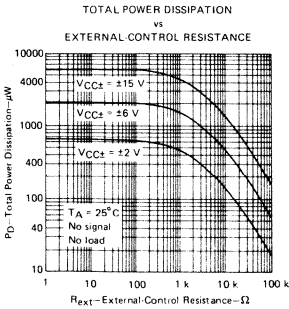


FIGURE 16

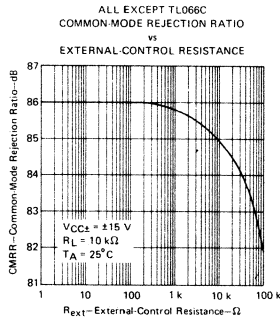


FIGURE 17

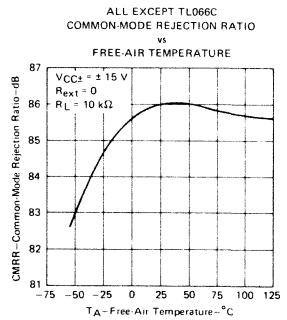


FIGURE 18

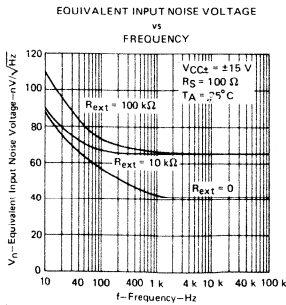


FIGURE 19

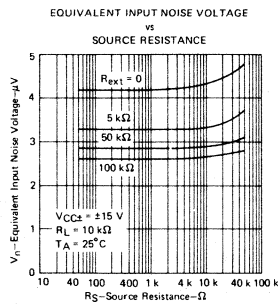


FIGURE 20

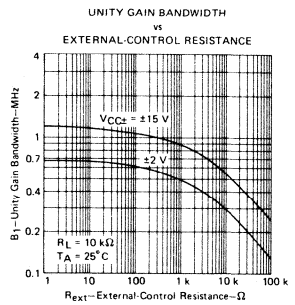


FIGURE 21

†Data at high and low temperatures are applicable only within the rated free-air temperature ranges of the various devices.



**TYPES TL066M, TL066I, TL066C, TL066AC, TL066BC**  
**ADJUSTABLE LOW-POWER JFET-INPUT OPERATIONAL AMPLIFIERS**

**TYPICAL APPLICATION DATA**

IC PREAMPLIFIER RESPONSE CHARACTERISTICS

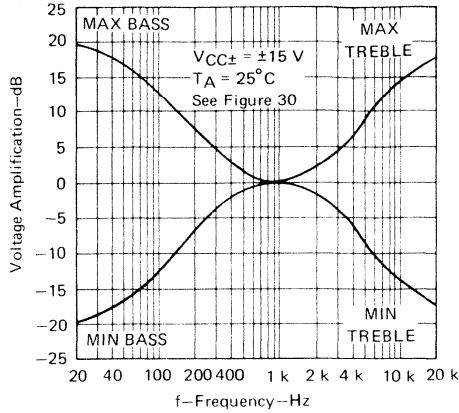


FIGURE 29

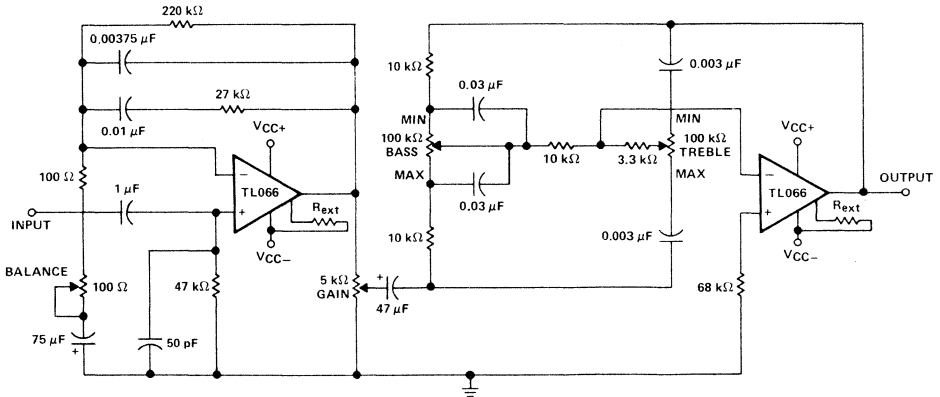
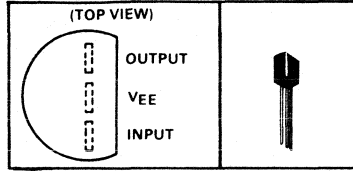


FIGURE 30-IC PREAMPLIFIER



- Standard TO-92 Package
- Supply Current . . . . . 300  $\mu$ A Max
- Wide Input/Output Voltage Range
- Low Input Bias Current
- Output Short-Circuit Protection
- High-Impedance Input . . . JFET Input Stage
- Internal Frequency Compensation
- Latch-Up-Free Operation

LP PACKAGE

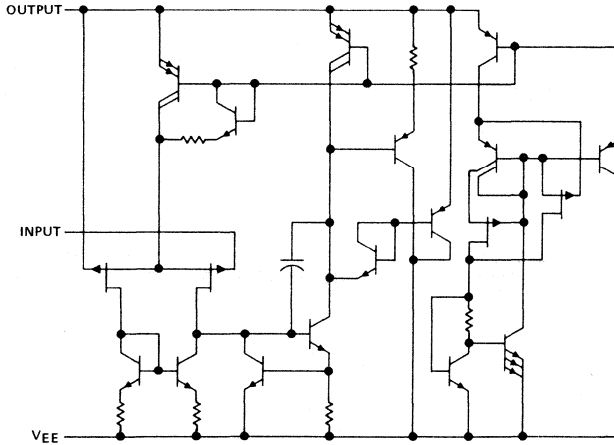


**description**

The TL068C is a JFET-input unity-gain amplifier featuring high input impedance, wide bandwidth, and low input bias current. A current-sourcing load such as a pull-up resistor is required for circuit operation.

The TL068C is characterized for operation over the commercial temperature range of 0°C to 70°C.

**schematic**



**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Voltage from output to V <sub>EE</sub> . . . . .	36 V
Voltage from input to V <sub>EE</sub> . . . . .	36 V
Voltage from input to output . . . . .	30 V
Duration of short circuit (see Note 1) . . . . .	Unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2) . . . . .	775 mW
Operating free-air temperature range . . . . .	0°C to 70°C
Storage temperature range . . . . .	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . .	260°C

- NOTES: 1. The output may be shorted to any point as long as the voltage from output to V<sub>EE</sub> does not exceed 36 V. Temperature and/or V<sub>EE</sub> must be limited to ensure that the dissipation rating is not exceeded.
2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves in Section 2.

**ADVANCE INFORMATION**

This document contains information on a new product. Specifications are subject to change without notice.

Copyright © 1983 by Texas Instruments Incorporated

# TYPE TL068C

## 3-PIN VOLTAGE FOLLOWER WITH JFET INPUT

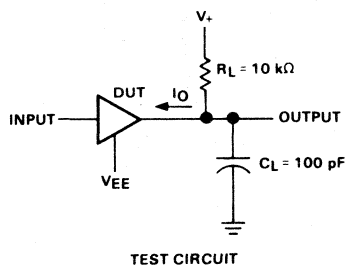
electrical characteristics,  $V_{EE} = -15\text{ V}$ ,  $V_+ = +15\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
$V_{IO}$	Input offset voltage $I_O = 2\text{ mA}$		3	15	mV
$I_{IB}$	Input bias current		$T_A = 25^\circ\text{C}$		pA
			$T_A = 0^\circ\text{C to } 70^\circ\text{C}$		
$V_{IR}$	Input voltage range	$V_{EE} = -15\text{ V}$ , $V_+ = 15\text{ V}$ , $R_L = 10\text{ k}\Omega$	12	13.5	V
			to	to	
$A_V$	Large-signal voltage amplification	$V_{EE} = -15\text{ V}$ , $V_+ = 15\text{ V}$ , $R_L = 10\text{ k}\Omega$	0.999	0.9997	V/V
$k_{SVR}$	Supply voltage rejection ratio	$V_{EE} = -15\text{ V to } +10\text{ V}$	70	78	dB
$k_{LCS}$	Load-circuit sensitivity ( $\Delta V_{IO}/\Delta I_O$ )	$I_O = 0.5\text{ mA to } 5\text{ mA}$	2	4	mV/mA
$I_{OS}$	Short-circuit output current		25		mA
$I_{EE}$	Supply current		-125	-300	$\mu\text{A}$

operating characteristics,  $V_{EE} = -15\text{ V}$ ,  $V_+ = 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$ ,  $C_L = 100\text{ pF}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Bandwidth			1		MHz
Slew rate	$V_O = \pm 10\text{ V}$	Positive-going edge		7	V/ $\mu\text{s}$
		Negative-going edge		100	
Rise time	$V_O = 100\text{ mV}$		130		ns
Overshoot			20%		

### PARAMETER MEASUREMENT INFORMATION



3

Operational Amplifiers

**19 DEVICES COVER COMMERCIAL, INDUSTRIAL, AND MILITARY TEMPERATURE RANGES**

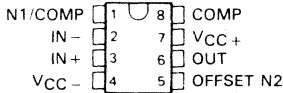
- Low Power Consumption
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- Low Total Harmonic Distortion 0.003% Typ
- Low Noise . . .  $V_n = 18 \text{ nV}\sqrt{\text{Hz}}$  Typ
- High Input Impedance . . . JFET-Input Stage
- Internal Frequency Compensation (Except TL070, TL070A)
- Latch-Up-Free Operation
- High Slew Rate . . .  $13 \text{ V}/\mu\text{s}$  Typ

**description**

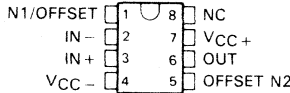
The JFET-input operational amplifiers on the TL07\_\_ series are designed as low-noise versions of the TL08\_\_ series amplifiers with low input bias and offset currents and fast slew rate. The low harmonic distortion and low noise make the TL07\_\_ series ideally suited as amplifiers for high-fidelity and audio preamplifier applications. Each amplifier features JFET-inputs (for high input impedance) coupled with bipolar output stages all integrated on a single monolithic chip.

Device types with an "M" suffix are characterized for operation over the full military temperature range of  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ , those with an "I" suffix are characterized for operation from  $-25^\circ\text{C}$  to  $85^\circ\text{C}$ , and those with a "C" suffix are characterized for operation from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

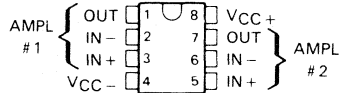
**TL070, TL070A**  
D, JG, OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



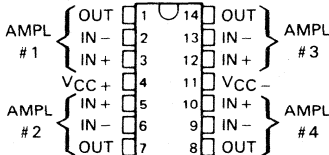
**TL071, TL071A, TL071B**  
D, JG, OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



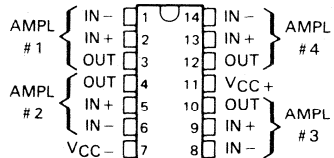
**TL072, TL072A, TL072B**  
D, JG, OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**TL074, TL074A, TL074B**  
D, J, OR N DUAL-IN-LINE  
OR W FLAT PACKAGE  
(TOP VIEW)



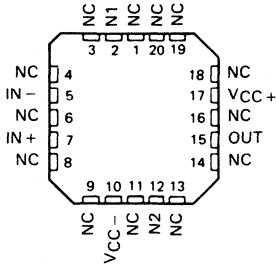
**TL075**  
N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



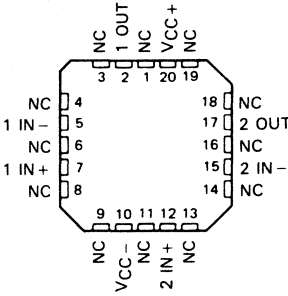
NC—No internal connection

**TYPES TL070, TL070A, TL071, TL071A, TL071B,  
TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075**  
**LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS**

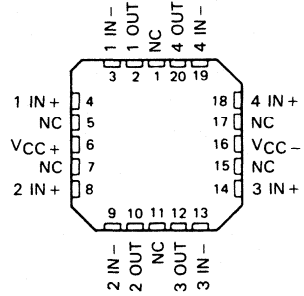
**TL071**  
FH OR FK CHIP-CARRIER PACKAGE  
(TOP VIEW)



**TL072**  
FH OR FK CHIP-CARRIER PACKAGE  
(TOP VIEW)



**TL074**  
FH OR FK CHIP-CARRIER PACKAGE  
(TOP VIEW)

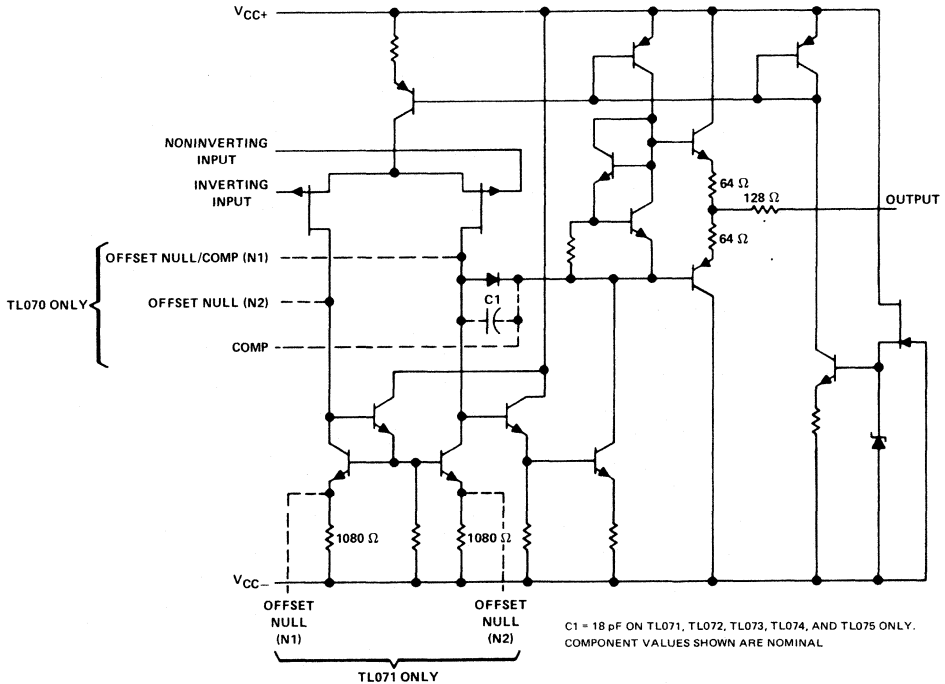


NC—No internal connection

schematic (each amplifier)

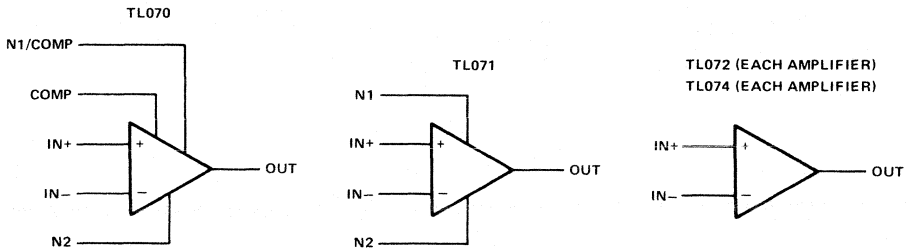
3

Operational Amplifiers



# TYPES TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

## symbols



DEVICE TYPES, SUFFIX VERSIONS, AND PACKAGES					
	TL070	TL071	TL072	TL074	TL075
TL07_M	*	FH, FK, JG	FH, FK, JG	FH, FK, J, W	*
TL07_I	D, JG, P	D, JG, P	D, JG, P	D, J, N	*
TL07_C	D, JG, P	D, JG, P	D, JG, P	D, J, N	N
TL07_AC	D, JG, P	D, JG, P	D, JG, P	D, J, N	*
TL07_BC	*	D, JG, P	D, JG, P	D, J, N	*

\*These combinations are not defined by this data sheet.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TL07_M	TL07_I	TL07_C TL07_AC TL07_BC	UNIT
Supply voltage, $V_{CC+}$ (see Note 1)	18	18	18	V
Supply voltage, $V_{CC-}$ (see Note 1)	-18	-18	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	$\pm 30$	V
Input voltage (see Notes 1 and 3)	$\pm 15$	$\pm 15$	$\pm 15$	V
Duration of output short circuit (see Note 4)	unlimited	unlimited	unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)	680	680	680	mW
Operating free-air temperature range	-55 to 125	-25 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J, JG, JH, FK, or W package		300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D, N, or P package		260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J and JG packages, TL07\_M chips are alloy-mounted; TL07\_I, TL07\_C, TL07\_AC, and TL07\_BC chips are glass mounted.

# TYPES TL071M, TL072M, TL074M

## LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC} \pm = \pm 15$  V (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	TL071M, TL072M			TL074M			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0,$ $R_S = 50 \Omega$	$T_A = 25^\circ\text{C}$	3	6	3	9	mV	
		$T_A = -55^\circ\text{C to } 125^\circ\text{C}$	9					
$\alpha_{VIO}$ Temperature coefficient of input offset voltage	$V_O = 0,$ $T_A = -55^\circ\text{ to } 125^\circ\text{C}$	$R_S = 50 \Omega,$			10			$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current <sup>‡</sup>	$V_O = 0$	$T_A = 25^\circ\text{C}$	5	100	5	100	pA	
		$T_A = -55^\circ\text{C to } 125^\circ\text{C}$	20			20	nA	
$I_{IB}$ Input bias current <sup>‡</sup>	$V_O = 0$	$T_A = 25^\circ\text{C}$	30	200	30	200	pA	
		$T_A = -55^\circ\text{C to } 125^\circ\text{C}$	50			20	nA	
$V_{ICR}$ Common-mode input voltage range	$T_A = 25^\circ\text{C}$	$\pm 11$	$\pm 12$	$\pm 11$	$\pm 12$	V		
$V_{OM}$ Maximum peak output voltage swing	$T_A = 25^\circ\text{C},$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	$R_L = 10 \text{ k}\Omega$	$\pm 12$	$\pm 13.5$	$\pm 12$	$\pm 13.5$	V	
		$R_L \geq 10 \text{ k}\Omega$	$\pm 12$					
		$R_L \geq 2 \text{ k}\Omega$	$\pm 10$	$\pm 12$	$\pm 10$	$\pm 12$		
$A_{VD}$ Large-signal differential voltage amplification	$V_O = \pm 10 \text{ V},$ $T_A = 25^\circ\text{C},$ $V_O = \pm 10 \text{ V},$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	$R_L \geq 2 \text{ k}\Omega,$	35	200	35	200	V/mV	
		$R_L \geq 2 \text{ k}\Omega,$	15			15		
$B_1$ Unity-gain bandwidth	$T_A = 25^\circ\text{C}$	3			3			MHz
$r_i$ Input resistance	$T_A = 25^\circ\text{C}$	$10^{12}$			$10^{12}$			$\Omega$
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR} \text{ min.},$ $R_S = 50 \Omega,$ $V_O = 0,$ $T_A = 25^\circ\text{C}$	80	86	80	86	dB		
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC} \pm / \Delta V_{IO}$ )	$V_{CC} = \pm 15 \text{ V to } \pm 9 \text{ V},$ $R_S = 50 \Omega,$ $V_O = 0,$ $T_A = 25^\circ\text{C}$	80	86	80	86	dB		
$I_{CC}$ Supply current (per amplifier)	No load, $T_A = 25^\circ\text{C}$	1.4 2.5			1.4 2.5			mA
$V_{O1}/V_{O2}$ Crosstalk attenuation	$A_{VD} = 100,$ $T_A = 25^\circ\text{C}$	120			120			dB

<sup>†</sup> All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

<sup>‡</sup> Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 18. Pulse techniques must be used that will maintain the junction temperatures as close to the ambient temperature as is possible.

# TYPES TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC} \pm = \pm 15$  V (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	TL070I			TL070C			TL070AC			TL071BC		
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX
$V_{IO}$	Input offset voltage $V_O = 0$ , $R_S = 50 \Omega$	3	6	6	3	10	13	3	6	6	2	3	
$\alpha_{VIO}$	Temperature coefficient of input offset voltage $V_O = 0$ , $T_A = \text{full range}$ $R_S = 50 \Omega$	10			10			10			10		
$I_{IO}$	Input offset current <sup>‡</sup> $V_O = 0$	5	100	100	5	100	100	5	100	100	5	100	
$I_{IB}$	Input bias current <sup>‡</sup> $V_O = 0$	30	200	200	30	200	200	30	200	200	30	200	
$V_{ICR}$	Common-mode input voltage range $T_A = 25^\circ\text{C}$	$\pm 11$	$\pm 12$		$\pm 11$	$\pm 12$		$\pm 11$	$\pm 12$		$\pm 11$	$\pm 12$	
$V_{OM}$	Maximum peak output voltage swing $T_A = 25^\circ\text{C}$ , $R_L = 10 \text{ k}\Omega$	$\pm 12$	$\pm 13.5$		$\pm 12$	$\pm 13.5$		$\pm 12$	$\pm 13.5$		$\pm 12$	$\pm 13.5$	
	Large-signal differential voltage amplification $V_O = \pm 10$ V, $V_O = 25^\circ\text{C}$	$\pm 10$	$\pm 12$		$\pm 10$	$\pm 12$		$\pm 10$	$\pm 12$		$\pm 10$	$\pm 12$	
$A_{VD}$	Unity-gain bandwidth $T_A = 25^\circ\text{C}$	50	200		25	200		50	200		50	200	
$f_T$	Input resistance $T_A = 25^\circ\text{C}$	25			15			25			25		
CMRR	Common-mode rejection ratio $V_{IC} = V_{ICR \text{ min}}$ , $V_O = 0$ , $R_S = 50 \Omega$ , $T_A = 25^\circ\text{C}$	80	86		70	86		80	86		80	86	
$k_{SVR}$	Supply voltage rejection ratio $V_{CC} = \pm 15$ V to $\pm 9$ V, $V_O = 0$ , $R_S = 50 \Omega$ , $T_A = 25^\circ\text{C}$ $(\Delta V_{CC} \pm / \Delta V_{IO})$	80	86		70	86		80	86		80	86	
$I_{CC}$	Supply current (per amplifier) No load, $V_O = 0$ , $T_A = 25^\circ\text{C}$	1.4	2.5		1.4	2.5		1.4	2.5		1.4	2.5	
$V_{01}/V_{02}$	Crosstalk attenuation $A_{VD} = 100$ , $T_A = 25^\circ\text{C}$	120			120			120			120		

<sup>†</sup> All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for  $T_A$  is  $25^\circ\text{C}$  to  $85^\circ\text{C}$  for TL07...I and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TL07...C, TL07...AC, and TL07...BC.

<sup>‡</sup> Input bias currents of a JFET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 18. Pulse techniques must be used that will maintain the junction temperatures as close to the ambient temperature as is possible.

# TYPES TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL07_M			ALL OTHERS			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain $V_I = 10\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1	10	13		8	13		$\text{V}/\mu\text{s}$
$t_r$	Rise time Overshoot factor $V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1		0.1			0.1		$\mu\text{s}$
$V_n$	Equivalent input noise voltage $R_S = 100\ \Omega$	$f = 1\text{ kHz}$		18		18		$\text{nV}/\sqrt{\text{Hz}}$
		$f = 10\text{ Hz to } 10\text{ kHz}$		4		4		$\mu\text{V}$
$I_n$	Equivalent input noise current $f = 1\text{ kHz}$		0.01		0.01			$\text{pA}/\sqrt{\text{Hz}}$
THD	Total harmonic distortion $V_{O(\text{rms})} = 10\text{ V}$ , $R_S \leq 1\text{ k}\Omega$ , $R_L \geq 2\text{ k}\Omega$ , $f = 1\text{ kHz}$		0.003		0.003			%

## PARAMETER MEASUREMENT INFORMATION

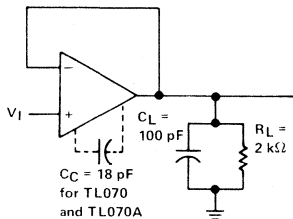


FIGURE 1—UNITY-GAIN AMPLIFIER

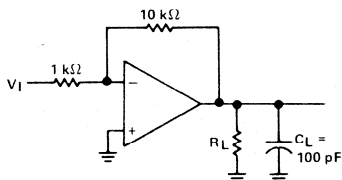


FIGURE 2—GAIN-OF-10 INVERTING AMPLIFIER

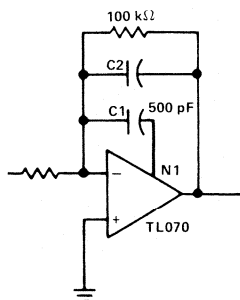


FIGURE 3—FEED-FORWARD COMPENSATION

## INPUT OFFSET VOLTAGE NULL CIRCUITS

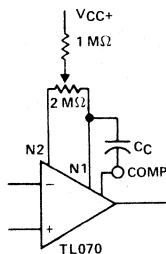


FIGURE 4

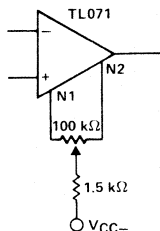


FIGURE 5



# TYPES TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

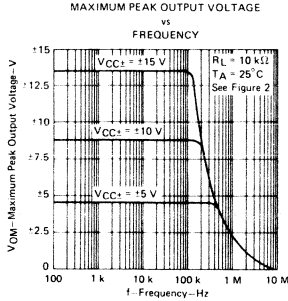


FIGURE 6

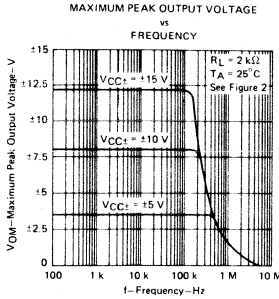


FIGURE 7

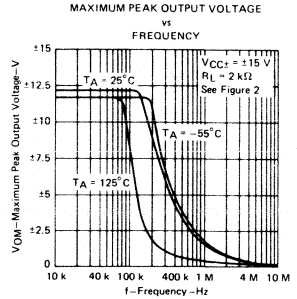


FIGURE 8

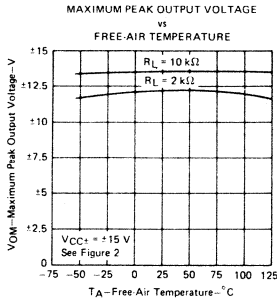


FIGURE 9

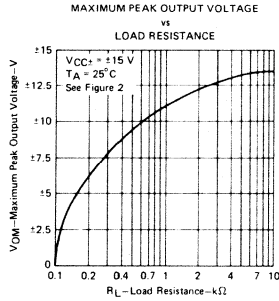


FIGURE 10

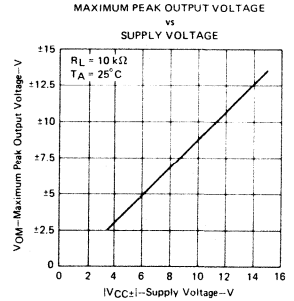


FIGURE 11

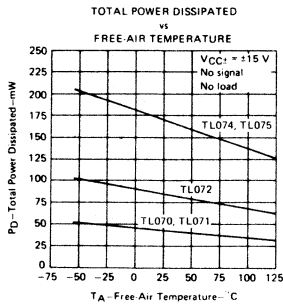


FIGURE 12

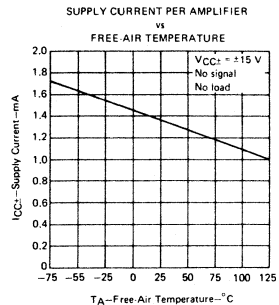


FIGURE 13

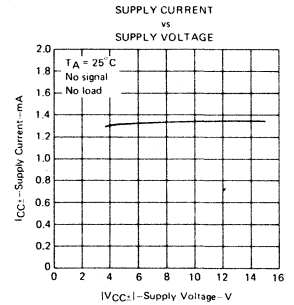


FIGURE 14

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 18-pF compensation capacitor is used with TL070 and TL070A.

# TYPES TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075

## LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

### TYPICAL CHARACTERISTICS†

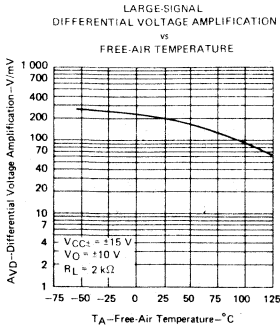


FIGURE 15

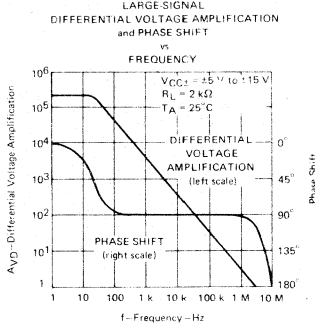


FIGURE 16

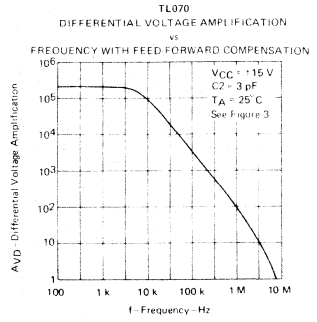


FIGURE 17

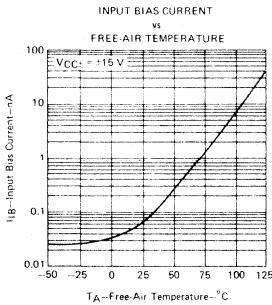


FIGURE 18

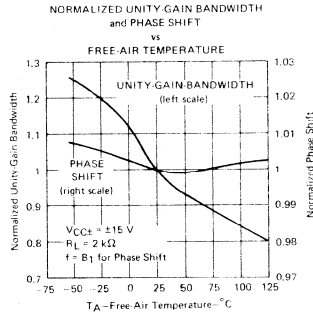


FIGURE 19

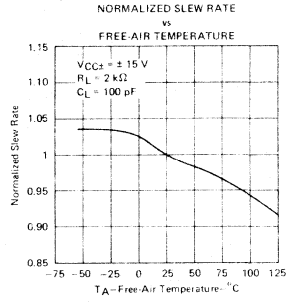


FIGURE 20

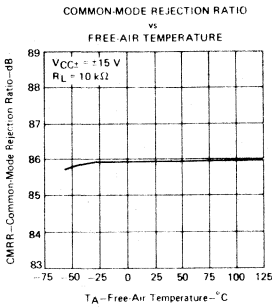


FIGURE 21

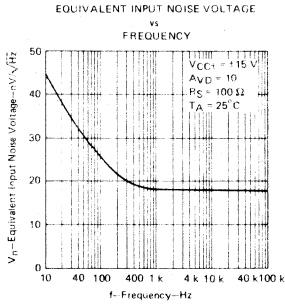


FIGURE 22

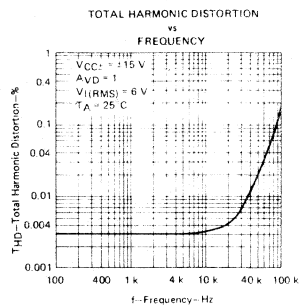


FIGURE 23

† Data at high and low temperatures are applicable only with the rated operating free-air temperature ranges of the various devices. A 18-pF compensation capacitor is used with TL070 and TL070A.

3  
Operational Amplifiers

# TYPES TL070, TL070A, TL071, TL071A, TL071B, TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075 LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS

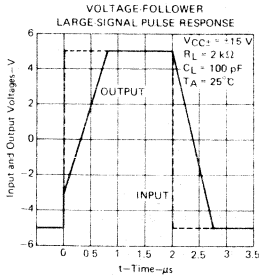


FIGURE 24

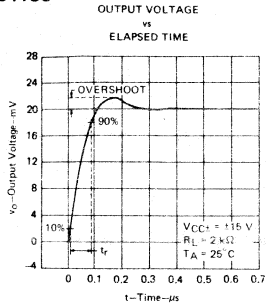


FIGURE 25

## TYPICAL APPLICATION DATA

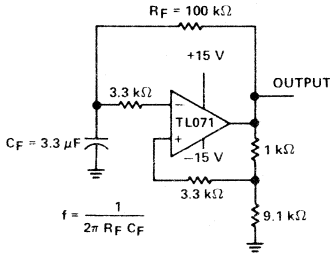


FIGURE 26—0.5-Hz SQUARE-WAVE OSCILLATOR

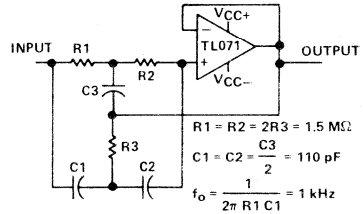
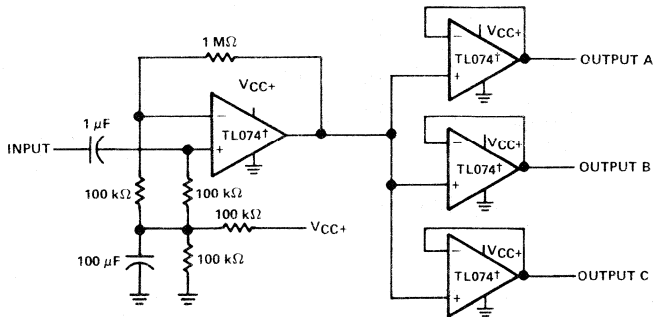


FIGURE 27—HIGH-Q NOTCH FILTER

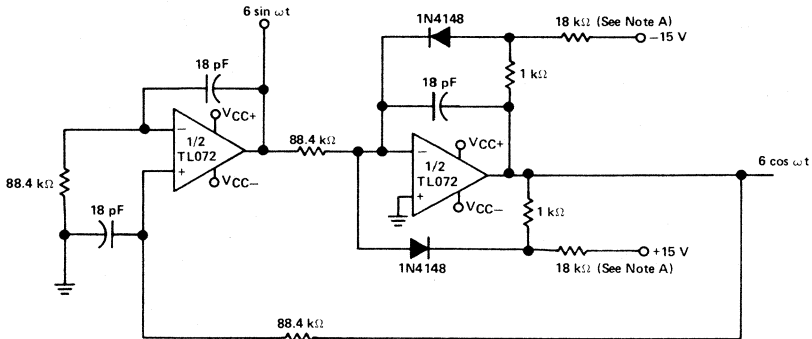


† or TL075

FIGURE 28—AUDIO DISTRIBUTION AMPLIFIER

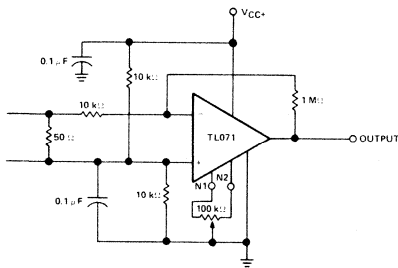
**TYPES TL070, TL070A, TL071, TL071A, TL071B,  
TL072, TL072A, TL072B, TL074, TL074A, TL074B, TL075**  
**LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS**

**TYPICAL APPLICATION DATA**

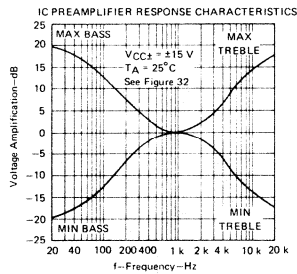


Note A: These resistor values may be adjusted for a symmetrical output.

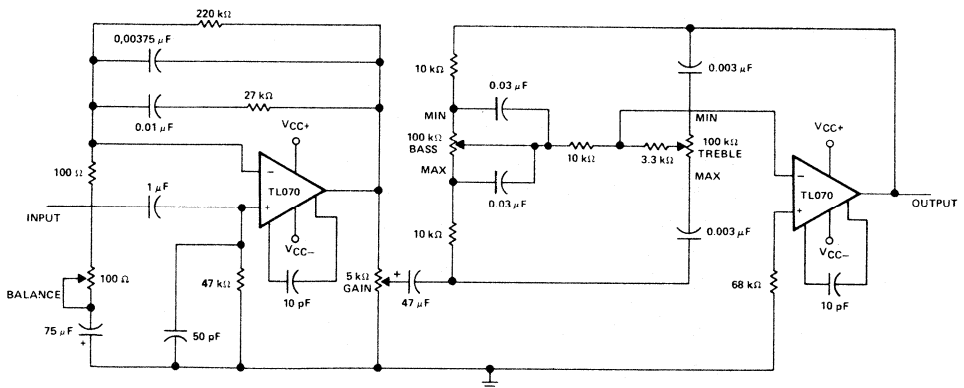
**FIGURE 29—100-KHz QUADRATURE OSCILLATOR**



**FIGURE 30—AC AMPLIFIER**



**FIGURE 31**



**FIGURE 32—IC PREAMPLIFIER**

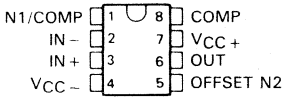
**3**  
**Operational Amplifiers**

**24 DEVICES COVER MILITARY, INDUSTRIAL AND COMMERCIAL TEMPERATURE RANGES**

- Low-Power Consumption
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- Low Total Harmonic Distortion . . . 0.003% TYP
- High Input Impedance . . . JFET-Input Stage
- Internal Frequency Compensation (Except TL080, TL080A)
- Latch-Up-Free Operation
- High Slew Rate . . . 13 V/μs Typ

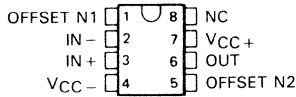
**TL080, TL080A**

JG OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



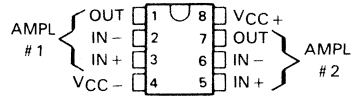
**TL081, TL081A, TL081B**

JG OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)

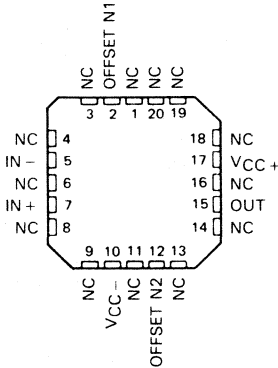


**TL082, TL082A, TL082B**

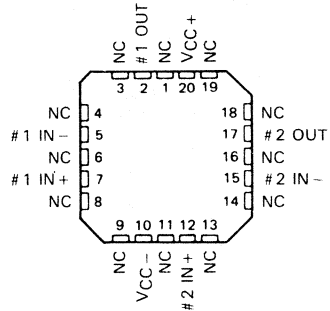
JG OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**TL081M . . . FH OR FK  
CHIP CARRIER PACKAGE  
(TOP VIEW)**



**TL082M . . . FH OR FK  
CHIP CARRIER PACKAGE  
(TOP VIEW)**



NC—No internal connection

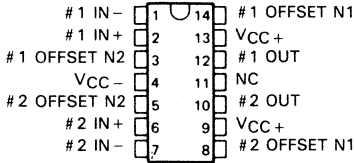
**DEVICE TYPES, SUFFIX VERSIONS, AND PACKAGES**

	TL080	TL081	TL082	TL083	TL084	TL085
TL08_M	JG	FH, FK, JG	FH, FK, JG	FH, FK, J	FH, FK, J, W	*
TL08_I	JG, P	JG, P	JG, P	J, N	J, N	*
TL08_C	JG, P	JG, P	JG, P	J, N	J, N	N
TL08_AC	JG, P	JG, P	JG, P	J, N	J, N	*
TL08_BC	*	JG, P	JG, P	*	J, N	*

\*These combinations are not defined by this data sheet.

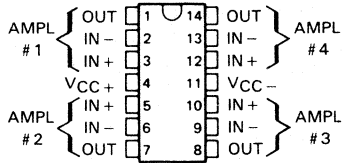
# TYPES TL080 THRU TL085, TL080A THRU TL084A TL081B, TL082B, TL084B JFET-INPUT OPERATIONAL AMPLIFIERS

TL083, TL083A  
J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)

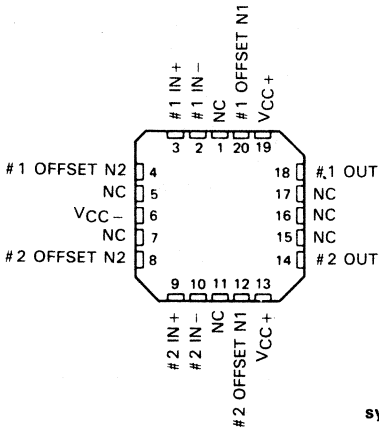


Pins 9 and 13 are internally interconnected

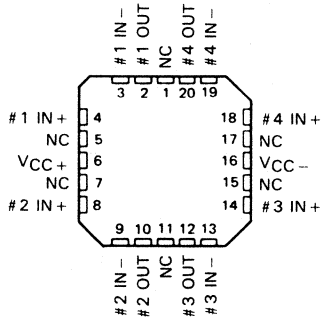
TL084, TL084A, TL084B  
J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



TL083M . . . FH OR FK  
CHIP CARRIER PACKAGE  
(TOP VIEW)

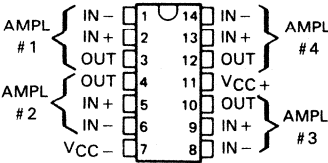


TL084M . . . FH OR FK  
CHIP CARRIER PACKAGE  
(TOP VIEW)



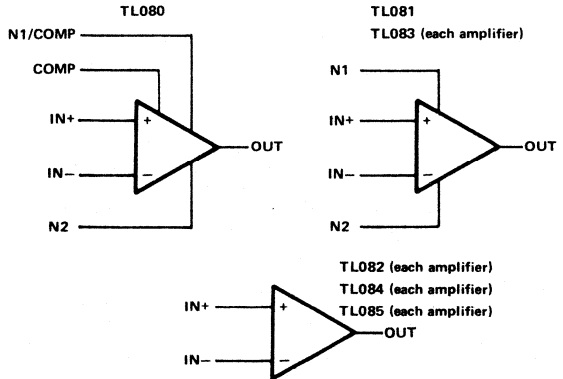
3  
Operational Amplifiers

TL085  
N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



NC—No internal connection

## symbols



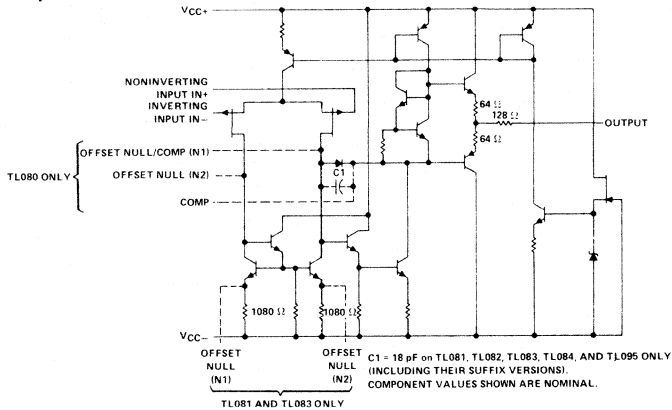
# TYPES TL080 THRU TL085, TL080A THRU TL084A TL081B, TL082B, TL084B JFET-INPUT OPERATIONAL AMPLIFIERS

## description

The TL08... JFET-input operational amplifier family is designed to offer a wider selection than any previously developed operational amplifier family. Each of these JFET-input operational amplifiers incorporates well-matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit. The devices feature high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient. Offset adjustment and external compensation options are available within the TL08... family.

Device types with an "M" suffix are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , those with an "I" suffix are characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and those with a "C" suffix are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## schematic (each amplifier)



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		TL08...M	TL08...I	TL08...C TL08...AC TL08...BC	UNIT
Supply voltage, $V_{CC+}$ (see Note 1)		18	18	18	V
Supply voltage, $V_{CC-}$ (see Note 1)		-18	-18	-18	V
Differential input voltage (see Note 2)		$\pm 30$	$\pm 30$	$\pm 30$	V
Input voltage (see Notes 1 and 3)		$\pm 15$	$\pm 15$	$\pm 15$	V
Duration of output short circuit (see Note 4)		unlimited	unlimited	unlimited	
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 5)		680	680	680	mW
Operating free-air temperature range		$-55$ to $125$	$-25$ to $85$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range		$-65$ to $150$	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	FH, FK, J, JG, or W package	300	300	300	$^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	N or P package		260	260	$^{\circ}\text{C}$

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.  
 4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.  
 5. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Curves in Section 2. In the J and JG packages, TL08...M chips are alloy-mounted; TL08...I, TL08...C, TL08...AC, and TL08...BC chips are glass-mounted.

# TYPES TL080M, TL081M, TL082M, TL083M, TL084M

## LOW-NOISE JFET-INPUT OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC} \pm = \pm 15$  V (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		TL080M, TL081M TL082M, TL083M			TL084M			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0$ , $R_S = 50 \Omega$	$T_A = 25^\circ\text{C}$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	3 6		3 9		15		mV
$\alpha_{VIO}$ Temperature coefficient of input offset voltage	$V_O = 0$ , $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	$R_S = 50 \Omega$	10		10				$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current‡	$V_O = 0$	$T_A = 25^\circ\text{C}$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	5 100		5 100		20		pA nA
$I_{IB}$ Input bias current‡	$V_O = 0$	$T_A = 25^\circ\text{C}$ $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	30 200		30 200		20		pA nA
$V_{ICR}$ Common-mode input voltage range	$T_A = 25^\circ\text{C}$		$\pm 11$	$\pm 12$	$\pm 11$	$\pm 12$			V
$V_{OM}$ Maximum peak output voltage swing	$T_A = 25^\circ\text{C}$ , $R_L = 10 \text{ k}\Omega$		$\pm 12$	$\pm 13.5$	$\pm 12$	$\pm 13.5$			V
	$T_A = -55^\circ\text{C to } 125^\circ\text{C}$ , $R_L \geq 10 \text{ k}\Omega$ $R_L \geq 2 \text{ k}\Omega$		$\pm 12$		$\pm 12$		$\pm 10$	$\pm 12$	
$A_{VD}$ Large-signal differential voltage amplification	$V_O = \pm 10$ V, $T_A = 25^\circ\text{C}$	$R_L \geq 2 \text{ k}\Omega$	25	200	25	200			V/mV
	$V_O = \pm 10$ V, $T_A = -55^\circ\text{C to } 125^\circ\text{C}$	$R_L \geq 2 \text{ k}\Omega$	15		15				
$B_1$ Unity-gain bandwidth	$T_A = 25^\circ\text{C}$		3		3				MHz
$r_i$ Input resistance	$T_A = 25^\circ\text{C}$		$10^{12}$		$10^{12}$				$\Omega$
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR} \text{ min.}$ , $R_S = 50 \Omega$	$V_O = 0$ , $T_A = 25^\circ\text{C}$	80	86	80	86			dB
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC} \pm / \Delta V_{IO}$ )	$V_{CC} = \pm 15$ V to $\pm 9$ V, $R_S = 50 \Omega$	$V_O = 0$ , $T_A = 25^\circ\text{C}$	80	86	80	86			dB
$I_{CC}$ Supply current (per amplifier)	No load, $T_A = 25^\circ\text{C}$	$V_O = 0$	1.4 2.8		1.4 2.8				mA
$V_{O1}/V_{O2}$ Crosstalk attenuation	$A_{VD} = 100$ , $T_A = 25^\circ\text{C}$		120		120				dB

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

‡ Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 18. Pulse techniques must be used that will maintain the junction temperatures as close to the ambient temperature as is possible.

3 Operational Amplifiers



**TYPES TL080 THRU TL085, TL080A THRU TL084A  
TL081B, TL082B, TL084B  
JFET-INPUT OPERATIONAL AMPLIFIERS**

electrical characteristics,  $V_{CC} \pm \pm 15 \text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL080I			TL080C			TL080AC			UNIT		
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX
$V_{IO}$	$V_O = 0$ , $R_S = 50 \Omega$	3	6	6	3	15	3	6	6	3	6	3	mV
$\alpha_{VIO}$	Temperature coefficient of input offset voltage	$T_A = 25^\circ\text{C}$ $R_S = 50 \Omega$			10			10			10		
		$T_A = 50 \Omega$ , $R_S = 50 \Omega$			7.5			7.5			7.5		
$I_{IO}$	$V_O = 0$	5	100	10	5	200	2	2	2	5	100	5	$\mu\text{A}$
$I_{IB}$	Common-mode input voltage range	$T_A = 25^\circ\text{C}$			10			10			10		
		$T_A = 25^\circ\text{C}$			20			20			20		
$V_{ICR}$	$V_O = 0$	30	200	20	30	400	10	10	10	30	200	30	$\mu\text{A}$
$V_{OM}$	Maximum peak output voltage swing	$T_A = 25^\circ\text{C}$			$\pm 11 \pm 12$			$\pm 11 \pm 12$			$\pm 11 \pm 12$		
		$R_L = 10 \text{ k}\Omega$			$\pm 12 \pm 13.5$			$\pm 12 \pm 13.5$			$\pm 12 \pm 13.5$		
AVD	Large-signal differential voltage amplification	$T_A = 25^\circ\text{C}$			$\pm 10 \pm 12$			$\pm 10 \pm 12$			$\pm 10 \pm 12$		
		$R_L = 2 \text{ k}\Omega$			$\pm 10 \pm 12$			$\pm 10 \pm 12$			$\pm 10 \pm 12$		
$B_1$	Unity-gain bandwidth	50	200	25	200	15	25	25	25	50	200	50	V/mV
$f_1$	Input resistance	25	25	25	15	15	15	15	15	25	25	25	$\Omega$
CMRR	Common-mode rejection ratio	$T_A = 25^\circ\text{C}$			3			3			3		
		$T_A = 25^\circ\text{C}$			$10^{12}$			$10^{12}$			$10^{12}$		
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{CC} \pm \Delta V_{IO}$ )	80	86	80	86	70	86	80	86	80	86	80	dB
$I_{CC}$	No load, $T_A = 25^\circ\text{C}$	80	86	80	86	70	86	80	86	80	86	80	mA
$V_{OS1/2}$	Crosstalk attenuation	1.4	2.8	1.4	2.8	1.4	2.8	1.4	2.8	1.4	2.8	1.4	dB
		120	120	120	120	120	120	120	120	120	120	120	dB

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for  $T_A$  is  $25^\circ\text{C}$  to  $85^\circ\text{C}$  for TL080 and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TL080-C, TL080-AC, and TL080-BC.  
 † Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive as shown in Figure 18. Pulse techniques must be used that will maintain the junction temperatures as close to the ambient temperature as is possible.

**TYPES TL080 THRU TL085, TL080A THRU TL084A  
TL081B, TL082B, TL084B  
JFET-INPUT OPERATIONAL AMPLIFIERS**

operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain $V_I = 10\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1	8	13		$\text{V}/\mu\text{s}$
$t_r$	Rise time $V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$		0.1		$\mu\text{s}$
	Overshoot factor $C_L = 100\text{ pF}$ , See Figure 1		10%		
$V_n$	Equivalent input noise voltage $R_S = 100\ \Omega$ , $f = 1\text{ kHz}$		18		$\text{nV}/\sqrt{\text{Hz}}$
			4		$\mu\text{V}$
$I_n$	Equivalent input noise current $R_S = 100\ \Omega$ , $f = 1\text{ kHz}$		0.01		$\text{pA}/\sqrt{\text{Hz}}$
THD	Total harmonic distortion $V_{O(\text{rms})} = 10\text{ V}$ , $R_L \geq 2\text{ k}\Omega$ , $R_S \leq 1\text{ k}\Omega$ , $f = 1\text{ kHz}$		0.003%		

**PARAMETER MEASUREMENT INFORMATION**

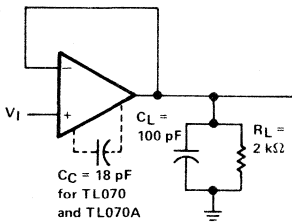


FIGURE 1—UNITY-GAIN AMPLIFIER

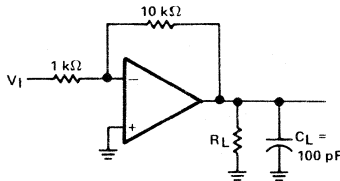


FIGURE 2—GAIN-OF-10 INVERTING AMPLIFIER

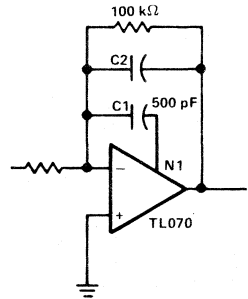


FIGURE 3—FEED-FORWARD COMPENSATION

**INPUT OFFSET VOLTAGE NULL CIRCUITS**

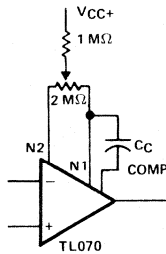


FIGURE 4

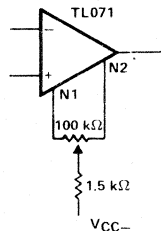


FIGURE 5

**3** Operational Amplifiers

# TYPES TL080 THRU TL085, TL080A THRU TL084A TL081B, TL082B, TL084B JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

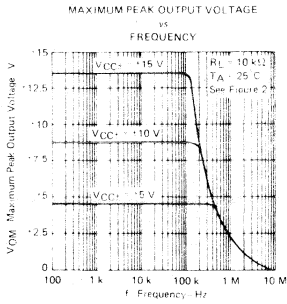


FIGURE 6

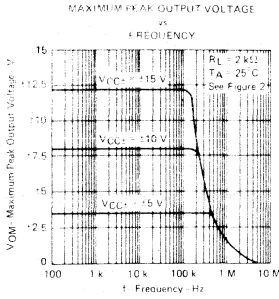


FIGURE 7

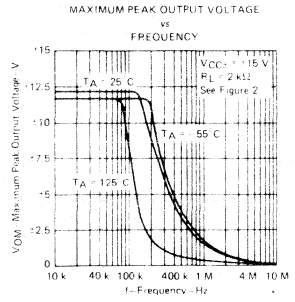


FIGURE 8

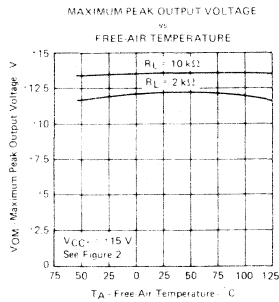


FIGURE 9

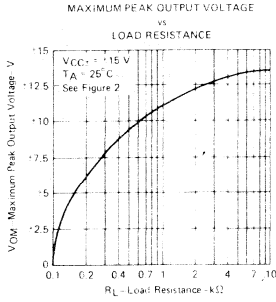


FIGURE 10

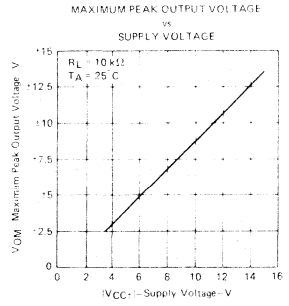


FIGURE 11

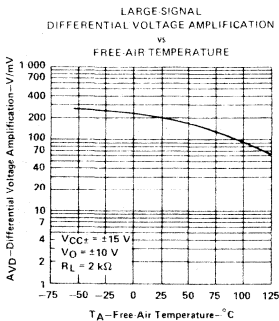


FIGURE 12

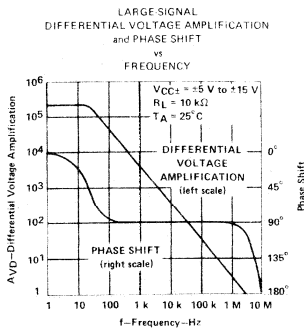


FIGURE 13

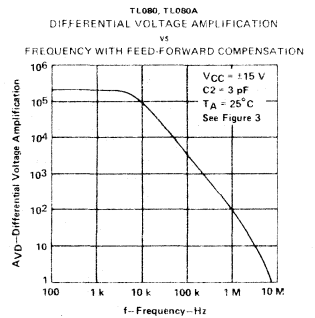


FIGURE 14

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 12 pF compensation capacitor is used with TL080 and TL080A.

# TYPES TL080 THRU TL085, TL080A THRU TL084A TL081B, TL082B, TL084B JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

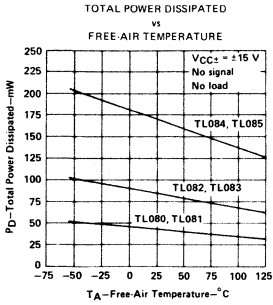


FIGURE 15

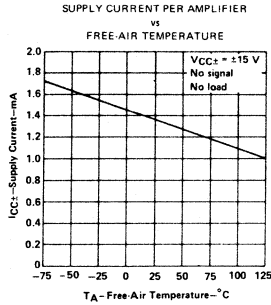


FIGURE 16

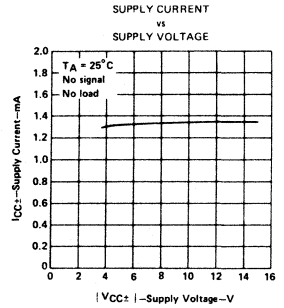


FIGURE 17

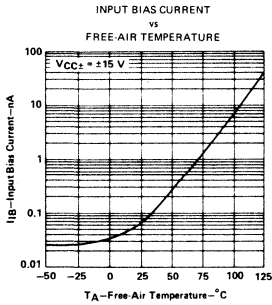


FIGURE 18

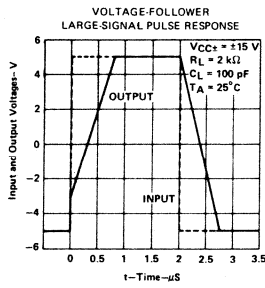


FIGURE 19

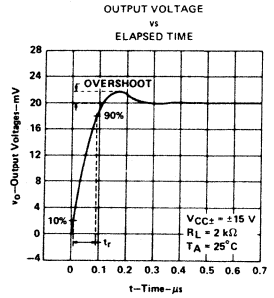


FIGURE 20

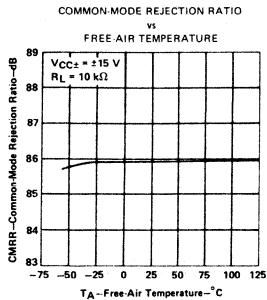


FIGURE 21

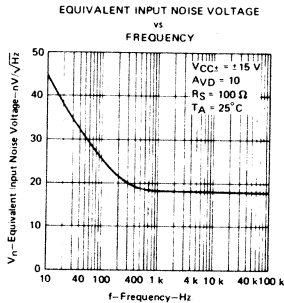


FIGURE 22

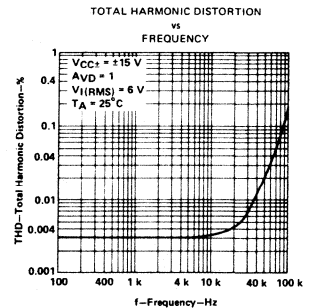


FIGURE 23

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. A 12-pF compensation capacitor is used with TL080 and TL080A.

3  
Operational Amplifiers

TYPES TL080 THRU TL085, TL080A THRU TL084A  
TL081B, TL082B, TL084B  
JFET-INPUT OPERATIONAL AMPLIFIERS

TYPICAL APPLICATION DATA

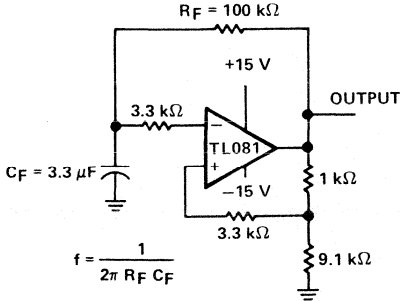


FIGURE 24—0.5-Hz SQUARE-WAVE OSCILLATOR

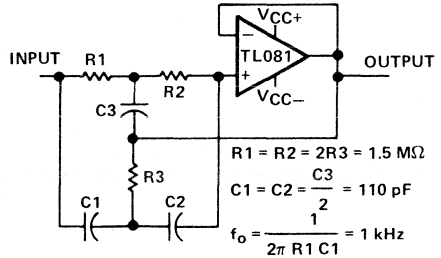


FIGURE 25—HIGH-Q NOTCH FILTER

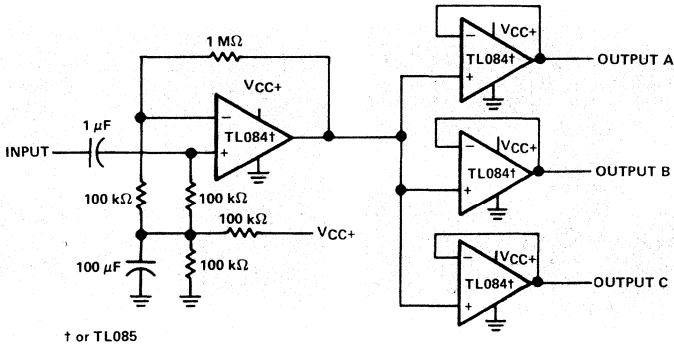


FIGURE 26—AUDIO DISTRIBUTION AMPLIFIER

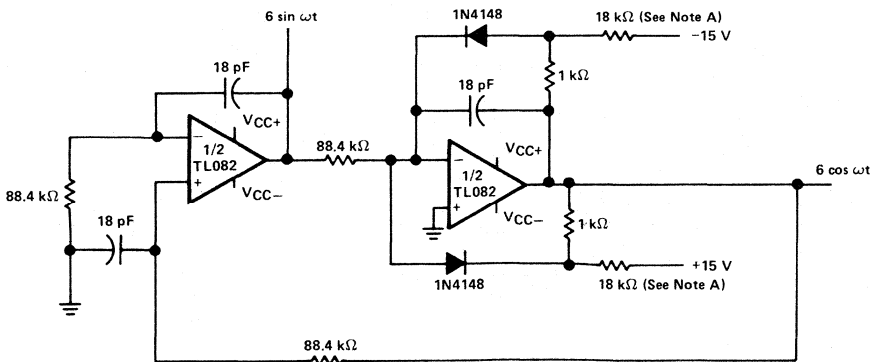
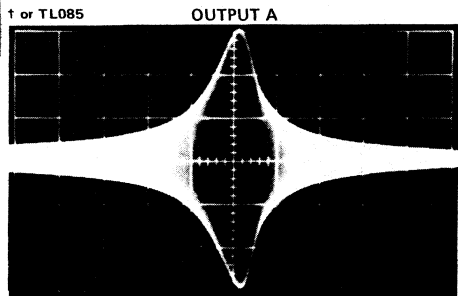
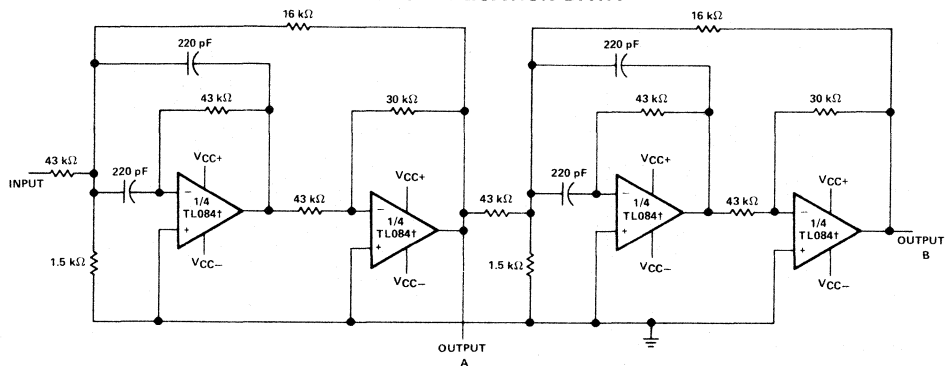


FIGURE 27—100-kHz QUADRATURE OSCILLATOR

**TYPES TL080 THRU TL085, TL080A THRU TL084A  
TL081B, TL082B, TL084B  
JFET-INPUT OPERATIONAL AMPLIFIERS**

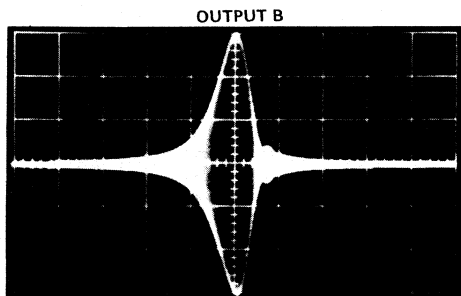
**TYPICAL APPLICATION DATA**



2 kHz/div

**SECOND-ORDER BANDPASS FILTER**

$f_o = 100 \text{ kHz}$ ,  $Q = 30$ ,  $\text{GAIN} = 4$

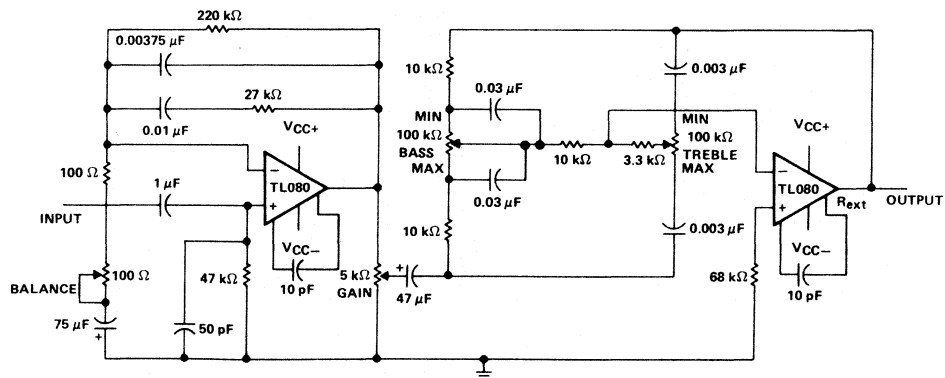


2 kHz/div

**CASCADED BANDPASS FILTER**

$f_o = 100 \text{ kHz}$ ,  $Q = 69$ ,  $\text{GAIN} = 16$

**FIGURE 28—POSITIVE-FEEDBACK BANDPASS FILTER**



**FIGURE 29—IC PREAMPLIFIER**

**3**

**Operational Amplifiers**

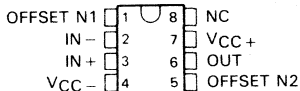
- Low Input Offset Voltage . . . 0.5 mV Max
- Low Power Consumption
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- High Input Impedance . . . JFET-Input Stage
- Internal Frequency Compensation
- Latch-Up-Free Operation
- High Slew Rate . . . 13 V/ $\mu$ s Typ
- Low Total Harmonic Distortion . . . 0.003% Typ

**description**

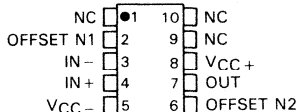
These JFET-input operational amplifiers incorporate well-matched high-voltage JFET and bipolar transistors in a monolithic integrated circuit. They feature low input offset voltage, high slew rate, low input bias and offset current, and low temperature coefficient of input offset voltage. Offset-voltage adjustment is provided for the TL087 and TL088.

Device types with an "M" suffix are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , those with an "I" suffix are characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and those with a "C" suffix are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

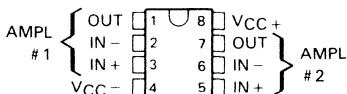
**TL087, TL088**  
D, JG, OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



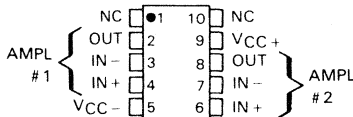
**TL088M**  
U FLAT PACKAGE  
(TOP VIEW)



**TL287, TL288**  
D, JG, OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)

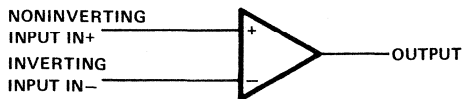


**TL288M**  
U FLAT PACKAGE  
(TOP VIEW)



NC--No internal connection

**symbol (each amplifier)**



# TYPES TL087, TL088, TL287, TL288

## JFET-INPUT OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		TL088M TL288M	TL087I TL088I TL287I TL288I	TL087C TL088C TL287C TL288C	UNIT
Supply voltage, $V_{CC+}$ (see Note 1)		18	18	18	V
Supply voltage, $V_{CC-}$ (see Note 1)		-18	-18	-18	V
Differential input voltage (see Note 2)		$\pm 30$	$\pm 30$	$\pm 30$	V
Input voltage (see Notes 1 and 3)		$\pm 15$	$\pm 15$	$\pm 15$	V
Duration of output short circuit (see Note 4)		unlimited	unlimited	unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)	JG or P package	680	680	680	mW
	U package	675			
	D package		725	725	
Operating free-air temperature range		-55 to 125	-25 to 85	0 to 70	°C
Storage temperature range		-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	JG or U package	300	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or P package		260	260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the JG package, TL088M and TL288M chips are alloy-mounted; TL087I, TL088I, TL287I, TL288I, TL087C, TL088C, TL287C, and TL288C chips are glass-mounted.



# TYPES TL087, TL088, TL287, TL288 JFET-INPUT OPERATIONAL AMPLIFIERS

electrical characteristics,  $V_{CC} \pm = \pm 15\text{ V}$

PARAMETER	TEST CONDITIONS†		TL088M TL288M		TL087I TL088I TL287I TL288I			TL087C TL088C TL287C TL288C			UNIT		
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP		MAX	
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$ , $V_O = 0$ , $T_A = 25^\circ\text{C}$	TL087, TL287			0.1	0.5	1	0.1	0.5	0.1	0.5		
	$R_S = 50\ \Omega$ , $V_O = 0$ , $T_A = \text{full range}$	TL088, TL288	0.1	3	0.1	1	2	0.1	1	0.1	1	mV	
	$R_S = 50\ \Omega$ , $V_O = 0$ , $T_A = \text{full range}$	TL087, TL287					2				1.5		
	$R_S = 50\ \Omega$ , $V_O = 0$ , $T_A = \text{full range}$	TL088, TL288			6		3				2.5		
$e_{VIO}$ Temperature coefficient of input offset voltage	$R_S = 50\ \Omega$ , $T_A = 25^\circ\text{C}$	$T_A = \text{full range}$	10		10			10		10		$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$ Input offset current	$T_A = 25^\circ\text{C}$		5	100	5	100	3	5	100	5	100	pA	
$I_{IB}$ Input bias current‡	$T_A = 25^\circ\text{C}$	$T_A = \text{full range}$	30	400	30	200	30	200	30	200	30	200	pA
	$T_A = 25^\circ\text{C}$	$T_A = \text{full range}$	100		100		20	20		20		7	nA
$V_{ICR}$ Common-mode input voltage range	$T_A = 25^\circ\text{C}$		$V_{CC-} + 4$ to $V_{CC+} - 4$		$V_{CC-} + 4$ to $V_{CC+} - 4$		$V_{CC-} + 4$ to $V_{CC+} - 4$		$V_{CC-} + 4$ to $V_{CC+} - 4$		$V_{CC-} + 4$ to $V_{CC+} - 4$	V	
$V_{OPP}$ Maximum-peak-to-peak output voltage swing	$T_A = 25^\circ\text{C}$ , $R_L = 10\ \text{k}\Omega$		24	27	24	27	24	27	24	27	24	27	V
	$T_A = \text{full range}$ , $R_L \geq 10\ \text{k}\Omega$		24		24		24		24		24		V
$A_{VD}$ Large-signal differential voltage amplification	$R_L \geq 2\ \text{k}\Omega$ , $T_A = 25^\circ\text{C}$	$V_O = \pm 10\ \text{V}$ , $V_O = \pm 10\ \text{V}$	50	200	50	200	50	200	50	200	50	200	V/mV
	$R_L \geq 2\ \text{k}\Omega$ , $T_A = 25^\circ\text{C}$	$V_O = \pm 10\ \text{V}$ , $V_O = \pm 10\ \text{V}$	25		25		25		25		25		V/mV
$B_1$ Unity-gain bandwidth	$T_A = 25^\circ\text{C}$		3		3		3		3		3	MHz	
$f_t$ Input resistance	$T_A = 25^\circ\text{C}$		10 <sup>12</sup>		10 <sup>12</sup>		10 <sup>12</sup>		10 <sup>12</sup>		10 <sup>12</sup>	$\Omega$	
$CMRR$ Common-mode rejection ratio	$R_S = 50\ \Omega$ , $V_{IC} = V_{ICR\ \text{min}}$ , $T_A = 25^\circ\text{C}$	$V_O = 0$ , $T_A = 25^\circ\text{C}$	80	95	80	95	80	95	80	95	80	95	dB
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ )	$R_S = 50\ \Omega$ , $V_{CC\pm} = \pm 9\ \text{V}$ to $\pm 15\ \text{V}$ , $T_A = 25^\circ\text{C}$	$V_O = 0\ \text{V}$ , $T_A = 25^\circ\text{C}$	80	95	80	95	80	95	80	95	80	95	dB
$I_{CC}$ Supply current (per amplifier)	No load, $T_A = 25^\circ\text{C}$	$V_O = 0$ , $T_A = 25^\circ\text{C}$	1.4	2.8	1.4	2.8	1.4	2.8	1.4	2.8	1.4	2.8	mA

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for  $T_A$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for TL<sub>xxx</sub>M;  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for TL<sub>xxx</sub>I; and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TL<sub>xxx</sub>C.

‡ Input bias currents of a JFET-input operational amplifier are normal junction reverse currents, which are temperature sensitive. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.



# TYPES TL087, TL088, TL287, TL288

## JFET-INPUT OPERATIONAL AMPLIFIERS

operating characteristics  $V_{CC} = \pm 15 \text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR Slew rate at unity gain	$V_I = 10 \text{ V}$ , $R_L = 2 \text{ k}\Omega$ , $C_L = 100 \text{ pF}$ , $A_{VD} = 1$	8	13		$\text{V}/\mu\text{s}$
$t_r$ Rise time	$V_I = 20 \text{ mV}$ , $R_L = 2 \text{ k}\Omega$ , $C_L = 100 \text{ pF}$ , $A_{VD} = 1$		0.1		$\mu\text{s}$
Overshoot factor	$R_S = 100 \Omega$ , $f = 1 \text{ kHz}$		10%		
$V_n$ Equivalent input noise voltage	$R_S = 100 \Omega$ , $f = 1 \text{ kHz}$		18		$\text{nV}/\sqrt{\text{Hz}}$

### TYPICAL CHARACTERISTICS†

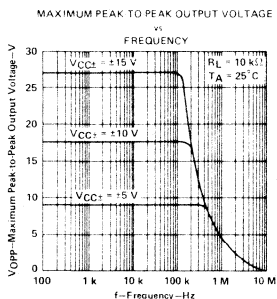


FIGURE 1

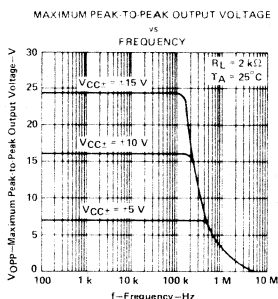


FIGURE 2

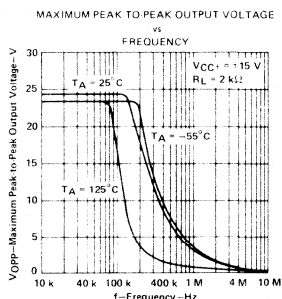


FIGURE 3

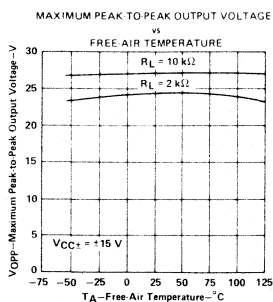


FIGURE 4

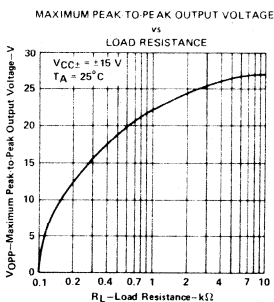


FIGURE 5

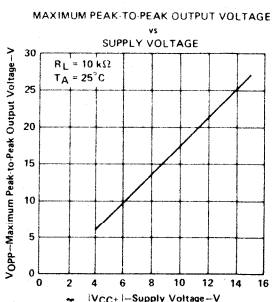
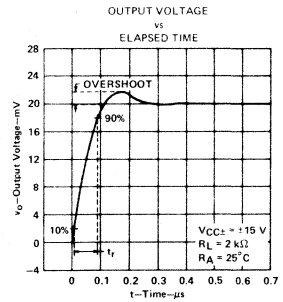
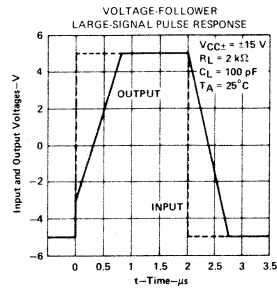
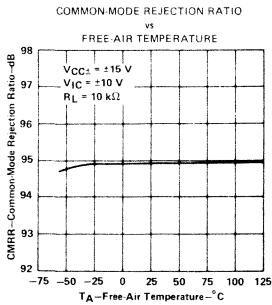
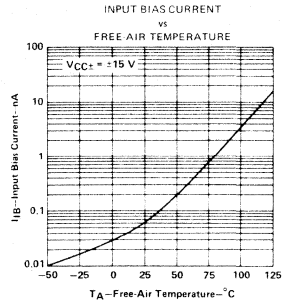
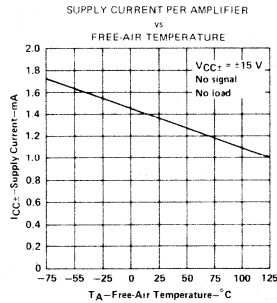
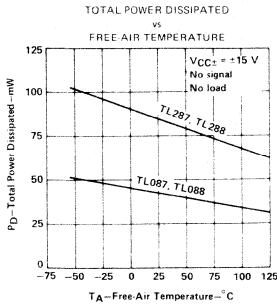
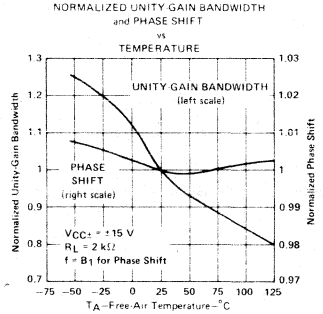
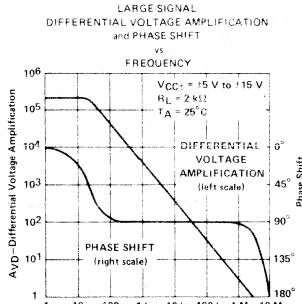
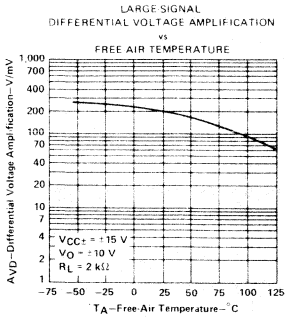


FIGURE 6

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

# TYPES TL087, TL088, TL287, TL288 JFET-INPUT OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†



†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

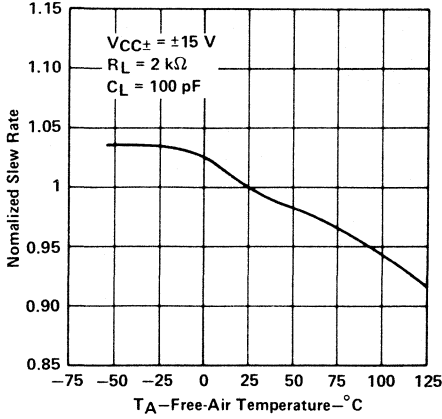


Operational Amplifiers

**TYPES TL087, TL088, TL287, TL288  
JFET-INPUT OPERATIONAL AMPLIFIERS**

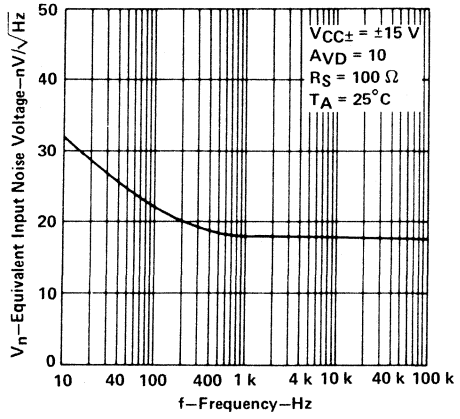
**TYPICAL CHARACTERISTICS†**

**NORMALIZED SLEW RATE  
vs  
TEMPERATURE**



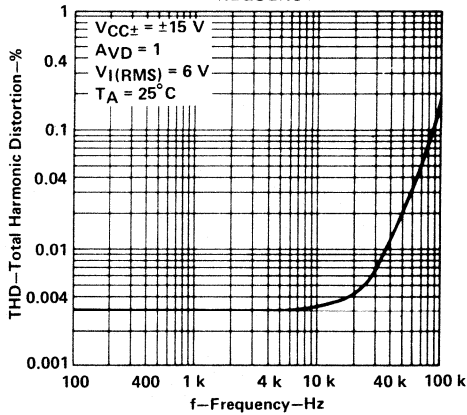
**FIGURE 16**

**EQUIVALENT INPUT NOISE VOLTAGE  
vs  
FREQUENCY**



**FIGURE 17**

**TOTAL HARMONIC DISTORTION  
vs  
FREQUENCY**



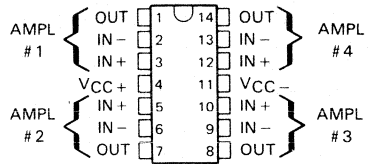
**FIGURE 18**

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

**3** Operational Amplifiers

- Continuous-Short Circuit Protection
- Wide Common-Mode and Differential Voltage Ranges
- No Frequency Compensation Required
- Low Power Consumption
- No Latch-up
- Unity-Gain Bandwidth 3 MHz Typical
- Gain and Phase Match Between Amplifiers

D, J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



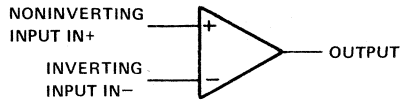
**description**

The TL136C is a quad high-performance operational amplifier with each amplifier electrically similar to uA741 except that offset null capability is not provided.

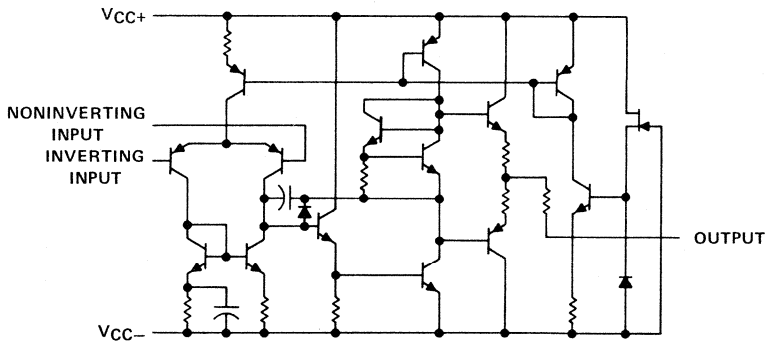
The high common-mode input voltage range and the absence of latch-up make these amplifiers ideal for voltage-follower applications. The devices are short-circuit protected and the internal frequency compensation ensures stability without external components.

The TL136C is characterized for operation from 0°C to 70°C.

**symbol (each amplifier)**



**schematic (each amplifier)**



# TYPE TL136C

## QUAD HIGH-PERFORMANCE OPERATIONAL AMPLIFIER

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage $V_{CC+}$ (see Note 1) . . . . .	18 V
Supply voltage $V_{CC-}$ (see Note 1) . . . . .	-18 V
Differential input voltage (see Note 2) . . . . .	$\pm 30$ V
Input voltage (any input, see Notes 1 and 3) . . . . .	$\pm 15$ V
Duration of output short-circuit to ground, one amplifier at a time (see Note 4) . . . . .	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5) . . . . .	800 mW
Operating free-air temperature range . . . . .	0°C to 70°C
Storage temperature range . . . . .	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package . . . . .	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, N package . . . . .	260°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves in Section 2. In the J package, the chips are glass-mounted.

**3**

**Operational Amplifiers**

# TYPE TL136C QUAD HIGH-PERFORMANCE OPERATIONAL AMPLIFIER

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
$V_{IO}$	Input offset voltage	$V_O = 0$ , $R_S = 50\ \Omega$	25°C	0.5	6	mV	
			0°C to 70°C		7.5		
$I_{IO}$	Input offset current	$V_O = 0$	25°C	5	200	nA	
			0°C to 70°C		300		
$I_{IB}$	Input bias current	$V_O = 0$	25°C	40	500	nA	
			0°C to 70°C		800		
$V_{ICR}$	Common-mode input voltage range		25°C	±12	±14	V	
$V_{OPP}$	Maximum peak-to-peak output voltage swing	$R_L = 10\text{ k}\Omega$	25°C	24	28	V	
		$R_L = 2\text{ k}\Omega$	25°C	20	26		
		$R_L \geq 2\text{ k}\Omega$	0°C to 70°C	20			
$A_{VD}$	Large-signal differential voltage amplification	$R_L \geq 2\text{ k}\Omega$ , $V_O = \pm 10\text{ V}$	25°C	20	300	V/mV	
			0°C to 70°C	15			
$B_1$	Unity-gain bandwidth		25°C	3		MHz	
$r_i$	Input resistance		25°C	0.3	5	M $\Omega$	
$CMRR$	Common-mode rejection ratio	$V_{IC} = V_{ICR}\text{ min.}$ , $R_S = 50\ \Omega$	25°C	70	90	dB	
$k_{SVS}$	Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$V_{CC\pm} = \pm 9\text{ V to } \pm 15\text{ V}$ , $R_S = 50\ \Omega$	25°C	30	150	$\mu\text{V/V}$	
$V_n$	Equivalent input noise voltage (closed-loop)	$A_{VD} = 100$ , $f = 1\text{ kHz}$ , $R_S = 100\ \Omega$ , $BW = 1\text{ Hz}$	25°C	7.5		$\text{nV}/\sqrt{\text{Hz}}$	
$I_{CC}$	Supply current (All four amplifiers)	No load, $V_O = 0\text{ V}$	25°C	5	11.3	mA	
			0°C	6	13.7		
			70°C	4.5	11.3		
$P_D$	Total power dissipation (All four amplifiers)	No load, $V_O = 0\text{ V}$	25°C	150	340	mW	
			0°C	180	400		
			70°C	135	300		
$V_{o1}V_{o2}$	Crosstalk attenuation Open loop $A_{VD}$	$R_S = 1\text{ k}\Omega$ , $f = 10\text{ kHz}$	25°C	105		dB	
			25°C	105			

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_r$	Rise time	$V_I = 20\text{ mV}$ , $C_L = 100\text{ pF}$	$R_L = 2\text{ k}\Omega$		0.13		$\mu\text{s}$
SR	Slew rate at unity gain	$V_I = 10\text{ V}$ , $C_L = 100\text{ pF}$	$R_L = 2\text{ k}\Omega$		2.0		$\text{V}/\mu\text{s}$

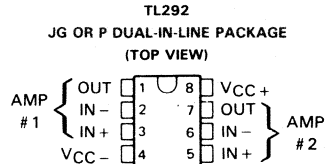
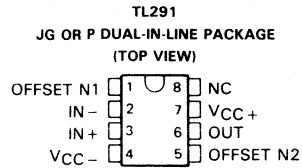
3

Operational Amplifiers

## **3** Operational Amplifiers



- **Small-Signal Unity-Gain Bandwidth**  
... 20 MHz Typ
- **Noninverting Slew Rate** ... 50 V/ $\mu$ s Typ  
(Unity-Gain Follower)
- **Internal Frequency Compensation**
- **Full-Power Bandwidth at  $V_{Opp} = 20$  V**  
... 400 kHz Typ
- **Open-Loop Gain at Full-Power Bandwidth,**  
 $V_{Opp} = 20$  V ... 34 dB Typ
- **Output Short-Circuit Protection**
- **TL291 Has Offset Null Capability**
- **Pinout is Same as Standard General Purpose  
Operational Amplifiers**



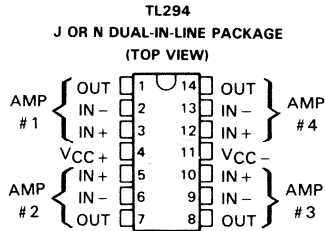
**description**

These devices are high-speed operational amplifiers designed for applications requiring wide bandwidth and a fast slew rate. These monolithic circuits incorporate new high-frequency P-N-P transistors that eliminate the need for large feed-forward capacitors required in previous moderately high-frequency designs to pass the signal around slow lateral P-N-P stages.

These operational amplifiers have a typical full-power bandwidth of 400 kilohertz for a 20-volt peak-to-peak output swing, because of the higher 20-megahertz unity-gain bandwidth, the typical open-loop gain at the 400-kilohertz full-power bandwidth is a very respectable 34 decibels.

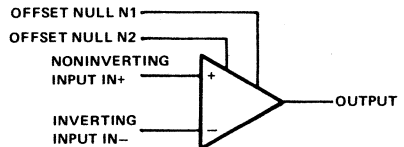
The TL291 single-channel operational amplifier pinout includes offset nulling, which is easily accomplished by connecting a potentiometer across the offset null pins with the wiper connected to the  $V_{CC-}$  pin.

The TL291M, TL292M, and TL294M will be characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The TL291C, TL292C, and TL294C will be characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .



NC—No internal connection

**symbol (each amplifier)**

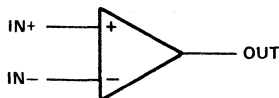


**3**

**Operational Amplifiers**

- **Wide Range of Supply Voltages Single Supply . . . 3 V to 30 V or Dual Supplies**
- **Low Supply Current Drain Independent of Supply Voltage . . . 0.8 mA Typ**
- **Common-Mode Input Voltage Range Includes Ground Allowing Direct Sensing near Ground**
- **Low Input Bias and Offset Parameters  
Input Offset Voltage . . . 2 mV TYP  
Input Offset Current . . . 3 nA Typ (TL321M)  
Input bias Current . . . 45 nA Typ**
- **Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . .  $\pm 32$  V**
- **Open-Loop Differential Voltage Amplification . . . 100 V/mV Typ**
- **Internal Frequency Compensation**

symbol



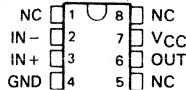
description

The TL321 is a high-gain, frequency-compensated operational amplifier that was designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies is also possible so long as the difference between the two supplies is 3 volts to 30 volts and Pin 7 is at least 1.5 volts more positive than the input common-mode voltage. The low supply current drain is independent of the magnitude of the supply voltage.

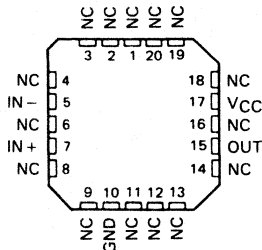
Applications include transducer amplifiers, d-c amplification blocks, and all the conventional operational amplifier circuits that now can be more easily implemented in single-supply-voltage systems. For example, the TL321 can be operated directly off of the standard five-volt supply that is used in digital systems and will easily provide the required interface electronics without requiring additional  $\pm 15$ -volt supplies.

The TL321M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The TL321I is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The TL321C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

TL321M . . . JG  
TL321I, TL321C . . . JG OR P  
DUAL-IN-LINE PACKAGE  
(TOP VIEW)



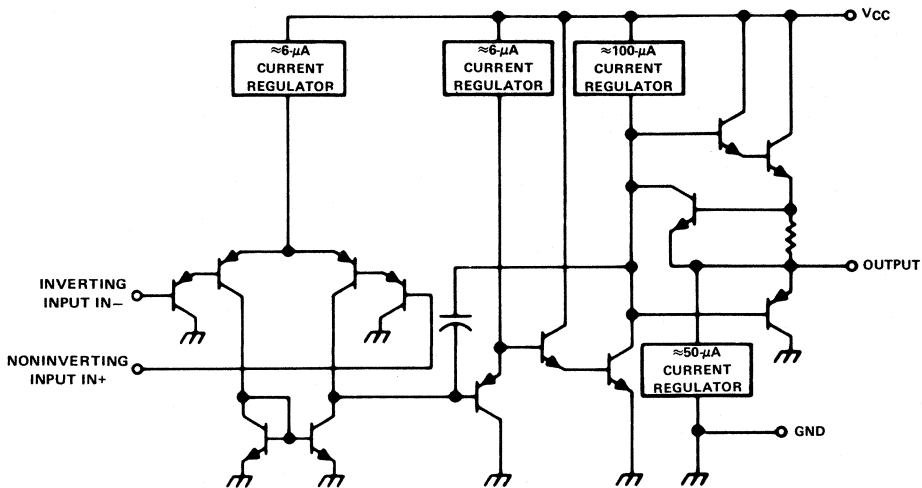
TL321M . . . FH OR FK  
CHIP CARRIER PACKAGE  
(TOP VIEW)



NC—No internal connection

# TYPES TL321M, TL321I, TL321C OPERATIONAL AMPLIFIERS

schematic



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	32 V
Differential input voltage (see Note 2)	$\pm 32$ V
Input voltage range (either input)	-0.3 V to 32 V
Duration of output short-circuit to ground at (or below) 25°C free-air temperature ( $V_{CC} \leq 15$ V) (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	680 mW
Operating free-air temperature range: TL321M	-55°C to 125°C
TL321I	-25°C to 85°C
TL321C	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: FH, FK, or JG package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: P package	260°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.

2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.

3. Short circuits from the output to  $V_{CC}$  can cause excessive heating and eventual destruction.

4. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the JG package, TL321M chips are alloy-mounted; TL321I and TL321C chips are glass-mounted.

# TYPES TL321M, TL321I, TL321C OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL321M, TL321I			TL321C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{IC} = V_{ICR\ min}$ , $V_{CC} = 5\text{ V to }30\text{ V}$ , $V_O = 1.4\text{ V}$ , $R_S = 50\text{ k}\Omega$	25°C	2	5	2	7	mV	
		Full range		7		9		
$I_{IO}$ Input offset current	$V_O = 1.4\text{ V}$	25°C	3	30	5	50	nA	
		Full range		100		150		
$I_{IB}$ Input bias current	$V_O = 1.4\text{ V}$	25°C	-45	-150	-45	-250	nA	
		Full range		-300		-500		
$V_{ICR}$ Common-mode input voltage range	$V_{CC} = 5\text{ V to }30\text{ V}$	25°C	0 to $V_{CC} - 1.5$		0 to $V_{CC} - 1.5$		V	
		Full range	0 to $V_{CC} - 2$		0 to $V_{CC} - 2$			
$V_{OH}$ High-level output voltage	$V_{CC} = 30\text{ V}$ , $R_L = 2\text{ k}\Omega$	Full range	26		26		V	
	$V_{CC} = 30\text{ V}$ , $R_L \geq 10\text{ k}\Omega$	Full range	27	28	27	28		
	$R_L \geq 2\text{ k}\Omega$	25°C	3.5		3.5			
$V_{OL}$ Low-level output voltage	$R_L \leq 10\text{ k}\Omega$	Full range		5	20	5	20	mV
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$ , $V_O = 1\text{ V to }11\text{ V}$ , $R_L \geq 2\text{ k}\Omega$	25°C	50	100	25	100	V/mV	
		Full range	25		15			
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR\ min}$ , $R_S = 50\ \Omega$	25°C	70	85	65	85	dB	
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{CC} = 5\text{ V to }30\text{ V}$ , $R_S = 50\ \Omega$	25°C	65	100	65	100	dB	
$I_O$ Output current	Source	25°C	-25	-40	-20	-40	mA	
		Full range	-10	-20	-10	-20		
	Sink	25°C	10	20	10	20		
		Full range	5	8	5	8		
	$V_{ID} = -1\text{ V}$ , $V_O = 200\text{ mV}$	25°C	12	50	12	50	$\mu\text{A}$	
$I_{CC}$ Supply current	No load $V_O = 15\text{ V}$ , $V_{CC} = 30\text{ V}$	Full range		2		2	mA	
	No load $V_O = 2.5\text{ V}$ , $V_{CC} = 5\text{ V}$	Full range	0.4	1		1		

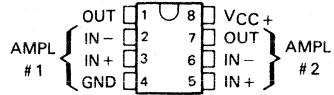
† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range is -55°C to 125°C for TL321M, -25°C to 85°C for TL321I, and 0°C to 70°C for TL321C.

# 3

## Operational Amplifiers

- Wide Range of Supply Voltages  
Single Supply . . . 3 V to 36 V or  
Dual Supplies
- Class AB Output Stage
- True Differential Input Stage
- Low Input Bias Current
- Internal Frequency Compensation
- Short-Circuit Protection

TL322M . . . JG PACKAGE  
TL322I, TL322C . . . D, JG, OR P PACKAGE  
(TOP VIEW)

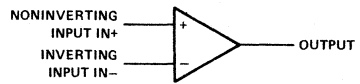


**description**

The TL322M, TL322I, and the TL322C are dual operational amplifiers similar in performance to the MC3403. They are designed to operate from a single supply over a range of voltages from 3 volts to 36 volts. Operation from split supplies is also possible provided the difference between the two supplies is 3 volts to 36 volts. The common-mode input range includes the negative supply. Output range is from the negative supply to  $V_{CC} - 1.5$  V. Quiescent supply currents per amplifier are typically less than one-half those of the uA741.

The TL322M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The TL322I is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The TL322C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**symbol (each amplifier)**



**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

	TL322M	TL322I	TL322C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	18	18	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-18	-18	-18	V
Supply voltage $V_{CC+}$ with respect to $V_{CC-}$	36	36	36	V
Differential input voltage (see Note 2)	$\pm 36$	$\pm 36$	$\pm 36$	V
Input voltage (see Notes 1 and 3)	$\pm 18$	$\pm 18$	$\pm 18$	V
Continuous total power dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 4)	680	680	680	mW
Operating free-air temperature range	$-55$ to $125$	$-40$ to $85$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature $1,6$ mm (1/16 inch) from case for 60 seconds	JG package	300	300	$^{\circ}\text{C}$
Lead temperature $1,6$ mm (1/16 inch) from case for 10 seconds	D or P package	260	260	$^{\circ}\text{C}$

- NOTES: 1. These voltage values are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Neither input must ever be more positive than  $V_{CC+}$  or more negative than  $V_{CC-}$ .  
 4. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Curves in Section 2. In the JG package, TL322M chips are alloy mounted and TL322I and TL322C chips are glass mounted.

# TYPES TL322M, TL322I, TL322C

## DUAL LOW-POWER OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC} \pm = \pm 15 \text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		TL322M			TL322I			TL322C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0,$ $R_S = 50 \Omega$	25 °C	2 8			2 8			2 10			mV
		Full range	10			10			12			
$\alpha_{VIO}$ Temperature coefficient of input offset voltage	$V_O = 0,$ $R_S = 50 \Omega$	25 °C	10			10			10			$\mu\text{V}/^\circ\text{C}$
$I_{IO}$ Input offset current	$V_O = 0$	25 °C	30 75			30 75			30 50			nA
		Full range	250			250			200			
$\alpha_{IIO}$ Temperature coefficient of input offset current	$V_O = 0$	25 °C	50			50			50			$\text{pA}/^\circ\text{C}$
$I_B$ Input bias current	$V_O = 0$	25 °C	-0.2 -0.5			-0.2 -0.5			-0.2 -0.5			$\mu\text{A}$
		Full range	-1.15			-1			-0.8			
$V_{ICR}$ Common-mode input voltage range‡		25 °C	$V_{CC-}$ to 13	$V_{CC-}$ to 13.5		$V_{CC-}$ to 13	$V_{CC-}$ to 13.5		$V_{CC-}$ to 13	$V_{CC-}$ to 13.5	V	
$V_{OM}$ Peak output voltage swing	$R_L = 10 \text{ k}\Omega$ $R_L = 2 \text{ k}\Omega$	25 °C	$\pm 12 \pm 13.5$			$\pm 12 \pm 12.5$			$\pm 12 \pm 13.5$			V
		25 °C	$\pm 10 \pm 13$			$\pm 10 \pm 12$			$\pm 10 \pm 13$			
		Full range	$\pm 10$			$\pm 10$			$\pm 10$			
$A_{VD}$ Large-signal differential voltage amplification	$V_O = \pm 10 \text{ V},$ $R_L = 2 \text{ k}\Omega$	25 °C	200			20 200			20 200			V/mV
		Full range	25			15			15			
$B_{OM}$ Maximum-output swing bandwidth	$V_{OPP} = 20 \text{ V},$ $A_{VD} = 1,$ $\text{THD} \leq 5\%,$ $R_L = 2 \text{ k}\Omega$	25 °C	9			9			9			kHz
$B_1$ Unity-gain bandwidth	$V_O = 50 \text{ mV},$ $R_L = 10 \text{ k}\Omega$	25 °C	1			1			1			MHz
$\phi_m$ Phase margin	$R_L = 2 \text{ k}\Omega,$ $C_L = 200 \text{ pF}$	25 °C	60°			60°			60°			
$r_i$ Input resistance	$f = 20 \text{ Hz}$	25 °C	0.3	1		0.3	1		0.3	1	M $\Omega$	
$r_o$ Output resistance	$f = 20 \text{ Hz}$	25 °C	75			75			75			$\Omega$
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR} \text{ min},$ $R_S = 50 \Omega$	25 °C	70	90		70	90		70	90	dB	
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$V_{CC} = \pm 2.5 \text{ V}$ to $\pm 15 \text{ V},$ $R_S = 50 \Omega$	25 °C	30 150			30 150			30 150			$\mu\text{V}/\text{V}$
$I_{OS}$ Short-circuit output current§	$V_O = 0$	25 °C	$\pm 10$	$\pm 30$	$\pm 45$	$\pm 10$	$\pm 30$	$\pm 45$	$\pm 10$	$\pm 30$	$\pm 45$	mA
$I_{CC}$ Total supply current	$V_O = 0,$ No load	25 °C	1.4 2.5			1.4 4			1.4 4			mA

† All characteristics are specified under open-loop conditions unless otherwise noted. Full range for  $T_A$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for TL322M;  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for TL322I, and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TL322C.

‡ The  $V_{ICR}$  limits are directly linked volt-for-volt to supply voltage, viz the positive limit is 2 volts less than  $V_{CC+}$ .

§ Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

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Operational Amplifiers



# TYPES TL322M, TL322I, TL322C DUAL LOW-POWER OPERATIONAL AMPLIFIERS

**electrical characteristics,  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = 0\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS <sup>1</sup>	TL322M			TL322I			TL322C			UNIT		
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX			
$V_{IO}$	Input offset voltage $V_O = 2.5\text{ V}$ , $R_S = 50\ \Omega$		2	8			8		2	10	mV		
$I_{IO}$	Input offset current $V_O = 2.5\text{ V}$		30	75			75		30	50	nA		
$I_{IB}$	Input bias current		-0.2	-0.5			-0.5		-0.2	-0.5	pA		
$V_{OM}$	Peak output voltage swing <sup>‡</sup> $R_L = 10\text{ k}\Omega$ , $R_L = 10\text{ k}\Omega$ , $V_{CC+} = 5\text{ V to } 30\text{ V}$		3.3	3.5			3.3	3.5			3.3	3.5	V
$A_{VD}$	Large-signal differential voltage amplification $V_O = 1.7\text{ V to } 3.3\text{ V}$ , $R_L = 2\text{ k}\Omega$		20	200			20	200			20	200	V/mV
$k_{SVS}$	Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC\pm}$ ) $V_{CC} = \pm 2.5\text{ V to } \pm 15\text{ V}$			150			150			150			$\mu\text{V/V}$
$I_{CC}$	Supply current $V_O = 2.5\text{ V}$ , No load		1.2	2.5			1.2	4			1.2	4	mA
$V_{O1}/V_{O2}$	Crosstalk attenuation $A_{VD} = 100$ , $f = 1\text{ kHz to } 20\text{ kHz}$		120				120				120		dB

<sup>†</sup>All characteristics are specified under open-loop conditions.

<sup>‡</sup>Output will swing essentially to ground.

**switching characteristics:  $V_{CC\pm} = \pm 15\text{ V}$ ,  $A_{VD} = 1$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS			MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain $V_I = \pm 10\text{ V}$ , $C_L = 100\text{ pF}$		See Figure 1		0.6		V/ $\mu\text{s}$
$t_r$	Rise time $\Delta V_O = 50\text{ mV}$ , $C_L = 100\text{ pF}$ , $R_L = 10\text{ k}\Omega$				0.35		$\mu\text{s}$
$t_f$	Fall time See Figure 1				0.35		$\mu\text{s}$
	Overshoot factor				20%		
	Crossover distortion $V_{Ipp} = 30\text{ mV}$ , $V_{Opp} = 2\text{ V}$ , $f = 10\text{ kHz}$				1%		

## PARAMETER MEASUREMENT INFORMATION

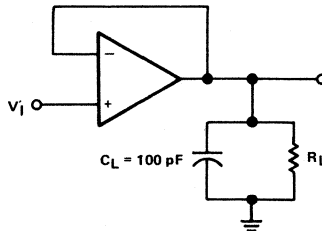


FIGURE 1—UNITY-GAIN AMPLIFIER

# TYPES TL322M, TL322I, TL322C DUAL LOW-POWER OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS†

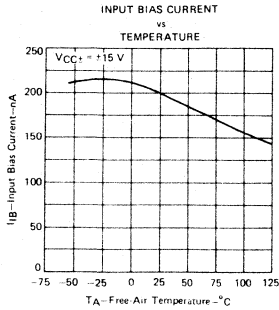


FIGURE 2

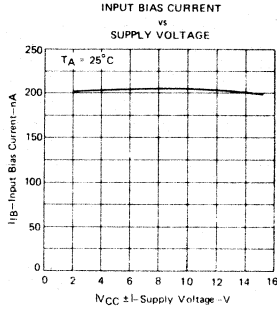


FIGURE 3

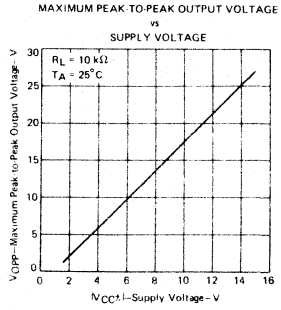


FIGURE 4

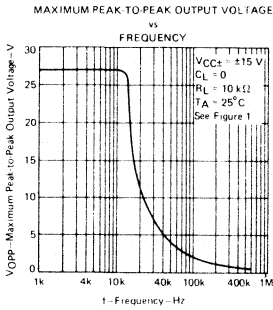


FIGURE 5

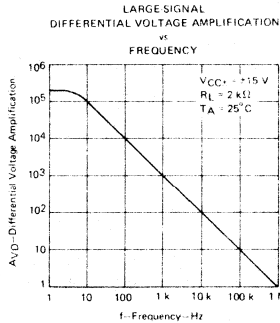


FIGURE 6

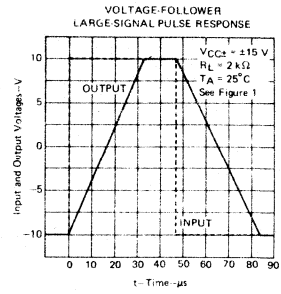
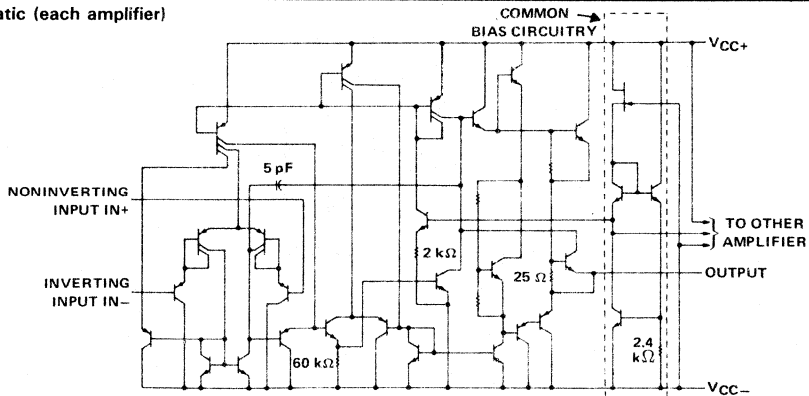


FIGURE 7

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

### schematic (each amplifier)



All component values shown are nominal

Operational Amplifiers

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- **Wide Range of Supply Voltages:**  
1 V to 16 V (TLC251C)  
3 V to 16 V (TLC271C, TLC271I)  
4 V to 16 V (TLC271M)
- **True Single Supply Operation**
- **Common-Mode Input Voltage Range Includes the Negative Rail**
- **Low Noise . . . 30 nV/√Hz Typ at 1 kHz (High Bias)**

**description**

The TLC251 and TLC271 series are low-cost, low-power programmable operational amplifiers designed to operate with single or dual supplies. Unlike traditional metal-gate CMOS op amps, these devices utilize Texas Instruments silicon-gate LinCMOST™ process, giving them stable input offset voltages without sacrificing the advantages of metal-gate CMOS. This series of parts is available in selected grades of input offset voltage and can be nulled with one external potentiometer. Because the input common-mode range extends to the negative rail and the power consumption is extremely low, this family is ideally suited for battery-powered or energy-conserving applications. A bias-select pin can be used to program one of three ac performance and power-dissipation levels to suit the application. The TLC251 offers the same operation as the TLC271, but also features guaranteed operation down to a 1 V supply. Both devices are stable at unity gain.

**TEMPERATURE RANGES AND PACKAGES**

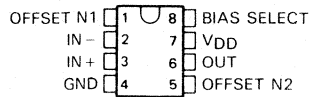
SERIES	TEMPERATURE RANGE	PACKAGES
TLC251_C Types	0°C to 70°C	JG, P, D
TLC271_C Types	0°C to 70°C	JG, P, D
TLC271_I Types	-40°C to 85°C	JG, P, D
TLC271_M Types	-55°C to 125°C	JG, FH, FK

**DEVICE FEATURES**

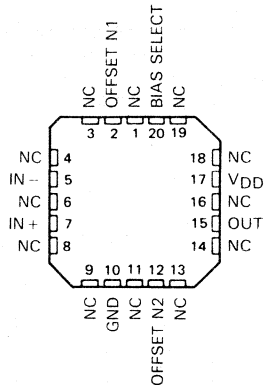
PARAMETER	LOW BIAS	MEDIUM BIAS	HIGH BIAS
Supply current (Typ)	10 μA	150 μA	1000 μA
Slew rate (Typ)	0.04 V/μs	0.6 V/μs	4.5 V/μs
Input offset voltage (Max)			
... Standard types	10 mV	10 mV	10 mV
... A-suffix types	5 mV	5 mV	5 mV
... B-suffix types	2 mV	2 mV	2 mV
Offset voltage drift (Typ)	0.1 μV/month†	0.1 μV/month†	0.1 μV/month†
Offset voltage temperature coefficient (Typ)	0.7 μV/°C	2 μV/°C	5 μV/°C
Input bias current (Typ)	1 pA	1 pA	1 pA
Input offset current (Typ)	1 pA	1 pA	1 pA

† The long-term drift value applies after the first month.

**D, JG, OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)**

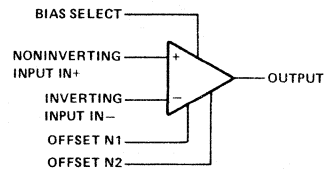


**FH OR FK PACKAGE  
(TOP VIEW)**



NC No internal connection

**symbol**



**ADVANCE INFORMATION**

This document contains information on a new product. Specifications are subject to change without notice.

# TYPES TLC251, TLC251A, TLC251B, TLC271, TLC271A, TLC271B PROGRAMMABLE LOW-POWER LinCMOS™ AMPLIFIERS

## description (continued)

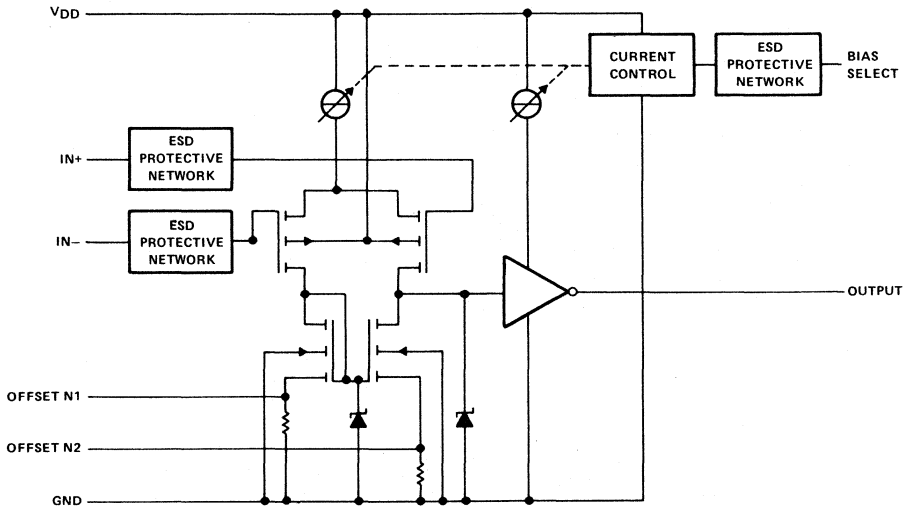
These devices have internal electrostatic discharge (ESD) protection circuits that will prevent catastrophic failures at voltages up to 2000 volts as tested under MIL-STD-883B, Method 3015.1. However, care should be exercised in handling these devices as exposure to ESD may result in a degradation of the device parametric performance.

Because of the extremely high input impedance and low input bias and offset currents, applications for the TLC251 and TLC271 series include many areas that have previously been limited to BIFET and NFET product types. Any circuit using high-impedance elements and requiring small offset errors is a good candidate for cost-effective use of these devices. Many features associated with bipolar technology are available with LinCMOS operational amplifiers without the power penalties of traditional bipolar devices. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are all easily designed with the TLC271. Remote and inaccessible equipment applications are possible using the low-voltage and low-power capabilities of the TLC251. In addition, by driving the bias-select input with a logic signal from a microprocessor, these operational amplifiers can have software-controlled performance and power consumption. The TLC251 is well suited to solve the difficult problems associated with single-battery and solar-cell-powered applications.



## schematic

Operational Amplifiers



# TYPES TLC251, TLC251A, TLC251B, TLC271, TLC271A, TLC271B PROGRAMMABLE LOW-POWER LinCMOST™ AMPLIFIERS

## absolute maximum ratings over operating free-air temperature (unless otherwise noted)

Supply voltage, $V_{DD}$ (see Note 1)	18 V
Differential input voltage (see Note 2)	$\pm 18$ V
Input voltage range (any input)	-0.3 V to 18 V
Duration of short-circuit at (or below) 25°C free-air temperature (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4):	
D package	725 mW
FH package (see Note 5)	1200 mW
FK package (see Note 5)	1375 mW
JG package	1050 mW
P package	725 mW
Operating free-air temperature range: TLC271M, TLC271AM, TLC271BM	-55°C to 125°C
TLC271I, TLC271AI, TLC271BI	-40°C to 85°C
TLC251C, TLC251AC, TLC251BC,	
TLC271C, TLC271AC, TLC271BC	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16) inch from the case for 60 seconds: JG package	300°C
Lead Temperature 1,6 mm (1/16) inch) from case for 10 seconds: D or P package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground terminal.  
 2. Differential voltages are at the noninverting input terminal, with respect to the inverting input terminal.  
 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table below.  
 5. For FH and FK packages, power rating and derating factor will vary with actual mounting technique used. The values stated here are believed to be conservative.

**DISSIPATION DERATING TABLE**

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE
			$T_A$
D	725 mW	5.8 mW/°C	25°C
FH	1200 mW	9.6 mW/°C	25°C
FK	1375 mW	11.0 mW/°C	25°C
JG	1050 mW	8.4 mW/°C	25°C
P	725 mW	5.8 mW/°C	25°C

## recommended operating conditions

		TLC251 TLC251A TLC251B			TLC271 TLC271A TLC271B			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{DD}$	M-suffix types				4		16	V
	I-suffix types				3		16	
	C-suffix types	1		16	3		16	
Common-mode input voltage, $V_{IC}$	$V_{DD} = 1$ V		0	0.2				V
	$V_{DD} = 4$ V		0	3	0		3	
	$V_{DD} = 10$ V		-0.05	9	-0.05		9	
	$V_{DD} = 16$ V		-0.05	14	-0.05		14	
Operating free-air temperature, $T_A$	M-suffix types				-55		125	°C
	I-suffix types				-40		85	
	C-suffix types	0		70	0		70	
Bias Select pin voltage		See application notes						

# TYPES TLC251, TLC251A, TLC251B, TLC271, TLC271A, TLC271B PROGRAMMABLE LOW-POWER LinCMOST™ AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{DD} = 10\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS <sup>1</sup>		BIAS	TLC271_M			TLC271_I			TLC251_C, TLC271_C			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$	25°C	Any	10			10			10			mV
			Full range		12			13			12			
			25°C	Any	5			5			5			
			Full range		6.5			7			6.5			
			25°C	Any	2			2			2			
			Full range		3			3.5			3			
$\alpha_{VIO}$	Average temperature coefficient of input offset voltage	Full range	Low	Any	0.7			0.7			0.7			$\mu\text{V}/^\circ\text{C}$
			Medium		2			2			2			
			High		5			5			5			
$I_{IO}$	Input offset current	$V_{IC} = 5\text{ V}$ , $V_O = 5\text{ V}$	25°C	Any	1			1			1			pA
			Full range		15000			200			100			
$I_{IB}$	Input bias current	$V_{IC} = 5\text{ V}$ , $V_O = 5\text{ V}$	25°C	Any	1			1			1			pA
			Full range		35000			300			150			
$V_{ICR}$	Common-mode input voltage range		25°C	Any	-0.2 to 9		-0.2 to 9		-0.2 to 9			V		
$V_{OM}$	Peak output voltage range†	$V_{ID} = 100\text{ mV}$	25°C	Any	8	8.6	8	8.6	8	8.6	8	8.6	V	
			Full range		7.8		7.8		7.8					
$A_{VD}$	Large-signal differential voltage amplification	$V_O = 1\text{ to }6\text{ V}$ , $R_S = 50\ \Omega$	25°C	Any	Low	30	500	30	500	30	500	V/mV		
					Medium	20	280	20	280	20	280			
			High	10	40	10	40	10	40					
			Full range	Low	20		20		25					
				Medium	10		10		15					
			High	7		7		7.5						
CMRR	Common-mode rejection ratio	$V_O = 1.4\text{ V}$ , $V_{IC} = V_{ICR\text{ min}}$	25°C	Any	70	88	70	88	70	88	dB			
					Low	70	88	70	88	70		88		
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{DD} = 5\text{ to }10\text{ V}$ , $V_O = 1.4\text{ V}$	25°C	Any	Medium	70	88	70	88	70	88	dB		
					High	65	82	65	82	65	82			
					Low	65	82	65	82	65	82			
$I_{OS}$	Short-circuit output current	$V_O = 0$ , $V_{ID} = 100\text{ mV}$ , $V_O = V_{DD}$ , $V_{ID} = -100\text{ mV}$	25°C	Any	-55			-55			-55			mA
					15			15			15			
$I_{IH(SEL)}$	High-level input current to bias select	$V_{I(SEL)} = 0\text{ V}$	25°C	High	10.5			10.5			10.5			$\mu\text{A}$
$I_{IL(SEL)}$	Low-level input current to bias select	$V_{I(SEL)} = 10\text{ V}$	25°C	Low	1.3			1.3			1.3			$\mu\text{A}$
$I_{DD}$	Supply current	No load, $V_O = 5\text{ V}$ , $V_{IC} = 5\text{ V}$	25°C	Any	Low	10	20	10	20	10	20	$\mu\text{A}$		
					Medium	150	300	150	300	150	300			
			High		1000	2000	1000	2000	1000	2000				
			Full range		Low	40		40		30				
					Medium	500		500		400				
			High		3000		2500		2200					

<sup>1</sup>All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for  $T_A$  is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for TLC2\_M,  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for TLC2\_I, and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for TLC2\_C. Unless otherwise noted, an output load resistor is connected from the output to ground and has the following values: for low bias  $R_L = 1\text{ M}\Omega$ , for medium bias  $R_L = 100\text{ k}\Omega$ , and for high bias  $R_L = 10\text{ k}\Omega$ .

<sup>†</sup>The output will swing to the potential of the ground pin.

3 Operational Amplifiers

# TYPES TLC251, TLC251A, TLC251B PROGRAMMABLE LOW-POWER LinCMOST™ AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{DD} = 1\text{ V}$

PARAMETER		TEST CONDITIONS†		BIAS	TLC251_C			UNIT	
					MIN	TYP	MAX		
$V_{IO}$	Input offset voltage	TLC251C	$V_O = 0.2\text{ V}$ , $R_S = 50\ \Omega$	25°C	Any	10		mV	
						0°C to 70°C			12
				TLC251AC	25°C	Any	5		
							0°C to 70°C		6.5
				TLC251BC	25°C	Any	2		
							0°C to 70°C		3
$\alpha_{VIO}$	Average Temperature Coefficient of Input Offset Voltage		0°C to 70°C	Any	1		$\mu\text{V}/^\circ\text{C}$		
$I_{IO}$	Input offset current	$V_O = 0.2\text{ V}$	25°C	Any	1		pA		
					0°C to 70°C			100	
$I_{IB}$	Input bias current	$V_O = 0.2\text{ V}$	25°C	Any	1		pA		
					0°C to 70°C			150	
$V_{ICR}$	Common-mode input voltage range		25°C	Any	0 to 0.2		V		
$V_{OM}$	Peak output voltage swing‡	$V_{ID} = 100\text{ mV}$	25°C	Any	450		mV		
$A_{VD}$	Large-signal differential voltage amplification	$V_O = 100\text{ to }300\text{ mV}$ , $R_S = 50\ \Omega$	25°C	Low	20		V/mV		
				High	10				
$CMRR$	Common-mode rejection ratio	$R_S = 50\ \Omega$ , $V_O = 0.2\text{ V}$ , $V_{IC} = V_{IC\text{ min}}$	25°C	Any	77		dB		
$I_{DD}$	Supply current	$V_O = 0.2\text{ V}$ , No load	25°C	Low	2		$\mu\text{A}$		
				High	12				

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Unless otherwise noted, an output load resistor is connected from the output to ground and has the following values: for low bias  $R_L = 1\text{ M}\Omega$ , for medium bias  $R_L = 100\text{ k}\Omega$ , and for high bias  $R_L = 10\text{ k}\Omega$ .

‡ The output will swing to the potential of the ground pin.

operating characteristics,  $V_{DD} = 1\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS		BIAS	TLC251_C			UNIT
					MIN	TYP	MAX	
$B_1$	Unity-gain bandwidth	$C_L = 10\text{ pF}$		Low	12		kHz	
				High	75			
SR	Slew rate at unity gain	See Figure 1		Low	0.001		$\text{V}/\mu\text{s}$	
				High	0.01			
Overshoot factor	See Figure 1			Low	35%			
				High	30%			

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Operational Amplifiers

# TYPES TLC251, TLC251A, TLC251B, TLC271, TLC271A, TLC271B PROGRAMMABLE LOW-POWER LinCMOS™ AMPLIFIERS

operating characteristics,  $V_{DD} = 10\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	BIAS	TLC2_M			TLC2_I			TLC2_C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$B_1$ Unity-gain bandwidth	$A_V = 40\text{ dB}$ , $C_L = 10\text{ pF}$ , $R_S = 50\ \Omega$	Low	0.1			0.1			0.1			MHz
		Medium	0.7			0.7			0.7			
		High	2.3			2.3			2.3			
SR Slew rate at unity gain	See Figure 1	Low	0.04			0.04			0.04			V/ $\mu\text{s}$
		Medium	0.6			0.6			0.6			
		High	4.5			4.5			4.5			
Overshoot factor	See Figure 1	Low	30%			30%			30%			
		Medium	35%			35%			35%			
		High	35%			35%			35%			
$\phi_m$ Phase margin at unity gain	$A_V = 40\text{ dB}$ , $R_S = 100\ \Omega$ , $C_L = \text{pF}$	Low	43°			43°			43°			
		Medium	43°			43°			43°			
		High	50°			50°			50°			
$V_n$ Equivalent input noise voltage	$f = 1\text{ kHz}$ , $R_S = 100\ \Omega$	Low	70			70			70			nV/ $\sqrt{\text{Hz}}$
		Medium	38			38			38			
		High	30			30			30			

## PARAMETER MEASUREMENT INFORMATION

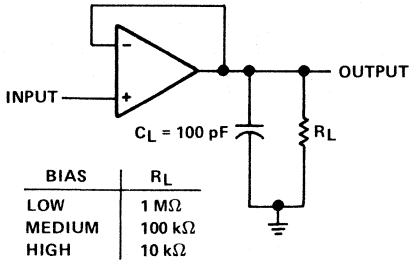


FIGURE 1—UNITY-GAIN AMPLIFIER

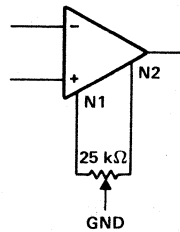


FIGURE 2—INPUT OFFSET VOLTAGE NULL CIRCUIT

3 Operational Amplifiers



# TYPES TLC251, TLC251A, TLC251B, TLC271, TLC271A, TLC271B PROGRAMMABLE LOW-POWER LinCMOST™ AMPLIFIERS

## TYPICAL CHARACTERISTICS

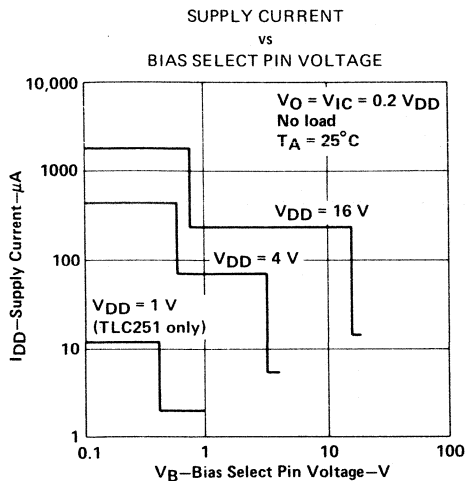
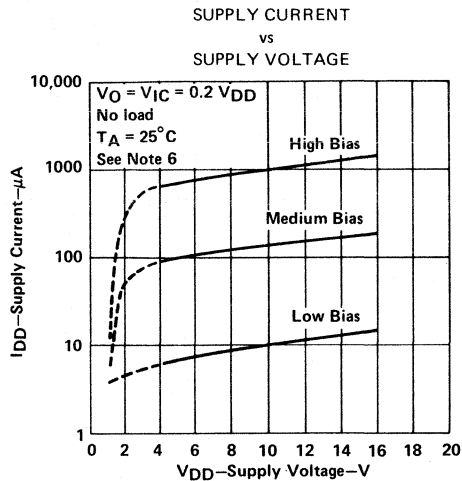


FIGURE 3



NOTE 6: Data for  $V_{DD}$  less than 4 V applies only for TLC251, TLC251A, and TLC251B.

FIGURE 4

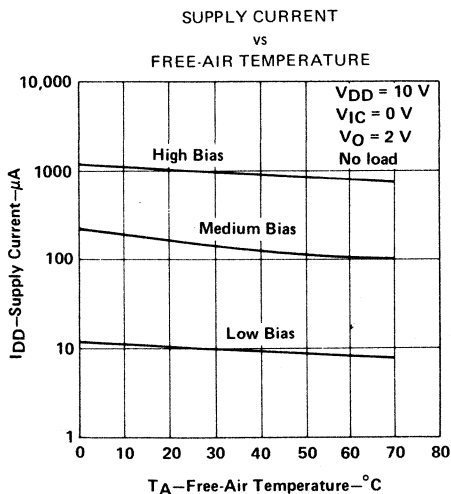


FIGURE 5

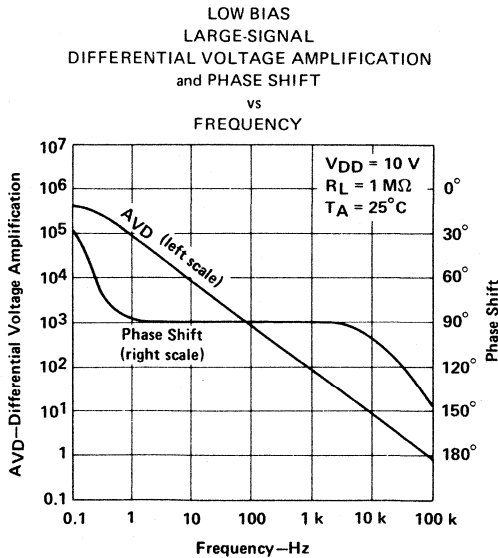


FIGURE 6

3  
Operational Amplifiers

**TYPES TLC251, TLC251A, TLC251B, TLC271, TLC271A, TLC271B**  
**PROGRAMMABLE LOW-POWER LinCMOST™ AMPLIFIERS**

**TYPICAL CHARACTERISTICS**  
 MEDIUM BIAS  
 LARGE-SIGNAL  
 DIFFERENTIAL VOLTAGE AMPLIFICATION  
 and PHASE SHIFT  
 vs  
 FREQUENCY

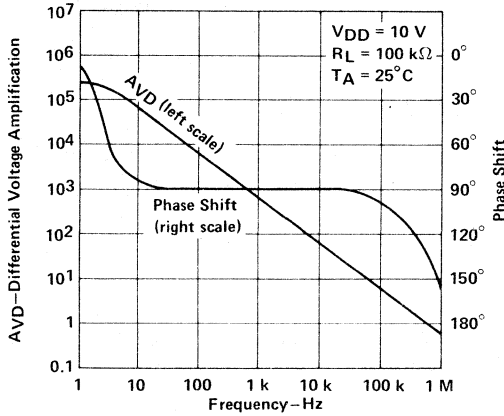


FIGURE 7

**HIGH BIAS**  
 LARGE-SIGNAL  
 DIFFERENTIAL VOLTAGE AMPLIFICATION  
 and PHASE SHIFT  
 vs  
 FREQUENCY

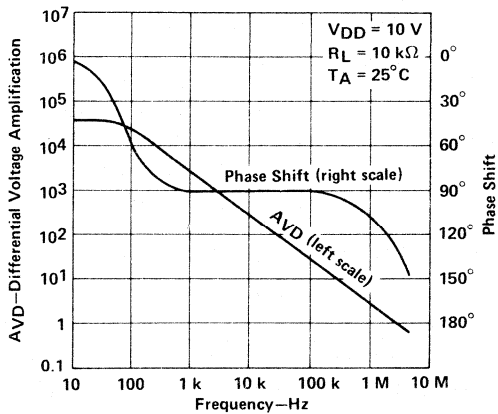


FIGURE 8

# TYPES TLC251, TLC251A, TLC251B, TLC271, TLC271A, TLC271B PROGRAMMABLE LOW-POWER LinCMOST™ AMPLIFIERS

## TYPICAL APPLICATION INFORMATION

### latchup avoidance

Junction-isolated CMOS circuits have an inherent parasitic PNP structure that can function as an SCR. Under certain conditions, this SCR may be triggered into a low-impedance state, resulting in excessive supply current. To avoid such conditions, no voltage greater than 0.3 V beyond the supply rails should be applied to any pin. In general, the op amp supplies should be applied simultaneously with, or before, application of any input signals.

### using the bias select pin

The TLC251 and TLC271 have a bias select pin that allows the selection of one of three  $I_{DD}$  conditions (10, 150, and 1000  $\mu\text{A}$  typical). This allows the user to trade-off power and ac performance. As shown in the typical supply current ( $I_{DD}$ ) versus supply voltage ( $V_{DD}$ ) curves (Figure 4), the  $I_{DD}$  varies only slightly from 4 to 16 V. Below 4 V, the  $I_{DD}$  varies more significantly. Note that the  $I_{DD}$  values in the medium and low-bias modes at  $V_{DD} = 1$  V are typically 2  $\mu\text{A}$ , and in the high mode are typically 12  $\mu\text{A}$ . The following table shows the recommended bias select pin connections at  $V_{DD} = 10$  V:

RECOMMENDED BIAS SELECT PIN USE AT  $V_{DD} = 10$  V

BIAS MODE	AC PERFORMANCE	BIAS SELECT CONNECTION <sup>1</sup>	TYPICAL $I_{DD}$ <sup>§</sup>
Low	Low	$V_{DD}$	10 $\mu\text{A}$
Medium	Medium	0.8 V to 9.2 V	150 $\mu\text{A}$
High	High	Ground pin	1000 $\mu\text{A}$

<sup>1</sup>The Bias Select pin may also be controlled by external circuitry to conserve power, etc. For information regarding the bias select pin, see Figure 3 in the typical characteristics curves.

<sup>§</sup>For  $I_{DD}$  characteristics at voltages other than 10 V, see Figure 4 in the typical characteristics curves.

### output stage considerations

The amplifier's output stage consists of a source-follower-connected pullup transistor and an open-drain pulldown transistor. The high-level output voltage ( $V_{OH}$ ) is virtually independent of the  $I_{DD}$  selection, and increases with higher values of  $V_{DD}$  and reduced output loading. The low-level output voltage ( $V_{OL}$ ) decreases with reduced output current and higher input common-mode voltage. With no load,  $V_{OL}$  is essentially equal to the GND pin potential.

### input offset nulling

Both the TLC251 and TLC271 offer external offset null control. Nulling may be achieved by adjusting a 25-k $\Omega$  potentiometer connected between the offset null terminals with the wiper connected to the device GND pin as shown in Figure 2. The amount of nulling range varies with the bias selection. At  $I_{DD}$  settings of 150 and 1000  $\mu\text{A}$  (medium and high bias), the nulling range will allow the maximum offset specified to be trimmed to zero. In low bias or when the TLC251 is used below 4 V, total nulling may not be possible on all units.

### supply configurations

Even though the TLC251 and TLC271 are characterized for single-supply operation, they can be used effectively in a split-supply configuration when the input common-mode voltage ( $V_{ICR}$ ), output swing ( $V_{OL}$  and  $V_{OH}$ ), and supply voltage limits are not exceeded.

### circuit layout precautions

The user is cautioned that whenever extremely high circuit impedances are used, care must be exercised in layout, construction, board cleanliness, and supply filtering to avoid hum and noise pickup, as well as excessive dc leakages.

# 3

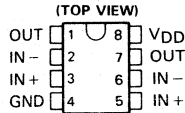
## Operational Amplifiers

- **Wide Range of Supply Voltages:**  
1 V to 16 V (TLC252C)  
3 V to 16 V (TLC272C, TLC272I)  
4 V to 16 V (TLC272M)
- **True Single-Supply Operation**
- **Common-Mode Input Voltage Includes the Negative Rail**
- **Low Noise . . . 30 nV/√Hz Typ at f = 1 kHz (High-Bias Versions)**

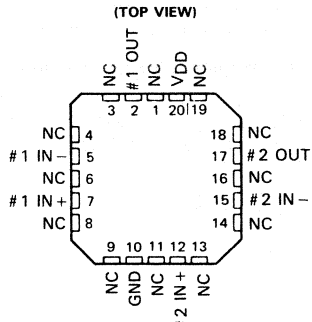
**description**

The TLC252 and TLC272 series are low-cost, low-power dual operational amplifiers designed to operate with single or dual supplies. These devices utilize the Texas Instruments silicon gate LinCMOSTM process, giving them stable input offset voltages that are available in selected grades of 2, 5 or 10 mV maximum, very high input impedances, and extremely low input offset and bias currents. Because the input common-mode range extends to the negative rail and the power consumption is extremely low, this series is ideally suited for battery-powered or energy-conserving applications. The TLC252 types offer guaranteed operation down to a 1-V supply. All devices are unity-gain stable and have excellent noise characteristics.

**D, JG, OR P DUAL-IN-LINE PACKAGE**

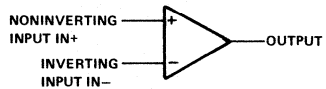


**FH OR FK PACKAGE**



NC—No internal connection

**symbol (each amplifier)**



**DEVICE FEATURES**

PARAMETER	TLC25L2 TLC27L2 (LOW BIAS)	TLC25M2 TLC27M2 (MEDIUM BIAS)	TLC252 TLC272 (HIGH BIAS)
Supply current (Typ)	20 $\mu$ A	300 $\mu$ A	2000 $\mu$ A
Slew rate (Typ)	0.04 V/ $\mu$ s	0.6 V/ $\mu$ s	4.5 V/ $\mu$ s
Input offset voltage (Max)			
. . . Standard types	10 mV	10 mV	10 mV
. . . A-suffix types	5 mV	5 mV	5 mV
. . . B-suffix types	2 mV	2 mV	2 mV
Offset voltage drift (Typ)	0.1 $\mu$ V/month <sup>†</sup>	0.1 $\mu$ V/month <sup>†</sup>	0.1 $\mu$ V/month <sup>†</sup>
Offset voltage temperature coefficient (Typ)	0.7 $\mu$ V/ $^{\circ}$ C	2 $\mu$ V/ $^{\circ}$ C	5 $\mu$ V/ $^{\circ}$ C
Input bias current (Typ)	1 pA	1 pA	1 pA
Input offset current (Typ)	1 pA	1 pA	1 pA

<sup>†</sup>The offset voltage drift applies after the first month only.

**TEMPERATURE RANGES AND PACKAGES**

TYPES	TEMPERATURE RANGE	PACKAGES
TLC25__2__C	0 $^{\circ}$ C to 70 $^{\circ}$ C	JG, P, D
TLC27__2__C	0 $^{\circ}$ C to 70 $^{\circ}$ C	JG, P, D
TLC27__2__I	-40 $^{\circ}$ C to 85 $^{\circ}$ C	JG, P, D
TLC27__2__M	-55 $^{\circ}$ C to 125 $^{\circ}$ C	JG, FH, FK

**ADVANCE INFORMATION**

This document contains information on a new product. Specifications are subject to change without notice.



# TYPES TLC252, TLC25L2, TLC25M2, TLC272, TLC27L2, TLC27M2

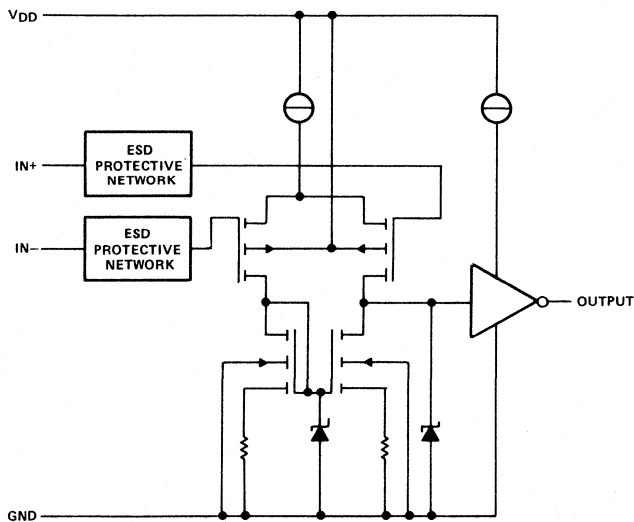
## LinCMOST™ DUAL OPERATIONAL AMPLIFIERS

### description (continued)

These devices have internal electrostatic discharge (ESD) protection circuits that will prevent catastrophic failures at voltages up to 2000 volts as tested under MIL-STD-883B, Method 3015.1. However, care should be exercised in handling these devices as exposure to ESD may result in a degradation of the device parametric performance.

Because of the extremely high input impedance and low input bias and offset currents, applications for the TLC252 and TLC272 series include many areas that have previously been limited to BIFET and NFET product types. Any circuit using high-impedance elements and requiring small offset errors is a good candidate for cost-effective use of these devices. Many features associated with bipolar technology are available with LinCMOST™ operational amplifiers without the power penalties of traditional bipolar devices. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are all easily designed with the TLC252 and TLC272 series. Remote and inaccessible equipment applications are possible using the low-voltage and low-power capabilities of the TLC252. The TLC252 types are well suited to solve the difficult problems associated with single-battery and solar-cell-powered applications. This series includes devices that are characterized for commercial, industrial, and military temperature ranges and are available in 8-pin plastic and ceramic dual-in-line (DIP) packages, small outline (D) package, and chip carrier (FH, FK) packages.

### schematic (each amplifier)



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Operational Amplifiers

# TYPES TLC252, TLC25L2, TLC25M2, TLC272, TLC27L2, TLC27M2 LinCMOST™ DUAL OPERATIONAL AMPLIFIERS

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{DD}$ (see Note 1)	18 V
Differential input voltage (see Note 2)	$\pm 18$ V
Input voltage range (any input)	-0.3 V to 18 V
Duration of short-circuit at (or below) 25°C free-air temperature (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4):	
D package	725 mW
FH package (see Note 5)	1200 mW
FK package (see Note 5)	1375 mW
JG package	1050 mW
P package	725 mW
Operating free-air temperature range:	
TLC27_2_M	-55°C to 125°C
TLC27_2_I	-40°C to 85°C
TLC25_2_C, TLC27_2_C	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from the case for 60 seconds: JG package	300°C
Lead temperature 1,6 mm (1/16 inch) from the case for 10 seconds: D or P package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.  
 4. For operation above 25°C free-air temperature, refer to the Dissipation Derating Table.  
 5. For FH and FK packages, power rating and derating factor will vary with the actual mounting technique used. The values stated here are believed to be conservative.

**DISSIPATION DERATING TABLE**

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
D	725 mW	5.8 mW/°C	25°C
FH	1200 mW	9.6 mW/°C	25°C
FK	1375 mW	11 mW/°C	25°C
JG	1050 mW	8.4 mW/°C	25°C
P	725 mW	5.8 mW/°C	25°C

## recommended operating conditions

		TLC25_2 TLC25_2A TLC25_2B			TLC27_2 TLC27_2A TLC27_2B			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{DD}$	M-suffix types				4		16	V
	I-suffix types				3		16	
	C-suffix types	1		16	3		16	
Common-mode input voltage, $V_{IC}$	$V_{DD} = 1$ V		0	0.2				V
	$V_{DD} = 4$ V		0	3	0		3	
	$V_{DD} = 10$ V		-0.05	9	-0.05		9	
	$V_{DD} = 16$ V		-0.05	14	-0.05		14	
Operating free-air temperature, $T_A$	M-suffix types				-55		125	°C
	I-suffix types				-40		85	
	C-suffix types	0		70	0		70	

# TYPES TLC272, TLC27L2, TLC27M2 LinCMOST™ QUAD OPERATIONAL AMPLIFIERS

## M-SUFFIX TYPES

electrical characteristics at specified free-air temperature,  $V_{DD} = 10\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS†	TLC272_M			TLC27L2_M			TLC27M2_M			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$	Input offset voltage	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$	25°C	10			10			10			mV
			-55°C to 125°C	12			12			12			
			25°C	5			5			5			
			-55°C to 125°C	6.5			6.5			6.5			
			25°C	2			2			2			
			-55°C to 125°C	3.5			3.5			3.5			
$\alpha_{VIO}$	Average temperature coefficient of input offset voltage		-55°C to 125°C	5			0.7			2			$\mu\text{V}/^\circ\text{C}$
$I_{IO}$	Input offset current	$V_{IC} = 5\text{ V}$ , $V_O = 5\text{ V}$	25°C	1			1			1			pA
			-55°C to 125°C	15			15			15			nA
$I_{IB}$	Input bias current	$V_{IC} = 5\text{ V}$ , $V_O = 5\text{ V}$	25°C	1			1			1			pA
			-55°C to 125°C	35			35			35			nA
$V_{ICR}$	Common-mode input voltage range		25°C	-0.2 to 9			-0.2 to 9			-0.2 to 9			V
$V_{OM}$	Peak output voltage swing‡	$V_{ID} = 100\text{ mV}$	25°C	8 8.6			8 8.6			8 8.6			V
			-55°C to 125°C	7.8			7.8			7.8			
$A_{VD}$	Large-signal differential voltage amplification	$V_O = 1\text{ to }6\text{ V}$ , $R_S = 50\ \Omega$	25°C	10 40			30 500			20 280			V/mV
			-55°C to 125°C	7			20			10			
$CMRR$	Common-mode rejection ratio	$V_O = 1.4\text{ V}$ , $V_{IC} = V_{ICR\text{ min}}$	25°C	70 88			70 88			70 88			dB
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{DD} = 5\text{ to }10\text{ V}$ , $V_O = 1.4\text{ V}$	25°C	65 82			70 88			70 88			dB
$I_{OS}$	Short-circuit output current	$V_O = 0$ , $V_{ID} = 100\text{ mV}$	25°C	-55			-55			-55			mA
		$V_O = V_{DD}$ , $V_{ID} = -100\text{ mV}$		15			15			15			
$I_{DD}$	Supply current (each amplifier)	No load, $V_O = 5\text{ V}$ , $V_{IC} = 5\text{ V}$	25°C	1000 2000			10 20			150 300			$\mu\text{A}$
			-55°C to 125°C	3000			40			500			

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Unless otherwise noted, an output load resistor is connected from the output to the ground pin.

‡ The output will swing to the potential of the ground pin.



# TYPES TLC272, TLC27L2, TLC27M2 LinCMOS™ QUAD OPERATIONAL AMPLIFIERS

## I-SUFFIX TYPES

electrical characteristics at specified free-air temperature,  $V_{DD} = 10\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS†		TLC272_I			TLC27L2_I			TLC27M2_I			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage	TLC27_2I TLC27_2AI TLC27_2BI	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$	25°C		10		10		10		mV	
				-40°C to 85°C		13		13		13			
				25°C		5		5		5			
				-40°C to 85°C		7		7		7			
				25°C		2		2		2			
			-40°C to 85°C		3.5		3.5		3.5				
$\alpha_{VIO}$	Average temperature coefficient of input offset voltage		-40°C to 85°C		5		0.7		2		$\mu\text{V}/^\circ\text{C}$		
$I_{IO}$	Input offset current	$V_{IC} = 5\text{ V}$ , $V_O = 5\text{ V}$	25°C		1		1		1		pA		
			-40°C to 85°C		200		200		200				
$I_{IB}$	Input bias current	$V_{IC} = 5\text{ V}$ , $V_O = 5\text{ V}$	25°C		1		1		1		pA		
			-40°C to 85°C		300		300		300				
$V_{ICR}$	Common-mode input voltage range		25°C	-0.2 to 9		-0.2 to 9		-0.2 to 9			V		
$V_{OM}$	Peak output voltage swing‡	$V_{ID} = 100\text{ mV}$	25°C	8	8.6	8	8.6	8	8.6		V		
			-40°C to 85°C	7.8		7.8		7.8					
$A_{VD}$	Large-signal differential voltage amplification	$V_O = 1\text{ to }6\text{ V}$ , $R_S = 50\ \Omega$	25°C	10	40	30	500	20	280		V/mV		
			-40°C to 85°C	7		20		10					
$CMRR$	Common-mode rejection ratio	$V_O = 1.4\text{ V}$ , $V_{IC} = V_{ICR\text{ min}}$	25°C	70	88	70	88	70	88		dB		
$KS_{VR}$	Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{DD} = 5\text{ to }10\text{ V}$ , $V_O = 1.4\text{ V}$	25°C	65	82	70	88	70	88		dB		
$I_{OS}$	Short-circuit output current	$V_O = 0$ , $V_{ID} = 100\text{ mV}$	25°C	-55			-55			-55			mA
		$V_O = V_{DD}$ , $V_{ID} = -100\text{ mV}$		15			15			15			
$I_{DD}$	Supply current (each amplifier)	No load, $V_O = 5\text{ V}$ , $V_{IC} = 5\text{ V}$	25°C	1000	2000	10	20	150	300		$\mu\text{A}$		
			-40°C to 85°C	2500			40			500			

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Unless otherwise noted, an output load resistor is connected from the output to the ground pin.

‡ The output will swing to the potential of the ground pin.

**TYPES TLC252, TLC25L2, TLC25M2, TLC272, TLC27L2, TLC27M2**  
**LinCMOST™ DUAL OPERATIONAL AMPLIFIERS**

**C-SUFFIX TYPES**

electrical characteristics at specified free-air temperature,  $V_{DD} = 10\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS†		TLC252_C, TLC272_C			TLC25L2_C, TLC27L2_C			TLC25M2_C, TLC27M2_C			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage	TLC2_2C TLC2_2AC TLC2_2BC	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$	25°C		10		10		10		mV	
				0°C to 70°C		12		12		12			
				25°C		5		5		5			
				0°C to 70°C		6.5		6.5		6.5			
				25°C		2		2		2			
			0°C to 70°C		3		3		3				
$\alpha_{VIO}$	Average temperature coefficient of input offset voltage		0°C to 70°C		5		0.7		2		$\mu\text{V}/^\circ\text{C}$		
$I_{IO}$	Input offset current	$V_{IC} = 5\text{ V}$ , $V_O = 5\text{ V}$	25°C		1		1		1		pA		
			0°C to 70°C		100		100		100				
$I_{IB}$	Input bias current	$V_{IC} = 5\text{ V}$ , $V_O = 5\text{ V}$	25°C		1		1		1		pA		
			0°C to 70°C		150		150		150				
$V_{ICR}$	Common-mode input voltage range		25°C		-0.2 to 9		-0.2 to 9		-0.2 to 9		V		
$V_{OM}$	Peak output voltage swing‡	$V_{ID} = 100\text{ mV}$	25°C		8	8.6		8	8.6		8	8.6	V
			0°C to 70°C		7.8		7.8		7.8				
$A_{VD}$	Large-signal differential voltage amplification	$V_O = 1\text{ to }6\text{ V}$ , $R_S = 50\ \Omega$	25°C		10	40		30	500		20	280	V/mV
			0°C to 70°C		7.5		25		15				
$CMRR$	Common-mode rejection ratio	$V_O = 1.4\text{ V}$ , $V_{IC} = V_{ICR\text{ min}}$	25°C		70	88		70	88		70	88	dB
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{DD} = 5\text{ to }10\text{ V}$ , $V_O = 1.4\text{ V}$	25°C		65	82		70	88		70	88	dB
$I_{OS}$	Short-circuit output current	$V_O = 0$ , $V_{ID} = 100\text{ mV}$ , $V_O = V_{DD}$ , $V_{ID} = -100\text{ mV}$	25°C		-55		-55		-55		15		mA
					15		15		15				
$I_{DD}$	Supply current (each amplifier)	No load, $V_O = 5\text{ V}$ , $V_{IC} = 5\text{ V}$	25°C		1000	2000		10	20		150	300	$\mu\text{A}$
			0°C to 70°C		2200		30		400				

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Unless otherwise noted, an output load resistor is connected from the output to the ground pin.

‡ The output will swing to the potential of the ground pin.

**3** Operational Amplifiers

# TYPES TLC252, TLC25L2, TLC25M2 LinCMOSTM QUAD OPERATIONAL AMPLIFIERS

## C-SUFFIX TYPES

electrical characteristics at specified free-air temperature,  $V_{DD} = 1\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS <sup>1</sup>	TLC252_C			TLC25L2_C			TLC25M2_C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage	$V_O = 0.2\text{ V}$ $R_S = 50\ \Omega$	25°C		10		10		10			mV
			0°C to 70°C		12		12		12			
			25°C		5		5		5			
			0°C to 70°C		6.5		6.5		6.5			
			25°C		2		2		2			
			0°C to 70°C		3		3		3			
$\alpha_{VIO}$	Average temperature coefficient of input offset voltage		0°C to 70°C		1		1		1		$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$	Input offset current	$V_O = 0.2\text{ V}$	25°C		1		1		1		pA	
			0°C to 70°C		100		100		100			
$I_{IB}$	Input bias current	$V_O = 0.2\text{ V}$	25°C		1		1		1		pA	
			0°C to 70°C		150		150		150			
$V_{ICR}$	Common-mode input voltage range		25°C	0 to 0.2		0 to 0.2		0 to 0.2			V	
$V_{OM}$	Peak output voltage swing <sup>†</sup>	$V_{ID} = 100\text{ mV}$	25°C		450		450		450		mV	
$A_{VD}$	Large-signal differential voltage amplification	$V_O = 100\text{ to }300\text{ mV}$ $R_S = 50\ \Omega$	25°C		10		20		20		V/mV	
$CMRR$	Common-mode rejection ratio	$V_O = 0.2\text{ V}$ $V_{IC} = V_{ICR}\text{ min}$	25°C		77		77		77		dB	
$I_{DD}$	Supply current (each amplifier)	No load, $V_O = 0.2\text{ V}$	25°C		12		2		2		$\mu\text{A}$	

<sup>†</sup> All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Unless otherwise noted, an output load resistor is connected from the output to the ground pin.

<sup>‡</sup> The output will swing to the potential of the ground pin.

operating characteristics,  $V_{DD} = 1\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS	TLC252_C			TLC25L2_C			TLC25M2_C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$B_1$	Unity-gain bandwidth	$A_V = 40\text{ dB}$ $C_L = 10\text{ pF}$ $R_S = 50\ \Omega$		75			12			12		kHz
$SR$	Slew rate at unity gain	See Figure 1		0.01			0.001			0.001		V/ $\mu\text{s}$
	Overshoot factor	See Figure 1		30%			35%			35%		

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Operational Amplifiers

# TYPES TLC252, TLC25L2, TLC25M2, TLC272, TLC27L2, TLC27M2 LinCMOS™ DUAL OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{DD} = 10\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TLC252_C TLC272_M TLC272_I TLC272_C			TLC25L2_C TLC27L2_M TLC27L2_I TLC27L2_C			TLC25M2_C TLC27M2_M TLC27M2_I TLC27M2_C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$B_1$	Unity-gain bandwidth $A_V = 40\text{ dB}$ , $C_L = 10\text{ pF}$ , $R_S = 50\ \Omega$	2.3			0.1			0.7			MHz
SR	Slew rate at unity gain Overshoot factor	4.5			0.04			0.6			$\text{V}/\mu\text{s}$
$\phi_m$	Phase margin at unity gain $A_V = 40\text{ dB}$ , $R_S = 100\ \Omega$ , $C_L = 10\text{ pF}$	$50^\circ$			$43^\circ$			$43^\circ$			
$V_n$	Equivalent input noise voltage $f = 1\text{ kHz}$ , $R_S = 100\ \Omega$	30			70			38			$\text{nV}/\sqrt{\text{Hz}}$
$V_{O1}/V_{O2}$	Cross talk attenuation $A_V = 100$	120			120			120			dB

## PARAMETER MEASUREMENT INFORMATION

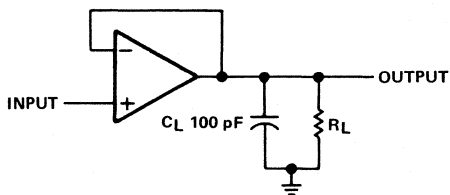


FIGURE 1—UNITY GAIN AMPLIFIER

# TYPES TLC252, TLC25L2, TLC25M2, TLC272, TLC27L2, TLC27M2 LinCMOST™ DUAL OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS

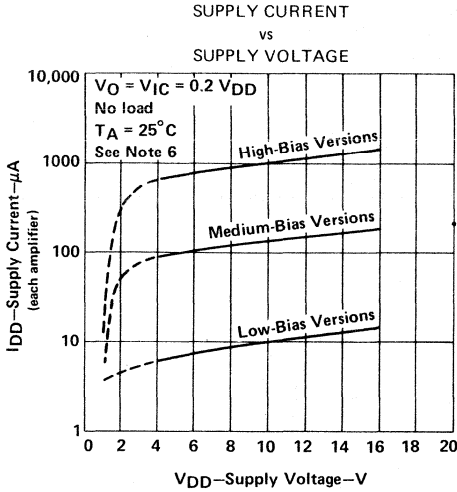


FIGURE 2

NOTE 6: Data for  $V_{DD}$  less than 4 V does not apply for the TLC272 series.

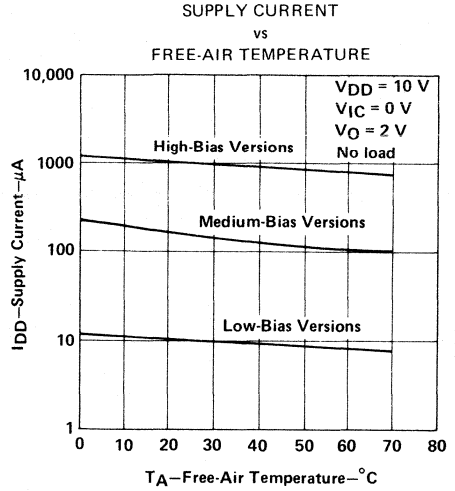


FIGURE 3

### LOW-BIAS VERSIONS LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION and PHASE SHIFT vs FREQUENCY

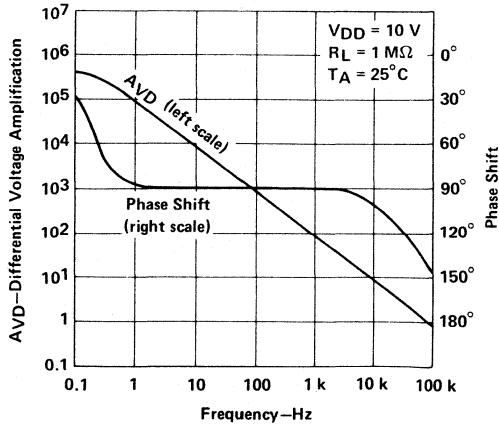


FIGURE 4

**TYPES TLC252, TLC25L2, TLC25M2, TLC272, TLC27L2, TLC27M2**  
**LinCMOS™ DUAL OPERATIONAL AMPLIFIERS**

**TYPICAL CHARACTERISTICS**

MEDIUM-BIAS VERSIONS  
 LARGE-SIGNAL  
 DIFFERENTIAL VOLTAGE AMPLIFICATION  
 and PHASE SHIFT

vs  
 FREQUENCY

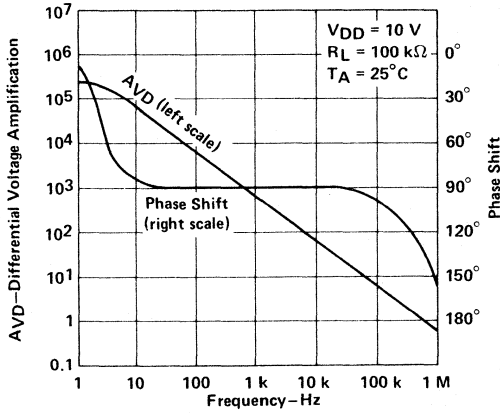


FIGURE 5

HIGH-BIAS VERSIONS  
 LARGE-SIGNAL  
 DIFFERENTIAL VOLTAGE AMPLIFICATION  
 and PHASE SHIFT

vs  
 FREQUENCY

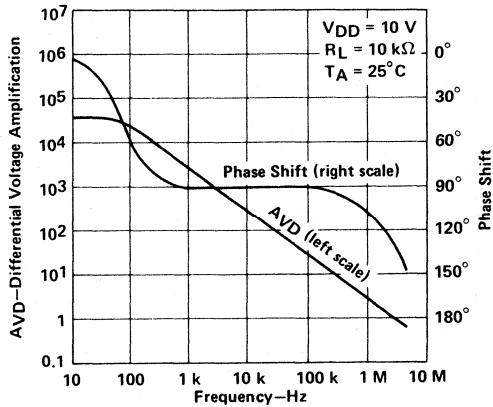


FIGURE 6

# TYPES TLC252, TLC25L2, TLC25M2, TLC272, TLC27L2, TLC27M2 LinCMOSTM DUAL OPERATIONAL AMPLIFIERS

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## TYPICAL APPLICATION INFORMATION

### latchup avoidance

Junction-isolated CMOS circuits have an inherent parasitic PNP structure that can function as an SCR. Under certain conditions, this SCR may be triggered into a low-impedance state, resulting in excessive supply current. To avoid such conditions, no voltage greater than 0.3 V beyond the supply rails should be applied to any pin. In general, the op amp supplies should be established simultaneously with, or before, any input signals are applied.

### output stage considerations

The amplifier's output stage consists of a source follower connected pullup transistor and an open drain pulldown transistor. The high-level output voltage ( $V_{OH}$ ) is virtually independent of the  $I_{DD}$  selection, and increases with higher values of  $V_{DD}$  and reduced output loading. The low-level output voltage ( $V_{OL}$ ) decreases with reduced output current and higher input common-mode voltage. With no load,  $V_{OL}$  is essentially equal to the GND pin potential.

### supply configurations

Even though the TLC252 and TLC272 are characterized for single-supply operation, they can be used effectively in a split supply configuration if the input common-mode voltage ( $V_{ICR}$ ), output swing ( $V_{OL}$  and  $V_{OH}$ ), and supply voltage limits are not exceeded.

### circuit layout precautions

The user is cautioned that whenever extremely high circuit impedances are used, care must be exercised in layout, construction, board cleanliness, and supply filtering to avoid hum and noise pickup, as well as excessive DC leakages.





# TYPES TLC254, TLC25L4, TLC25M4, TLC274, TLC27L4, TLC27M4 LinCMOST™ QUAD OPERATIONAL AMPLIFIERS

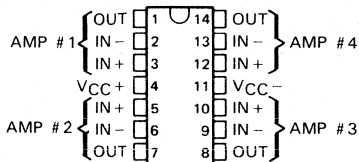
D2753, JUNE 1983—REVISED NOVEMBER 1983

- **Wide Range of Supply Voltages:**  
1 V to 16 V (TLC254C)  
3 V to 16 V (TLC274C, TLC274I)  
4 V to 16 V (TLC274M)
- **True Single-Supply Operation**
- **Common-Mode Input Voltage Includes the Negative Rail**
- **Low Noise . . . 30 nV/√Hz Typ at f = 1 kHz (High-Bias Versions)**

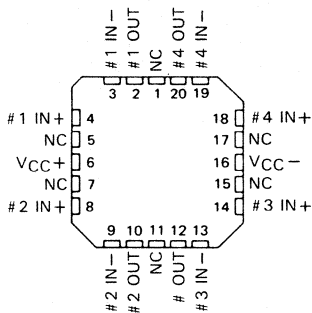
## description

The TLC254 and TLC274 series are low-cost, low-power quad operational amplifiers designed to operate with single or dual supplies. These devices utilize the Texas Instruments silicon-gate LinCMOST™ process, giving them stable input offset voltages that are available in selected grades of 2, 5 or 10 mV maximum, very high input impedances, and extremely low input offset and bias currents. Because the input common-mode range extends to the negative rail and the power consumption is extremely low, this series is ideally suited for battery-powered or energy-conserving applications. The TLC254 types offer guaranteed operation down to a 1-V supply. All devices are unity-gain stable and have excellent noise characteristics.

D, J, OR N DUAL IN-LINE-PACKAGE  
(TOP VIEW)



FH OR FK PACKAGE  
(TOP VIEW)

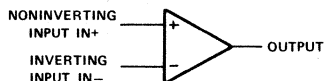


NC—No internal connection

## TEMPERATURE RANGES AND PACKAGES

TYPES	TEMPERATURE RANGE	PACKAGES
TLC25_4_C	0°C to 70°C	J, N, D
TLC27_4_C	0°C to 70°C	J, N, D
TLC27_4_I	-40°C to 85°C	J, N, D
TLC27_4_M	-55°C to 125°C	J, FH, FK

## symbol (each amplifier)



## DEVICE FEATURES

PARAMETER	TLC25L4 TLC27L4 (LOW BIAS)	TLC25M4 TLC27M4 (MEDIUM BIAS)	TLC254 TLC274 (HIGH BIAS)
Supply current (Typ)	40 μA	600 μA	4000 μA
Slew rate (Typ)	0.04 V/μs	0.6 V/μs	4.5 V/μs
Input offset voltage (Max)			
... Standard types	10 mV	10 mV	10 mV
... A-suffix types	5 mV	5 mV	5 mV
... B-suffix types	2 mV	2 mV	2 mV
Offset voltage drift (Typ)	0.1 μV/month†	0.1 μV/month†	0.1 μV/month†
Offset voltage temperature coefficient (Typ)	0.7 μV/°C	2 μV/°C	5 μV/°C
Input bias current (Typ)	1 pA	1 pA	1 pA
Input offset current (Typ)	1 pA	1 pA	1 pA

†The long-term drift value applies after the first month.

## ADVANCE INFORMATION

This document contains information on a new product. Specifications are subject to change without notice.

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TEXAS  
INSTRUMENTS

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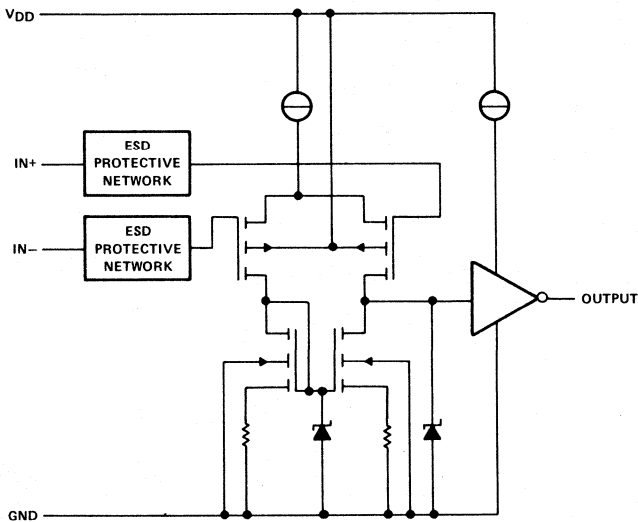
# TYPES TLC254, TLC25L4, TLC25M4, TLC274, TLC27L4, TLC27M4 LinCMOST™ QUAD OPERATIONAL AMPLIFIERS

## description (continued)

These devices have internal electrostatic discharge (ESD) protection circuits that will prevent catastrophic failures at voltages up to 2000 volts as tested under MIL-STD-883B, Method 3015.1. However, care should be exercised in handling these devices as exposure to ESD may result in a degradation of the device parametric performance.

Because of the extremely high input impedance and low input bias and offset currents, applications for the TLC254 and TLC274 series include many areas that have previously been limited to BIFET and NFET product types. Any circuit using high-impedance elements and requiring small offset errors is a good candidate for cost-effective use of these devices. Many features associated with bipolar technology are available with LinCMOST™ operational amplifiers without the power penalties of traditional bipolar devices. General applications such as transducer interfacing, analog calculations, amplifier blocks, active filters, and signal buffering are all easily designed with the TLC254 and TLC274 series. Remote and inaccessible equipment applications are possible using the low-voltage and low-power capabilities of the TLC254. The TLC254 types are well suited to solve the difficult problems associated with single-battery and solar-cell-powered applications. This series includes devices that are characterized for commercial, industrial, and military temperature ranges and are available in 14-pin plastic and ceramic dual-in-line (DIP) packages, small outline (D) package, and chip carrier (FH, FK) packages.

## schematic (each amplifier)



# TYPES TLC254, TLC25L4, TLC25M4, TLC274, TLC27L4, TLC27M4 LinCMOS™ OPERATIONAL AMPLIFIERS

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{DD}$ (see Note 1)	18 V
Differential input voltage (see Note 2)	$\pm 18$ V
Input voltage range (any input)	-0.3 V to 18 V
Duration of short-circuit at (or below) 25°C free-air temperature (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4):	
D package	950 mW
FH package (see Note 5)	1200 mW
FK package (see Note 5)	1375 mW
J package	1375 mW
N package	875 mW
Operating free-air temperature range: TLC27_4_M	-55°C to 125°C
TLC27_4_I	-25°C to 85°C
TLC25_4_C, TLC27_4_C	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from the case for 60 seconds: J package	300°C
Lead temperature 1,6 mm (1/16 inch) from the case for 10 seconds: D or N package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.  
 4. For operation above 25°C free-air temperature, refer to the Dissipation Derating Table.  
 5. For FH and FK packages, power rating and derating factor will vary with the actual mounting technique used. The values stated here are believed to be conservative.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE
			$T_A$
D	950 mW	7.6 mW/°C	25°C
FH	1200 mW	9.6 mW/°C	25°C
FK	1375 mW	11 mW/°C	25°C
J	1375 mW	11 mW/°C	25°C
N	875 mW	7 mW/°C	25°C

## recommended operating conditions

		TLC25_4			TLC27_4			UNIT
		TLC25_4A			TLC27_4A			
		MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{DD}$	M-suffix types				4		16	V
	I-suffix types				3		16	
	C-suffix types	1		16	3		16	
Common-mode input voltage, $V_{IC}$	$V_{DD} = 1$ V		0	0.2				V
	$V_{DD} = 4$ V		0	3	0		3	
	$V_{DD} = 10$ V	-0.05		9	-0.05		9	
	$V_{DD} = 16$ V	-0.05		14	-0.05		14	
Operating free-air temperature, $T_A$	M-suffix types				-55		125	°C
	I-suffix types				-40		85	
	C-suffix types	0		70	0		70	

# TYPES TLC274, TLC27L4, TLC27M4

## LinCMOST™ QUAD OPERATIONAL AMPLIFIERS

### M-SUFFIX TYPES

electrical characteristics at specified free-air temperature,  $V_{DD} = 10\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS <sup>†</sup>		TLC274_M			TLC27L4_M			TLC27M4_M			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage	TLC27...4M TLC27...4AM TLC27...48M	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$	25°C		10		10		10		mV	
				-55°C to 125°C		12		12		12			
				25°C		5		5		5			
				-55°C to 125°C		6.5		6.5		6.5			
				25°C		2		2		2			
				-55°C to 125°C		3.5		3.5		3.5			
$\alpha_{VIO}$	Average temperature coefficient of input offset voltage		-55°C to 125°C	5		0.7		2			$\mu\text{V}/^\circ\text{C}$		
$I_{IO}$	Input offset current	$V_{IC} = 5\text{ V}$ , $V_O = 5\text{ V}$	25°C	1		1		1			pA		
			-55°C to 125°C	15		15		15			nA		
$I_{IB}$	Input bias current	$V_{IC} = 5\text{ V}$ , $V_O = 5\text{ V}$	25°C	1		1		1			pA		
			-55°C to 125°C	35		35		35			nA		
$V_{ICR}$	Common-mode input voltage range		25°C	-0.2 to 9		-0.2 to 9		-0.2 to 9			V		
$V_{OM}$	Peak output voltage swing <sup>‡</sup>	$V_{ID} = 100\text{ mV}$	25°C	8	8.6	8	8.6	8	8.6		V		
			-55°C to 125°C	7.8		7.8		7.8					
$A_{VD}$	Large-signal differential voltage amplification	$V_O = 1\text{ to }6\text{ V}$ , $R_S = 50\ \Omega$	25°C	10	40	30	500	20	280		V/mV		
			-55°C to 125°C	7		20		10					
$CMRR$	Common-mode rejection ratio	$V_O = 1.4\text{ V}$ , $V_{IC} = V_{ICR\text{ min}}$	25°C	70	88	70	88	70	88		dB		
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{DD} = 5\text{ to }10\text{ V}$ , $V_O = 1.4\text{ V}$	25°C	65	82	70	88	70	88		dB		
$I_{OS}$	Short-circuit output current	$V_O = 0$ , $V_{ID} = 100\text{ mV}$ $V_O = V_{DD}$ , $V_{ID} = -100\text{ mV}$	25°C		-55		-55		-55		mA		
				15		15		15					
$I_{DD}$	Supply current (each amplifier)	No load, $V_O = 5\text{ V}$ , $V_{IC} = 5\text{ V}$	25°C	1000	2000	10	20	150	300		$\mu\text{A}$		
			-55°C to 125°C	3000		40		500					

<sup>†</sup> All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Unless otherwise noted, an output load resistor is connected from the output to the ground pin.

<sup>‡</sup> The output will swing to the potential of the ground pin.

# TYPES TLC274, TLC27L4, TLC27M4 LinCMOS™ QUAD OPERATIONAL AMPLIFIERS

## I-SUFFIX TYPES

electrical characteristics at specified free-air temperature,  $V_{DD} = 10\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS†	TLC274_I			TLC27L4_I			TLC27M4_I			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$	25°C		10		10		10			mV
			-40°C to 85°C		13		13		13			
			25°C		5		5		5			
			-40°C to 85°C		7		7		7			
			25°C		2		2		2			
			-40°C to 85°C		3.5		3.5		3.5			
$\alpha_{VIO}$	Average temperature coefficient of input offset voltage		-40°C to 85°C		5		0.7		2		$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$	Input offset current	$V_{IC} = 5\text{ V}$ , $V_O = 5\text{ V}$	25°C		1		1		1		pA	
			-40°C to 85°C		200		200		200			
$I_{IB}$	Input bias current	$V_{IC} = 5\text{ V}$ , $V_O = 5\text{ V}$	25°C		1		1		1		pA	
			-40°C to 85°C		300		300		300			
$V_{ICR}$	Common-mode input voltage range		25°C		-0.2 to 9		-0.2 to 9		-0.2 to 9		V	
$V_{OM}$	Peak output voltage swing‡	$V_{ID} = 100\text{ mV}$	25°C		8 8.6		8 8.6		8 8.6		V	
			-40°C to 85°C		7.8		7.8		7.8			
$A_{VD}$	Large-signal differential voltage amplification	$V_O = 1\text{ to }6\text{ V}$ , $R_S = 50\ \Omega$	25°C		10 40		30 500		20 280		V/mV	
			-40°C to 85°C		7		20		10			
$CMRR$	Common-mode rejection ratio	$V_O = 1.4\text{ V}$ , $V_{IC} = V_{ICR\text{ min}}$	25°C		70 88		70 88		70 88		dB	
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{DD} = 5\text{ to }10\text{ V}$ , $V_O = 1.4\text{ V}$	25°C		65 82		70 88		70 88		dB	
$I_{OS}$	Short-circuit output current	$V_O = 0$ , $V_{ID} = 100\text{ mV}$	25°C		-55		-55		-55		mA	
		$V_O = V_{DD}$ , $V_{ID} = -100\text{ mV}$			15		15		15			
$I_{DD}$	Supply current (each amplifier)	No load, $V_O = 5\text{ V}$ , $V_{IC} = 5\text{ V}$	25°C		1000 2000		10 20		150 300		$\mu\text{A}$	
			-40°C to 85°C		2500		40		500			

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Unless otherwise noted, an output load resistor is connected from the output to the ground pin.

‡ The output will swing to the potential of the ground pin.

3

Operational Amplifiers

**TYPES TLC254, TLC25L4, TLC25M4, TLC274, TLC27L4, TLC27M4**  
**LinCMOS™ QUAD OPERATIONAL AMPLIFIERS**

**C-SUFFIX TYPES**

electrical characteristics at specified free-air temperature,  $V_{DD} = 10\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS <sup>†</sup>	TLC254_C, TLC274_C			TLC25L4_C, TLC27L4_C			TLC25M4_C, TLC27M4_C			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$	Input offset voltage	$V_O = 1.4\text{ V}$ , $R_S = 50\ \Omega$	25°C	10			10			10			mV
			0°C to 70°C	12			12			12			
			25°C	5			5			5			
			0°C to 70°C	6.5			6.5			6.5			
$\alpha_{VIO}$	Average temperature coefficient of input offset voltage	0°C to 70°C	5			0.7			2			$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$	Input offset current	$V_{IC} = 5\text{ V}$ , $V_O = 5\text{ V}$	25°C	1			1			1			pA
			0°C to 70°C	100			100			100			
$I_{IB}$	Input bias current	$V_{IC} = 5\text{ V}$ , $V_O = 5\text{ V}$	25°C	1			1			1			pA
			0°C to 70°C	150			150			150			
$V_{ICR}$	Common-mode input voltage range	$R_S$	25°C	-0.2 to 9			-0.2 to 9			-0.2 to 9			V
$V_{OM}$	Peak output voltage swing <sup>‡</sup>	$V_{ID} = 100\text{ mV}$	25°C	8 8.6			8 8.6			8 8.6			V
			0°C to 70°C	7.8			7.8			7.8			
$A_{VD}$	Large-signal differential voltage amplification	$V_O = 1\text{ to }6\text{ V}$ , $R_S = 50\ \Omega$	25°C	10 40			30 500			20 280			V/mV
			0° to 70°C	7.5			25			15			
$CMRR$	Common-mode rejection ratio	$V_O = 1.4\text{ V}$ , $V_{IC} = V_{ICR\text{ min}}$	25°C	70 88			70 88			70 88			dB
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{DD} = 5\text{ to }10\text{ V}$ , $V_O = 1.4\text{ V}$	25°C	65 82			70 88			70 88			dB
$I_{OS}$	Short-circuit output current	$V_O = 0$ , $V_{ID} = 100\text{ mV}$	25°C	-55			-55			-55			mA
		$V_O = V_{DD}$ , $V_{ID} = -100\text{ mV}$		15			15			15			
$I_{DD}$	Supply current (each amplifier)	No load, $V_O = 5\text{ V}$ , $V_{IC} = 5\text{ V}$	25°C	1000 2000			10 20			150 300			$\mu\text{A}$
			0°C to 70°C	2200			30			400			

<sup>†</sup> All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Unless otherwise noted, an output load resistor is connected from the output to the ground pin.

<sup>‡</sup> The output will swing to the potential of the ground pin.

# TYPES TLC254, TLC25L4, TLC25M4 LinCMOS™ QUAD OPERATIONAL AMPLIFIERS

## C-SUFFIX TYPES

electrical characteristics at specified free-air temperature,  $V_{DD} = 1\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS <sup>1</sup>	TLC254_C			TLC25L4_C			TLC25M4_C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$	Input offset voltage	$V_O = 0.2\text{ V}$ , $R_S = 50\ \Omega$	TLC25_4C	25 °C		10		10		10		mV
				0 °C to 70 °C		12		12		12		
			TLC25_4AC	25 °C		5		5		5		
				0 °C to 70 °C		6.5		6.5		6.5		
	TLC25_4BC		25 °C		2		2		2			
			0 °C to 70 °C		3		3		3			
$\alpha_{VIO}$	Average temperature coefficient of input offset voltage		0 °C to 70 °C		1		1		1		$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$	Input offset current	$V_O = 0.2$	25 °C		1		1		1		pA	
			0 °C to 70 °C		100		100		100			
$I_{IB}$	Input bias current	$V_O = 0.2$	25 °C		1		1		1		pA	
			0 °C to 70 °C		150		150		150			
$V_{ICR}$	Common-mode input voltage range		25 °C	0 to 0.2		0 to 0.2		0 to 0.2			V	
$V_{OM}$	Peak output voltage swing <sup>2</sup>	$V_{IO} = 100\text{ mV}$	25 °C		450		450		450		mV	
$A_{VD}$	Large signal differential voltage amplification	$V_O = 100\text{ to }300\text{ mV}$ , $R_S = 50\ \Omega$	25 °C		10		20		20		V/mV	
CMRR	Common-mode rejection ratio	$V_O = 0.2\text{ V}$ , $V_{IC} = V_{ICR}\text{ min}$	25 °C		77		77		77		dB	
$I_{DD}$	Supply current (each amplifier)	No load, $V_O = 0.2\text{ V}$	25 °C		12		2		2		$\mu\text{A}$	

<sup>1</sup> All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Unless otherwise noted, an output load resistor is connected from the output to the ground pin.

<sup>2</sup> The output will swing to the potential of the ground pin.

operating characteristics,  $V_{DD} = 1\text{ V}$ ,  $T_A = 25\text{ }^\circ\text{C}$

PARAMETER		TEST CONDITIONS	TLC254_C			TLC25L4_C			TLC25M4_C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$B_1$	Unity-gain bandwidth	$A_V = 40\text{ dB}$ , $C_L = 10\text{ pF}$ , $R_S = 50\ \Omega$		75			12			12		kHz
SR	Slew rate at unity gain	See Figure 1		0.01			0.001			0.001		V/ $\mu\text{s}$
	Overshoot factor	See Figure 1		30%			35%			35%		

3

Operational Amplifiers

# TYPES TLC254, TLC25L4, TLC25M4, TLC274, TLC27L4, TLC27M4 LinCMOST™ QUAD OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{DD} = 10\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TLC254_C TLC274_M TLC274_I TLC274_C			TLC25L4_C TLC27L4_M TLC27L4_I TLC27L4_C			TLC25M4_C TLC27M4_M TLC27M4_I TLC27M4_C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$B_1$	Unity-gain bandwidth $A_V = 40\text{ dB}$ , $C_L = 10\text{ pF}$ , $R_S = 50\ \Omega$	2.3			0.1			0.7			MHz
SR	Slew rate at unity gain See Figure 1	4.5			0.04			0.6			V/ $\mu\text{s}$
	Overshoot factor See Figure 1	35%			30%			35%			
$\phi_m$	Phase margin at unity gain $A_V = 40\text{ dB}$ , $R_S = 100\ \Omega$ , $C_L = 10\text{ pF}$	50°			43°			43°			
$V_n$	Equivalent input noise voltage $f = 1\text{ kHz}$ , $R_S = 100\ \Omega$	30			70			38			n $\sqrt{\text{V}/\text{Hz}}$
$V_{O1}/V_{O2}$	Cross talk attenuation $A_V = 100$	120			120			120			dB

## PARAMETER MEASUREMENT INFORMATION

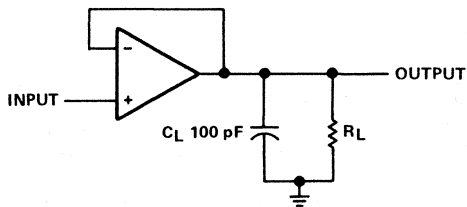
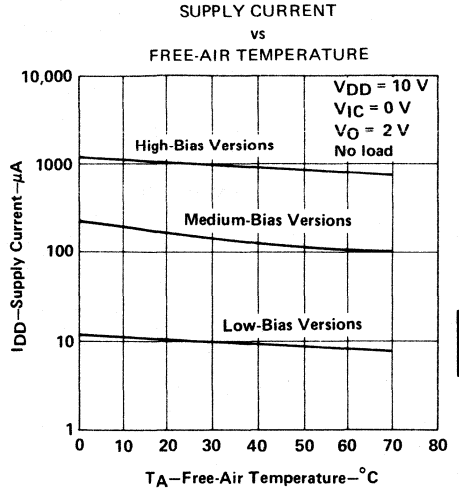
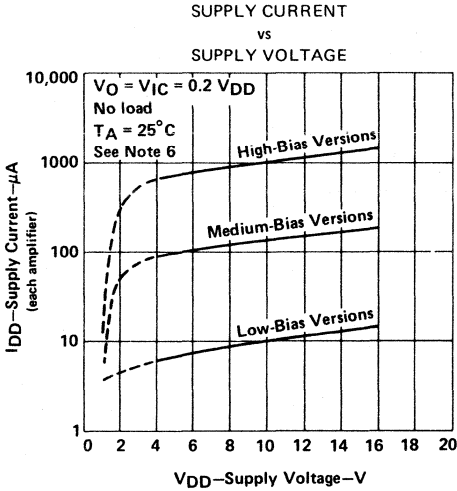


FIGURE 1—UNITY-GAIN AMPLIFIER



**TYPES TLC254, TLC25L4, TLC25M4, TLC274, TLC27L4, TLC27M4**  
**LinCMOS™ QUAD OPERATIONA AMPLIFIERS**

**TYPICAL CHARACTERISTICS**

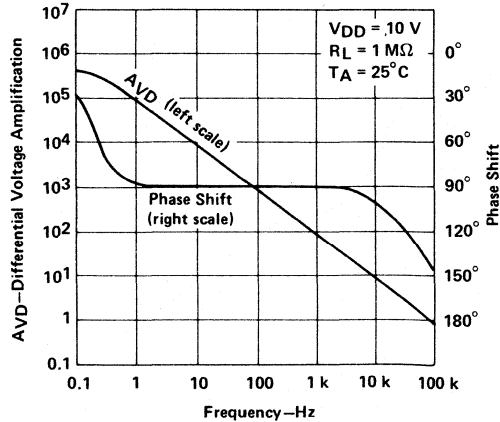


**FIGURE 2**

NOTE 6: Data for  $V_{DD}$  less than 4 V does not apply for the TLC274 series.

**FIGURE 3**

LOW-BIAS VERSIONS  
 LARGE-SIGNAL  
 DIFFERENTIAL VOLTAGE AMPLIFICATION  
 and PHASE SHIFT  
 vs  
 FREQUENCY



**FIGURE 4**

**TYPES TLC254, TLC25L4, TLC25M4, TLC274, TLC27L4, TLC27M4**  
**LinCMOS™ QUAD OPERATIONAL AMPLIFIERS**

**TYPICAL CHARACTERISTICS**

MEDIUM-BIAS VERSIONS  
 LARGE-SIGNAL  
 DIFFERENTIAL VOLTAGE AMPLIFICATION  
 and PHASE SHIFT  
 vs  
 FREQUENCY

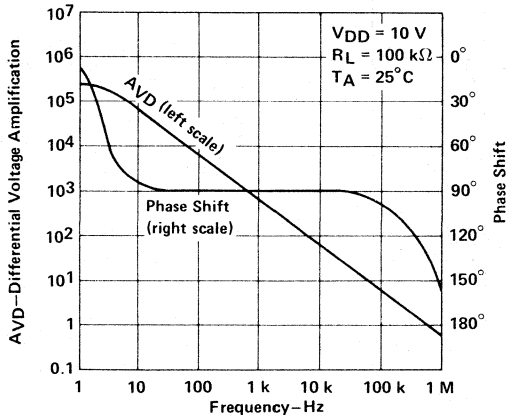


FIGURE 5

HIGH-BIAS VERSIONS  
 LARGE-SIGNAL  
 DIFFERENTIAL VOLTAGE AMPLIFICATION  
 and PHASE SHIFT  
 vs  
 FREQUENCY

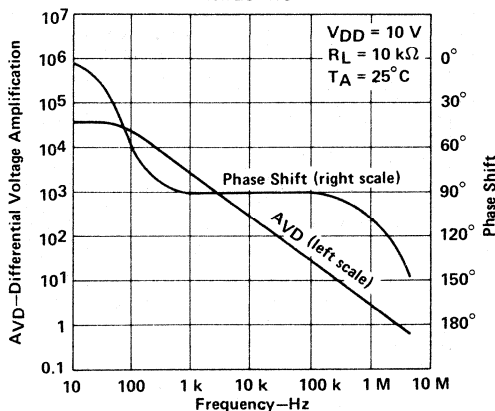


FIGURE 6

# TYPES TLC254, TLC25L4, TLC25M4, TLC274, TLC27L4, TLC27M4 LinCMOST™ QUAD OPERATIONAL AMPLIFIERS

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## TYPICAL APPLICATION INFORMATION

### latchup avoidance

Junction-isolated CMOS circuits have an inherent parasitic PNP structure that can function as an SCR. Under certain conditions, this SCR may be triggered into a low-impedance state, resulting in excessive supply current. To avoid such conditions, no voltage greater than 0.3 V beyond the supply rails should be applied to any pin. In general, the op amp supplies should be established simultaneously with, or before, any input signals are applied.

### output stage considerations

The amplifier's output stage consists of a source-follower-connected pullup transistor and an open-drain pulldown transistor. The high-level output voltage ( $V_{OH}$ ) is virtually independent of the  $I_{DD}$  selection, and increases with higher values of  $V_{DD}$  and reduced output loading. The low-level output voltage ( $V_{OL}$ ) decreases with reduced output current and higher input common-mode voltage. With no load,  $V_{OL}$  is essentially equal to the GND pin potential.

### supply configurations

Even though the TLC254 and TLC274 are characterized for single-supply operation, they can be used effectively in a split-supply configuration if the input common-mode voltage ( $V_{ICR}$ ), output swing ( $V_{OL}$  and  $V_{OH}$ ), and supply voltage limits are not exceeded.

### circuit layout precautions

The user is cautioned that whenever extremely high circuit impedances are used, care must be exercised in layout, construction, board cleanliness, and supply filtering to avoid hum and noise pickup, as well as excessive DC leakages.

# 3

## Operational Amplifiers

- Wide Range of Supply Voltage: 2 V to 16 V
- True Single-Supply Operation
- Designed for Performance Similar to Popular BIFET Op Amps
- Common-Mode Input Voltage Includes the Negative Rail
- Slew Rate . . . 12 V/μs Typ
- High Input Impedance . . . 10<sup>12</sup> Ω Typ

**DEVICE FEATURES**

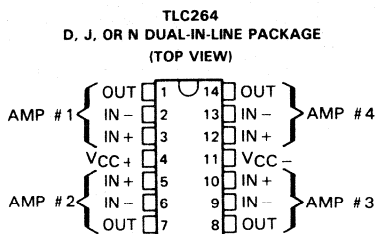
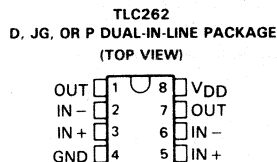
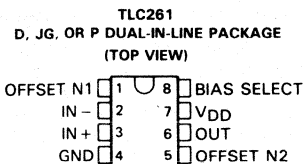
PARAMETER	FEATURE
Supply current per channel (Typ)	2.5 mA
Slew rate (Typ)	12 V/μs
Input offset voltage (Max)	
. . . Standard types	10 mV
. . . A-suffix types	5 mV
. . . B-suffix types	2 mV
Offset voltage drift (Typ)	0.1 μV/month <sup>†</sup>
Offset voltage temperature coefficient (Typ)	5 μV/°C
Input bias current (Typ)	1 pA
Input offset current (Typ)	1 pA
Operating temperature range	-40 °C to 85 °C

<sup>†</sup>The long-term drift value applies after the first month.

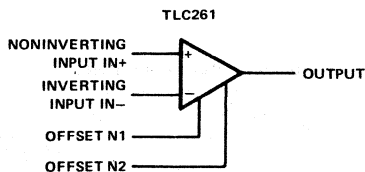
**description**

The TLC261, TLC262, and TLC264 LinCMOST™ operational amplifiers are designed to provide a true single-supply alternative to the popular BIFET op amps. The negative supply rail is included in both input and output common-mode voltage ranges. In addition, these devices feature input offset voltage selection.

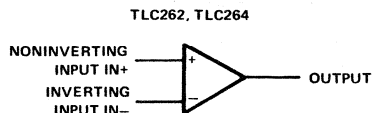
Unlike traditional metal-gate CMOS op amps, these devices utilize the Texas Instruments silicon-gate LinCMOST™ process giving them stable input offset voltages without sacrificing the advantage of metal-gate CMOS. Because the input common-mode range extends to the negative rail and the power consumption is extremely low, this family is ideally suited for battery-powered or energy-conserving applications. All devices are stable at unity gain.



**symbol**



**symbol (each amplifier)**



**PRODUCT PREVIEW**

This document contains information on a product under development. Texas Instruments reserves the right to change or discontinue this product without notice.

# TYPES TLC261, TLC262, TLC264 PROGRAMMABLE LOW-POWER LinCMOS™ OPERATIONAL AMPLIFIERS

## absolute maximum ratings over operating free-air temperature (unless otherwise noted)

Supply voltage, $V_{DD}$ (see Note 1)	18 V
Differential input voltage (see Note 2)	$\pm 18$ V
Input voltage range (any input)	-0.3 V to 18 V
Duration of short-circuit at (or below) 25°C free-air temperature (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4):	
TLC261ID, TLC262ID	725 mW
TLC261JG, TLC262JG	825 mW
TLC261IP, TLC262IP	725 mW
TLC264ID	950 mW
TLC264IJ	1025 mW
TLC264IN	875 mW
Operating free-air temperature range	-40°C to 85°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J or JG package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, N, or P package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Table below. In the J and JG packages, these chips are glass mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
D (8-Pin)	725 mW	5.8 mW/°C	25°C
D (14-Pin)	950 mW	7.6 mW/°C	25°C
J (glass mounted)	1025 mW	8.2 mW/°C	25°C
JG (glass mounted)	825 mW	6.6 mW/°C	25°C
N	875 mW	7 mW/°C	25°C
P	725 mW	5.8 mW/°C	25°C

## recommended operating conditions

		MIN	NOM	MAX	UNIT
Supply voltage, $V_{DD}$		2		16	V
Common-mode input voltage, $V_{IC}$	$V_{DD} = 2$ V	0		1.2	V
	$V_{DD} = 4$ V	0		3	
	$V_{DD} = 10$ V	-0.05		9	
	$V_{DD} = 16$ V	-0.05		14	
Operating free-air temperature, $T_A$		-40		85	°C

3

Operational Amplifiers

- **Common-Mode Input Range . . .  $\pm 10$  V Typical**
- **Designed to be Interchangeable with Fairchild  $\mu$ A709A,  $\mu$ A709, and  $\mu$ A709C**
- **Maximum Peak-to-Peak Output Voltage Swing . . . 28-V Typical with 15-V Supplies**

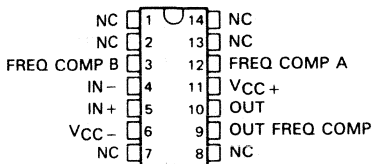
**description**

These circuits are general-purpose operational amplifiers, each having high-impedance differential inputs and a low-impedance output. Component matching, inherent with silicon monolithic circuit-fabrication techniques, produces an amplifier with low-drift and low-offset characteristics. Provisions are incorporated within the circuit whereby external components may be used to compensate the amplifier for stable operation under various feedback or load conditions. These amplifiers are particularly useful for applications requiring transfer or generation of linear or nonlinear functions.

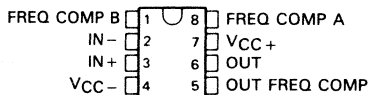
The  $\mu$ A709A circuit features improved offset characteristics, reduced input-current requirements, and lower power dissipation when compared to the  $\mu$ A709 circuit. In addition, maximum values of the average temperature coefficients of offset voltage and current are guaranteed.

The  $\mu$ A709AM and  $\mu$ A709M are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The  $\mu$ A709C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

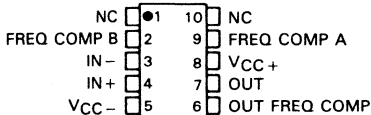
$\mu$ A709AM,  $\mu$ A709M . . . J OR W PACKAGE  
(TOP VIEW)



$\mu$ A709AM,  $\mu$ A709M . . . JG PACKAGE  
 $\mu$ A709C . . . JG OR P PACKAGE  
(TOP VIEW)

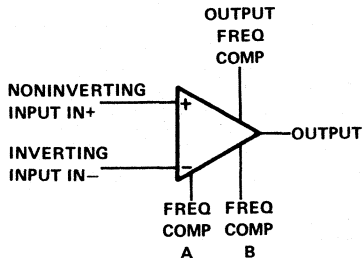


$\mu$ A709AM,  $\mu$ A709M . . . U FLAT PACKAGE  
(TOP VIEW)



NC—No internal connection

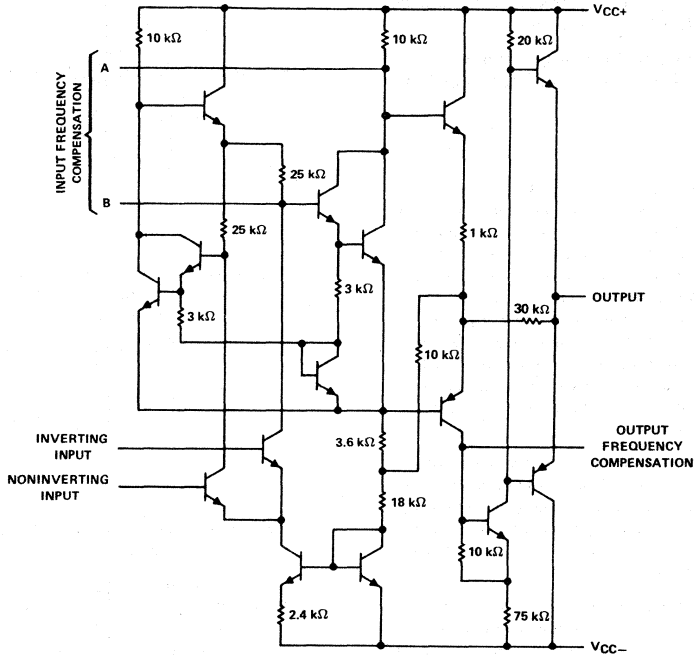
**symbol**



# TYPES $\mu$ A709AM, $\mu$ A709M, $\mu$ A709C

## GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

schematic



Component values shown are nominal.

3 Operational Amplifiers

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	$\mu$ A709AM $\mu$ A709M	$\mu$ A709C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	18	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-18	-18	V
Differential input voltage (see Note 2)	$\pm 5$	$\pm 5$	V
Input voltage (either input, see Notes 1 and 3)	$\pm 10$	$\pm 10$	V
Duration of output short-circuit (see Note 4)	5	5	s
Continuous total dissipation at (or below) 70°C free-air temperature (see Note 5)	300	300	mW
Operating free-air temperature range	-55 to 125	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J, JG, U, or W package	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	P package	260	°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 10 volts, whichever is less.
4. The output may be shorted to ground or either power supply.
5. For operation of  $\mu$ A709AM and  $\mu$ A709M above 70°C free-air temperature, refer to the Dissipation Derating Curves, Section 2. In the J and JG packages,  $\mu$ A709AM and  $\mu$ A709M chips are alloy-mounted;  $\mu$ A709C chips are glass-mounted.



# TYPES $\mu$ A709AM, $\mu$ A709M, $\mu$ A709C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC} \pm = \pm 9 \text{ V to } \pm 15 \text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		$\mu$ A709AM			$\mu$ A709M			UNIT
			MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0$ , $R_S \leq 10 \text{ k}\Omega$	25°C		0.6	2		1	5	mV
		Full range			3			6	
$\alpha_{VIO}$ Average temperature coefficient of input offset voltage	$V_O = 0$ , $R_S = 50 \Omega$	Full range		1.8	10		3		$\mu\text{V}/^\circ\text{C}$
	$V_O = 0$ , $R_S = 10 \text{ k}\Omega$	Full range		4.8	25		6		
$I_{IO}$ Input offset current	$V_O = 0$	25°C		10	50		50	200	nA
		-55°C		40	250		100	500	
		125°C		3.5	50		20	200	
$\alpha_{IIO}$ Average temperature coefficient of input offset current	$V_O = 0$	-55°C to 25°C		0.45	2.8				nA/°C
		25°C to 125°C		0.08	0.5				
$I_{IB}$ Input bias current	$V_O = 0$	25°C		0.1	0.2		0.2	0.5	$\mu\text{A}$
		-55°C		0.3	0.6		0.5	1.5	
$V_{ICR}$ Common-mode input voltage range	$V_{CC} \pm = \pm 15 \text{ V}$	25°C	$\pm 8$	$\pm 10$		$\pm 8$	$\pm 10$		V
		Full range	$\pm 8$			$\pm 8$			
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$V_{CC} \pm = \pm 15 \text{ V}$ , $R_L \geq 10 \text{ k}\Omega$	25°C	24	28		24	28		V
		Full range	24			24			
		$V_{CC} \pm = \pm 15 \text{ V}$ , $R_L = 2 \text{ k}\Omega$	25°C	20	26		20	26	
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} \pm = \pm 15 \text{ V}$ , $R_L \geq 2 \text{ k}\Omega$ , $V_O = \pm 10 \text{ V}$	25°C		45		45			V/mV
		Full range	25	70		25	70		
		25°C	350	750		150	400		
$r_i$ Input resistance		25°C	85	185		40	100		k $\Omega$
		-55°C							
$r_o$ Output resistance	$V_O = 0$ See Note 6	25°C		150		150			$\Omega$
		25°C	80	110		70	90		
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR} \text{ min}$	25°C	80	110		70	90		dB
		Full range	80			70			
$k_{SVS}$ Power supply sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$V_{CC} \pm = \pm 9 \text{ V to } \pm 15 \text{ V}$	25°C		40	100		25	150	$\mu\text{V}/\text{V}$
		Full range			100			150	
$I_{CC}$ Supply current	$V_{CC} \pm = \pm 15 \text{ V}$ , No load, $V_O = 0$	25°C		2.5	3.6		2.6	5.5	mA
		-55°C		2.7	4.5				
		125°C		2.1	3				
$P_D$ Total power dissipation	$V_{CC} \pm = \pm 15 \text{ V}$ , No load, $V_O = 0$	25°C		75	108		78	165	mW
		-55°C		81	135				
		125°C		63	90				

<sup>†</sup> All characteristics are specified under open-loop with zero common-mode input voltage unless otherwise specified. Full range for  $\mu$ A709AM and  $\mu$ A709M is -55°C to 125°C.

<sup>‡</sup> All typical values are at  $V_{CC} \pm = \pm 15 \text{ V}$ .

NOTE 6: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

Operational Amplifiers

# TYPES $\mu$ A709AM, $\mu$ A709M, $\mu$ A709C

## GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature (unless otherwise noted  $V_{CC\pm} = \pm 15$  V)

PARAMETER	TEST CONDITIONS†	$\mu$ A709C			UNIT
		MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{CC\pm} = \pm 9$ V to $\pm 15$ V, $V_O = 0$	25°C	2	7.5	mV
		Full range		10	
$I_{IO}$ Input offset current	$V_{CC\pm} = \pm 9$ V to $\pm 15$ V, $V_O = 0$	25°C	100	500	nA
		Full range		750	
$I_{IB}$ Input bias current	$V_{CC\pm} = \pm 9$ V to $\pm 15$ V, $V_O = 0$	25°C	0.3	1.5	$\mu$ A
		Full range		2	
$V_{ICR}$ Common-mode input voltage range		25°C	$\pm 8$	$\pm 10$	V
		25°C	24	28	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L \geq 10$ k $\Omega$	25°C	24	28	V
		Full range	24		
		25°C	20	26	
		Full range	20		
$A_{VD}$ Large-signal differential voltage amplification	$R_L \leq 2$ k $\Omega$ , $V_O = \pm 10$ V	25°C	15	45	V/mV
		Full range	12		
		25°C	50	250	
		Full range	35		
$r_i$ Input resistance					k $\Omega$
$r_o$ Output resistance	$V_O = 0$ , See Note 6	25°C		150	$\Omega$
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR}$ min	25°C	65	90	dB
kSVS Supply voltage sensitivity	$V_{CC} = \pm 9$ V to $\pm 15$ V	25°C	25	200	$\mu$ V/V
$P_D$ Total power dissipation	$V_O = 0$ No load	25°C	80	200	mW

†All characteristics are specified under open-loop operation with zero volts common-mode voltage unless otherwise specified. Full range for  $\mu$ A709C is 0°C to 70°C.

NOTE 6: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

operating characteristics  $V_{CC\pm} = \pm 9$  V to  $\pm 15$  V,  $T_A = 25^\circ$  C

PARAMETER	TEST CONDITIONS	$\mu$ A709AM $\mu$ A709M $\mu$ A709C			UNIT
		MIN	TYP	MAX	
$t_r$ Rise time	$V_I = 20$ mV, $R_L = 2$ k $\Omega$ , See Figure 1	$C_L = 0$			$\mu$ s
Overshoot factor		$C_L = 100$ pF			

### PARAMETER MEASUREMENT INFORMATION

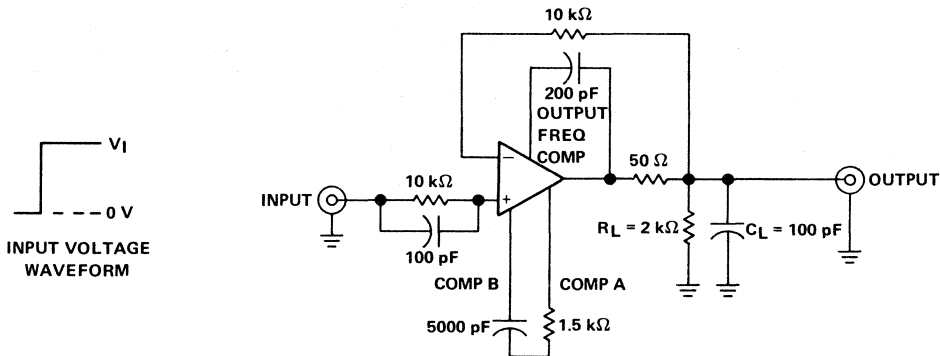
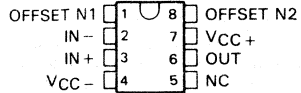


FIGURE 1—RISE TIME AND SLEW RATE

3 Operational Amplifiers

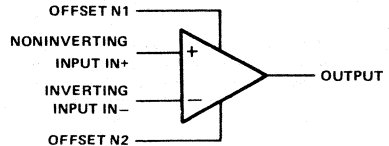
- Ultra-Low Offset Voltage . . . 30  $\mu$ V Typ ( $\mu$ A714E)
- Ultra-Low Offset Voltage Temperature Coefficient . . . 0.3  $\mu$ V/ $^{\circ}$ C Typ ( $\mu$ A714E)
- Ultra-Low Noise
- No External Components Required
- Replaces Chopper Amplifiers at a Lower Cost
- Single-Chip Monolithic Fabrication
- Wide Input Voltage Range  
0 to  $\pm 14$  V Typ
- Wide Supply Voltage Range  
 $\pm 3$  V to  $\pm 18$  V
- Essentially Equivalent to PMI OP-07 Series Operational Amplifiers
- Direct Replacements for Fairchild  $\mu$ A714C,  $\mu$ A714E,  $\mu$ A714L

JG OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



NC—No internal connection

symbol

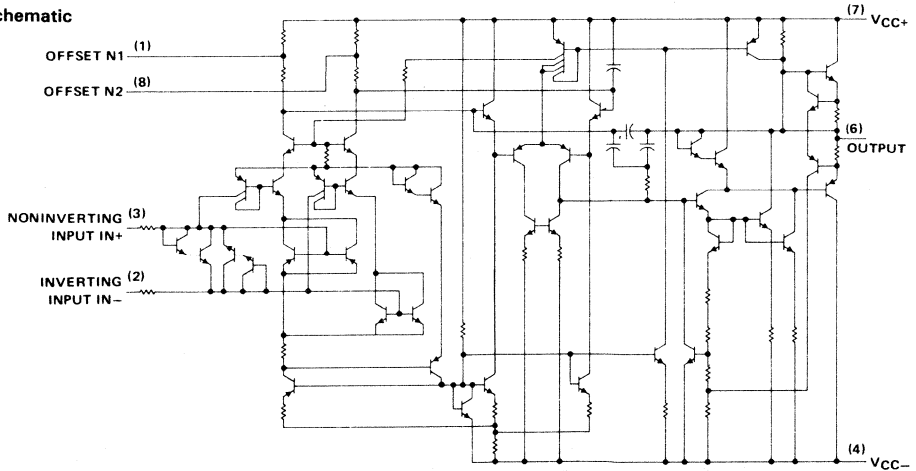


**description**

These devices represent a breakthrough in operational amplifier performance. Low offset and long-term stability are achieved by means of a low-noise, chopperless, bipolar-input-transistor amplifier circuit. For most applications, no external components are required for offset nulling and frequency compensation. The true differential input, with a wide input voltage range and outstanding common-mode rejection, provides maximum flexibility and performance in high-noise environments and in noninverting applications. Low bias currents and extremely high input impedances are maintained over the entire temperature range. The  $\mu$ A714 is unsurpassed for low-noise, high-accuracy amplification of very-low-level signals.

These devices are characterized for operation from 0 $^{\circ}$ C to 70 $^{\circ}$ C.

**schematic**



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**TYPES  $\mu$ A714C,  $\mu$ A714E,  $\mu$ A714L**  
**ULTRA-LOW-OFFSET VOLTAGE OPERATIONAL AMPLIFIERS**

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage $V_{CC+}$ (see Note 1) .....	22 V
Supply voltage $V_{CC-}$ .....	-22 V
Differential input voltage (see Note 2) .....	$\pm 30$ V
Input voltage (either input, see Note 3) .....	$\pm 22$ V
Duration of output short circuit (see Note 4) .....	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5) .....	500 mW
Operating free-air temperature range .....	0°C to 70°C
Storage temperature range .....	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package .....	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: P package .....	260°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves in Section 2. In the JG package, these chips are glass mounted.

**3**

**Operational Amplifiers**

# TYPES $\mu$ A714C, $\mu$ A714E, $\mu$ A714L

## ULTRA-LOW-OFFSET VOLTAGE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC} \pm = \pm 15\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS †	$\mu$ A714C			$\mu$ A714E			$\mu$ A714L			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0$ , $R_S = 50\ \Omega$	25°C 0°C to 70°C	60 85	150 250	30 45	75 130	100 250	250 400			$\mu\text{V}$
$e_{VIO}$ Temperature coefficient of input offset voltage	$V_O = 0$ , $R_S = 50\ \Omega$	0°C to 70°C	0.5	1.8	0.3	1.3	1	3			$\mu\text{V}/^\circ\text{C}$
Long-term drift of input offset voltage	See Note 6										
Offset adjustment range	$R_S = 20\ \text{k}\Omega$ , See Figure 1	25°C	±4		±4		±4				mV
$I_{IO}$ Input offset current		25°C 0°C to 70°C	0.8 1.6	6 8	0.5 0.9	3.8 5.3	5 8	2.0 4.0			nA
$e_{IIO}$ Temperature coefficient of input offset current		0°C to 70°C	12	50	8	35	20	100			$\text{pA}/^\circ\text{C}$
$I_{IB}$ Input bias current		25°C	±1.8	±7	±1.2	±4	±6	±30			nA
$e_{IIB}$ Temperature coefficient of input bias current		0°C to 70°C	±2.2	±9	±1.5	±5.5	±15	±60			nA
$V_{ICR}$ Common-mode input voltage range		0°C to 70°C	18	50	13	35	35	150			$\text{pA}/^\circ\text{C}$
$V_{OM}$ Peak output voltage	$R_L \geq 10\ \text{k}\Omega$ $R_L \geq 2\ \text{k}\Omega$ $R_L \geq 1\ \text{k}\Omega$ $R_L \geq 2\ \text{k}\Omega$	25°C 0°C to 70°C 25°C 0°C to 70°C	±13 ±13 ±11.5	±14 ±13.5 ±12.8	±13 ±13.5 ±12.8	±4 ±13 ±12.8	±13 ±13.5 ±11	±14 ±13.5 ±12.8			V
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} \pm = \pm 3\text{ V}$ , $V_O = \pm 0.5\text{ V}$ , $R_L \geq 500\ \text{k}\Omega$	25°C	100	400	150	500	50	150			V/mV
$B_1$ Unity gain bandwidth	$V_O = \pm 10\text{ V}$ , $R_L = 2\ \text{k}\Omega$	0°C to 70°C	100	400	180	450	80	400			MHz
$f_T$ Input resistance		25°C	8	33	15	50	8	33			M $\Omega$
CMRR Common-mode rejection ratio	$V_{IC} = \pm 13\text{ V}$ , $R_S = 50\ \Omega$	25°C 0°C to 70°C	100	120	108	123	100	120			dB
$k_{SVR}$ Supply voltage rejection ratio $(\Delta V_{CC}/\Delta V_O)$	$V_{CC} \pm = \pm 3\text{ V}$ to $\pm 18\text{ V}$ , $R_S = 50\ \Omega$	25°C	90	104	94	107	90	104			dB
$P_D$ Power dissipation	$V_O = 0$ , No load $V_{CC} \pm = \pm 3\text{ V}$ , $V_O = 0$ , No load	25°C	80	150	75	120	100	180			mW

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise noted.  
NOTE 6: Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the averaged trend line of drift versus time over extended periods after the first thirty days of operation.

# TYPES $\mu$ A714C, $\mu$ A714E, $\mu$ A714L

## ULTRA-LOW-OFFSET VOLTAGE OPERATIONAL AMPLIFIERS

operating characteristics at specified free-air temperature,  $V_{CC} \pm = \pm 15$  V (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	$\mu$ A714C			$\mu$ A714E			$\mu$ A714L			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_n$ Equivalent input noise voltage	$T_A = 25^\circ\text{C}$	$f = 10$ Hz	10.5	20	10.3	18	10.5				$\text{nV}/\sqrt{\text{Hz}}$
		$f = 100$ Hz	10.2	13.5	10	13	10.2				
		$f = 1$ kHz	9.8	11.5	9.6	11	9.8				
$V_{NPP}$ Peak-to-peak equivalent input noise voltage	$f = 0.1$ Hz to 10 Hz, $T_A = 25^\circ\text{C}$	0.38	0.65	0.35	0.6					$\mu\text{V}$	
$I_n$ Equivalent input noise current	$T_A = 25^\circ\text{C}$	$f = 10$ Hz	0.35	0.9	0.32	0.8	0.35	0.8			$\text{pA}/\sqrt{\text{Hz}}$
		$f = 100$ Hz	0.15	0.27	0.14	0.23	0.15	0.23			
		$f = 1$ kHz	0.13	0.18	0.12	0.17	0.13	0.17			
$I_{NPP}$ Peak-to-peak equivalent input noise current	$f = 0.1$ Hz to 10 Hz, $T_A = 25^\circ\text{C}$	15	35	14	30	15				$\text{pA}$	
SR Slew rate	$R_L \geq 2$ k $\Omega$ , $T_A = 25^\circ\text{C}$	0.17		0.17		0.17				$\text{V}/\mu\text{s}$	

<sup>†</sup>All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

3

Operational Amplifiers

### TYPICAL APPLICATION DATA

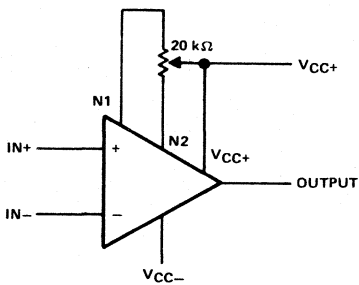


FIGURE 1—INPUT OFFSET VOLTAGE NULL CIRCUIT

- Short-Circuit Protection
- Offset-Voltage Null Capability
- Large Common-Mode and Differential Voltage Ranges
- No Frequency Compensation Required
- Low Power Consumption
- No Latch-up
- Designed to be Interchangeable with Fairchild  $\mu$ A741M,  $\mu$ A741C

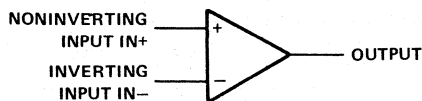
**description**

The  $\mu$ A741 is a general-purpose operational amplifier featuring offset-voltage null capability.

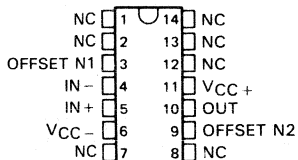
The high common-mode input voltage range and the absence of latch-up make the amplifier ideal for voltage-follower applications. The device is short-circuit protected and the internal frequency compensation ensures stability without external components. A low potentiometer may be connected between the offset null inputs to null out the offset voltage as shown in Figure 2.

The  $\mu$ A741M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the  $\mu$ A741C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

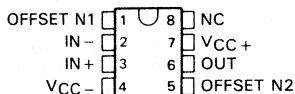
**symbol**



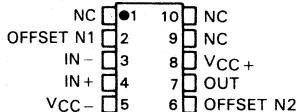
$\mu$ A741M . . . J PACKAGE  
(TOP VIEW)



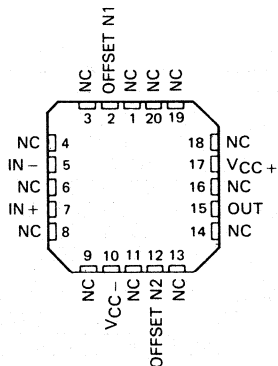
$\mu$ A741M . . . JG PACKAGE  
 $\mu$ A741C . . . D, P, OR JG PACKAGE  
(TOP VIEW)



$\mu$ A741M . . . U FLAT PACKAGE  
(TOP VIEW)



$\mu$ A741M . . . FH, FK PACKAGE  
(TOP VIEW)

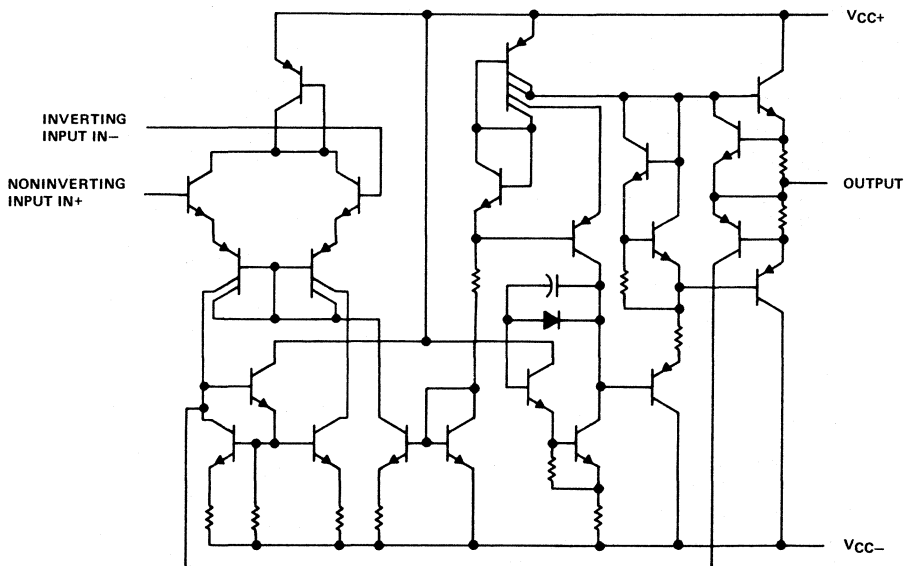


NC—No internal connection

# TYPES $\mu$ A741M, $\mu$ A741C

## GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

schematic



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	$\mu$ A741M	$\mu$ A741C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	22	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-22	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	V
Input voltage any input (see Notes 1 and 3)	$\pm 15$	$\pm 15$	V
Voltage between either offset null terminal (N1/N2) and $V_{CC-}$	$\pm 0.5$	$\pm 0.5$	V
Duration of output short-circuit (see Note 4)	unlimited	unlimited	
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5)	500	500	mW
Operating free-air temperature range	-55 to 125	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds FH, FK, J, JG, or U package	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds D, N or P package		260	°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply. For the  $\mu$ A741M only, the unlimited duration of the short-circuit applies at (or below) 125°C case temperature or 75°C free-air temperature.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J and JG packages,  $\mu$ A741M chips are alloy mounted;  $\mu$ A741C chips are glass mounted.



# TYPES $\mu$ A741M, $\mu$ A741C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$

PARAMETER		TEST CONDITIONS <sup>†</sup>		$\mu$ A741M			$\mu$ A741C			UNIT		
				MIN	TYP	MAX	MIN	TYP	MAX			
$V_{IO}$	Input offset voltage	$V_O = 0$	25°C	1		1		6		mV		
			Full range	6		7.5						
$\Delta V_{IO}(\text{adj})$	Offset voltage adjust range	$V_O = 0$	25°C	±15			±15			mV		
$I_{IO}$	Input offset current	$V_O = 0$	25°C	20		200		20		200		nA
			Full range	500		300						
$I_{IB}$	Input bias current	$V_O = 0$	25°C	80		500		80		500		nA
			Full range	1500		800						
$V_{ICR}$	Common-mode input voltage range		25°C	±12	±13	±12	±13			V		
			Full range	±12		±12						
$V_{OM}$	Maximum peak output voltage swing	$R_L = 10\text{ k}\Omega$	25°C	±12	±14	±12	±14			V		
			Full range	±12		±12						
			$R_L = 2\text{ k}\Omega$	25°C	±10	±13	±10	±13				
			Full range	±10		±10						
$A_{VD}$	Large-signal differential voltage amplification	$R_L \geq 2\text{ k}\Omega$	25°C	50	200	20	200			V/mV		
			Full range	25		15						
$r_i$	Input resistance		25°C	0.3	2	0.3	2			M $\Omega$		
$r_o$	Output resistance	$V_O = 0$ , See Note 6	25°C	75		75				$\Omega$		
$C_i$	Input capacitance		25°C	1.4		1.4				pF		
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR\text{ min}}$	25°C	70	90	70	90			dB		
			Full range	70		70						
$k_{SVS}$	Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$V_{CC} = \pm 9\text{ V}$ to $\pm 15\text{ V}$	25°C	30		150		30		150		$\mu\text{V/V}$
			Full range	150		150						
$I_{OS}$	Short-circuit output current		25°C	±25	±40	±25	±40			mA		
$I_{CC}$	Supply current	No load, $V_O = 0$	25°C	1.7	2.8	1.7	2.8			mA		
			Full range	3.3		3.3						
$P_D$	Total power dissipation	No load, $V_O = 0$	25°C	50		85		50		85		mW
			Full range	100		100						

<sup>†</sup>All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for  $\mu$ A741M is -55°C to 125°C and for  $\mu$ A741C is 0°C to 70°C.

NOTE 6: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

Operational Amplifiers 3

**TYPES  $\mu$ A741M,  $\mu$ A741C**  
**GENERAL-PURPOSE OPERATIONAL AMPLIFIERS**

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	$\mu$ A741M			$\mu$ A741C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$	Rise time	$V_i = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$			0.3			$\mu\text{s}$
	Overshoot factor	$C_L = 100\text{ pF}$ , See Figure 1			5%			
SR	Slew rate at unity gain	$V_i = 10\text{ V}$ , $R_L = 2\text{ k}\Omega$			0.5			$\text{V}/\mu\text{s}$
		$C_L = 100\text{ pF}$ , See Figure 1						

**PARAMETER MEASUREMENT INFORMATION**

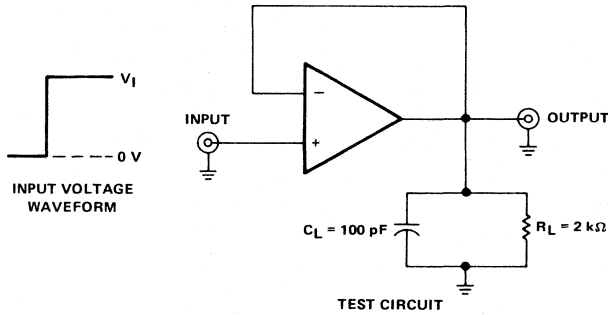


FIGURE 1—RISE TIME, OVERSHOOT, AND SLEW RATE

**TYPICAL APPLICATION DATA**

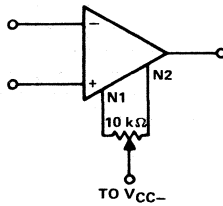


FIGURE 2—INPUT OFFSET VOLTAGE NULL CIRCUIT

**3** Operational Amplifiers

TYPICAL CHARACTERISTICS

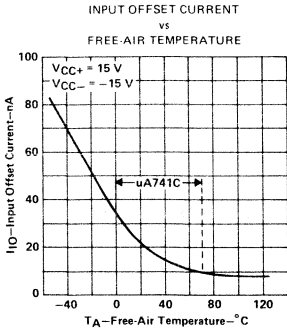


FIGURE 3

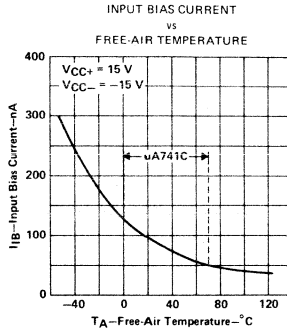


FIGURE 4

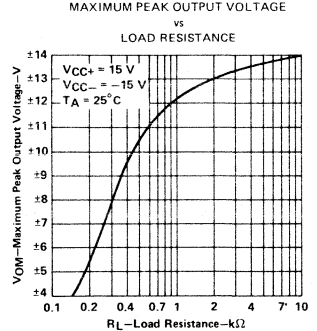


FIGURE 5

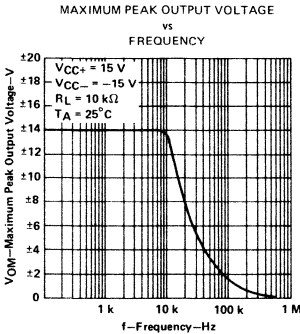


FIGURE 6

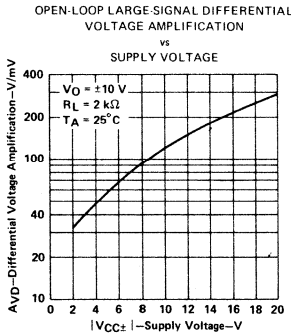


FIGURE 7

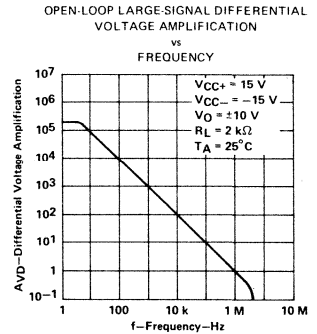


FIGURE 8

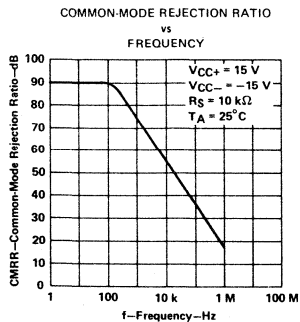


FIGURE 9

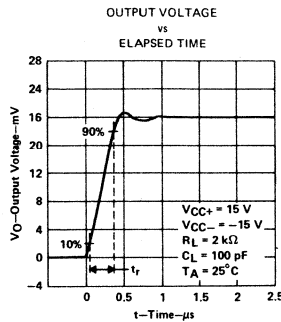


FIGURE 10

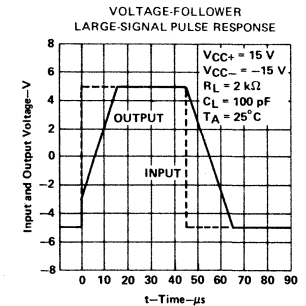


FIGURE 11

3  
Operational Amplifiers

# 3

## Operational Amplifiers

- No Frequency Compensation Required
- Low Power Consumption
- Short-Circuit Protection
- Offset-Voltage Null Capability
- Wide Common-Mode and Differential Voltage Ranges
- No Latch-up
- Designed to be Interchangeable with Fairchild  $\mu$ A747M and  $\mu$ A747C

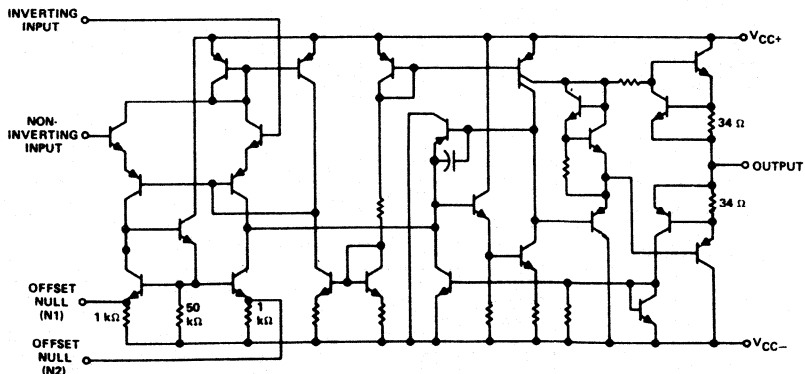
**description**

The  $\mu$ A747 is a dual general-purpose operational amplifier featuring offset-voltage null capability. Each half is electrically similar to  $\mu$ A741.

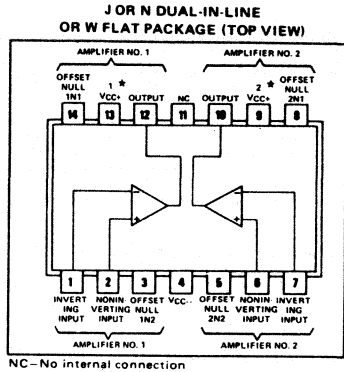
The high common-mode input voltage range and the absence of latch-up make this amplifier ideal for voltage-follower applications. The device is short-circuit protected and the internal frequency compensation ensures stability without external components. A low-value potentiometer may be connected between the offset null inputs to null out the offset voltage as shown in Figure 2.

The  $\mu$ A747M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the  $\mu$ A747C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**schematic (each amplifier)**



Resistor values shown are nominal



\* On parts date-coded 7701 or higher, the two positive supply terminals (1  $V_{CC+}$  and 2  $V_{CC+}$ ) are connected together internally. For parts without this internal connection, order  $\mu$ A747-1M or  $\mu$ A747-1C.

# TYPES $\mu$ A747M, $\mu$ A747C

## DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		$\mu$ A747M	$\mu$ A747C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)		22	18	V
Supply voltage $V_{CC-}$ (see Note 1)		-22	-18	V
Differential input voltage (see Note 2)		$\pm 30$	$\pm 30$	V
Input voltage any input (see Notes 1 and 3)		$\pm 15$	$\pm 15$	V
Voltage between any offset null terminal (N1/N2) and $V_{CC-}$		$\pm 0.5$	$\pm 0.5$	V
Duration of output short-circuit (see Note 4)		unlimited	unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)	Each amplifier	500	500	mW
	Total package	800	800	
Operating free-air temperature range		-55 to 125	0 to 70	°C
Storage temperature range		-65 to 150	-65 to 150	°C
Lead temperature 1/16 inch (1.6 mm) from case for 60 seconds		J or W package	300	°C
Lead temperature 1/16 inch (1.6 mm) from case for 10 seconds		N package	260	°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply. For the  $\mu$ A747M only, the unlimited duration of the short-circuit applies at (or below) 125°C case temperature or 75°C free-air temperature.
5. For operation above 25°C free-air temperature and for total package ratings, refer to Dissipation Derating Table, in the J package,  $\mu$ A747M chips are alloy-mounted;  $\mu$ A747C chips are glass-mounted.

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15$  V,  $V_{CC-} = -15$  V

PARAMETER	TEST CONDITIONS†	$\mu$ A747M			$\mu$ A747C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S < 10$ k $\Omega$	25°C	1	5	1	6	mV	
	Full range			6		7.5		
$\Delta V_{IO}(\text{adj})$ Offset voltage adjust range		25°C	$\pm 15$		$\pm 15$		mV	
$I_{IO}$ Input offset current		25°C	20	200	20	200	nA	
	Full range			500		300		
$I_{IB}$ Input bias current		25°C	80	500	80	500	nA	
	Full range			1500		800		
$V_{ICR}$ Common-mode input voltage range		25°C	$\pm 12$	$\pm 13$	$\pm 12$	$\pm 13$	V	
	Full range		$\pm 12$		$\pm 12$			
$V_{OPP}$ Maximum peak-to-peak output voltage swing	$R_L = 10$ k $\Omega$	25°C	24	28	24	28	V	
	$R_L > 10$ k $\Omega$	Full range		24		24		
	$R_L = 2$ k $\Omega$	25°C	20	26	20	26		
	$R_L > 2$ k $\Omega$	Full range		20		20		
$A_{VD}$ Large-signal differential voltage amplification	$R_L > 2$ k $\Omega$ , $V_O = \pm 10$ V	25°C	50	200	25	200	V/mV	
$r_i$ Input resistance		25°C	0.3	2	0.3	2	M $\Omega$	
$r_o$ Output resistance	$V_O = 0$ V, See Note 6	25°C	75		75		$\Omega$	
$C_i$ Input capacitance		25°C	1.4		1.4		pF	
		25°C	70	90	70	90		
CMRR Common-mode rejection ratio	$R_S < 10$ k $\Omega$	25°C	70	90	70	90	dB	
	Full range		70		70			
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$R_S < 10$ k $\Omega$	25°C	30	150	30	150	$\mu$ V/V	
	Full range			150		150		
$I_{OS}$ Short-circuit output current		25°C	$\pm 25$	$\pm 40$	$\pm 25$	$\pm 40$	mA	
$I_{CC}$ Supply current (each amplifier)	No load,	25°C	1.7	2.8	1.7	2.8	mA	
	No signal	Full range		3.3		3.3		
$P_D$ Power dissipation (each amplifier)	No load,	25°C	50	85	50	85	mW	
	No signal	Full range		100		100		
$V_{O1}/V_{O2}$ Channel separation		25°C	120		120		dB	

† All characteristics are specified under open-loop operation. Full range for  $\mu$ A747M is -55°C to 125°C and for  $\mu$ A747C is 0°C to 70°C.

NOTE 6: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

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Operational Amplifiers

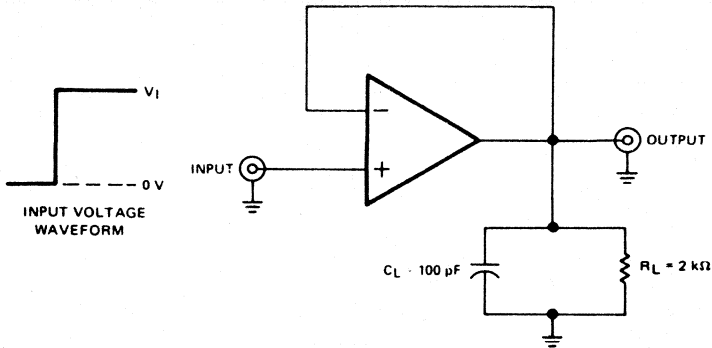
# TYPES $\mu$ A747M, $\mu$ A747C

## DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	$\mu$ A747M		$\mu$ A747C		UNIT
		MIN	TYP	MAX	MIN	
Rise time	$V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$		0.3		0.3	$\mu\text{s}$
Overshoot factor	$C_L = 100\text{ pF}$ , See Figure 1		5%		5%	
Slew rate at unity gain	$V_I = 10\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , See Figure 1		0.5		0.5	$\text{V}/\mu\text{s}$

### PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

FIGURE 1—RISE TIME, OVERSHOOT, AND SLEW RATE

### TYPICAL APPLICATION DATA

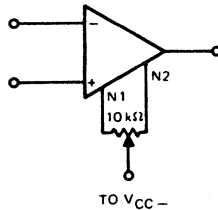


FIGURE 2—INPUT OFFSET VOLTAGE NULL CIRCUIT

### DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	800 mW	11.0 $\text{mW}/^\circ\text{C}$	77 $^\circ\text{C}$
J (Glass-Mounted Chip)	800 mW	8.2 $\text{mW}/^\circ\text{C}$	52 $^\circ\text{C}$
N	800 mW	9.2 $\text{mW}/^\circ\text{C}$	63 $^\circ\text{C}$
W	800 mW	8.0 $\text{mW}/^\circ\text{C}$	50 $^\circ\text{C}$

Also see Dissipation Derating Curves, Section 2.

# TYPES uA747M, uA747C DUAL GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS

INPUT OFFSET CURRENT  
VS  
FREE-AIR TEMPERATURE

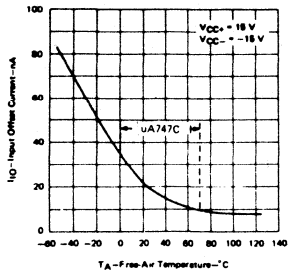


FIGURE 3

INPUT BIAS CURRENT  
VS  
FREE-AIR TEMPERATURE

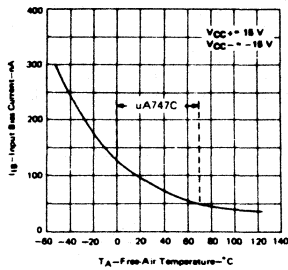


FIGURE 4

MAXIMUM PEAK-TO-PEAK  
OUTPUT VOLTAGE  
VS  
LOAD RESISTANCE

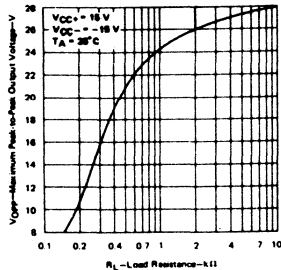


FIGURE 5

MAXIMUM PEAK-TO-PEAK  
OUTPUT VOLTAGE  
VS  
FREQUENCY

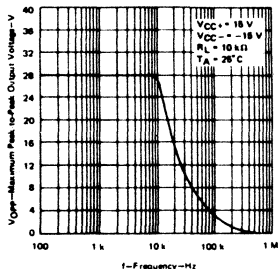


FIGURE 6

OPEN-LOOP LARGE-SIGNAL  
DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
VS  
SUPPLY VOLTAGE

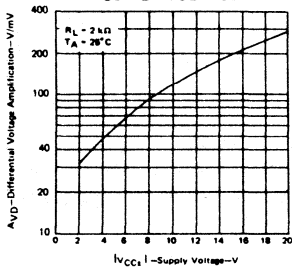


FIGURE 7

OPEN-LOOP LARGE-SIGNAL  
DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
VS  
FREQUENCY

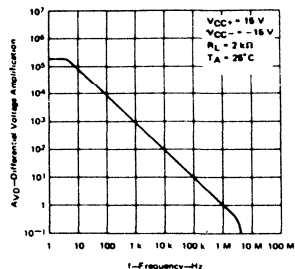


FIGURE 8

COMMON-MODE REJECTION RATIO  
VS  
FREQUENCY

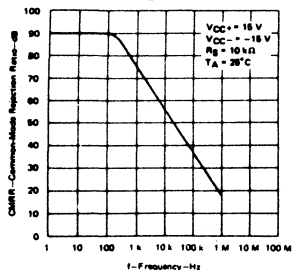


FIGURE 9

OUTPUT VOLTAGE  
VS  
ELAPSED TIME

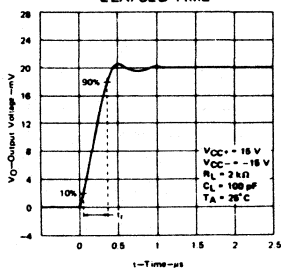


FIGURE 10

VOLTAGE-FOLLOWER  
LARGE-SIGNAL PULSE RESPONSE

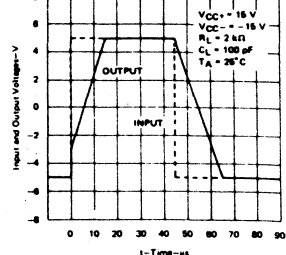


FIGURE 11

3

Operational Amplifiers



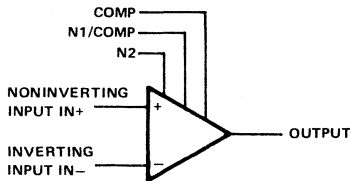
- Frequency and Transient Response Characteristics Adjustable
- Short-Circuit Protection
- Offset-Voltage Null Capability
- Wide Common-Mode and Differential Voltage Ranges
- Low Power Consumption
- No Latch-Up
- Same Pin Assignments as  $\mu$ A709

**description**

The  $\mu$ A748 is a general-purpose operational amplifier that offers the same advantages and attractive features as the  $\mu$ A741 except for internal compensation. External compensation can be as simple as a 30-pF capacitor for unity-gain conditions and, when the closed-loop gain is greater than one, can be changed to obtain wider bandwidth or higher slew rate. This circuit features high gain, large differential and common-mode input voltage range, and output short-circuit protection. Input offset voltage adjustment can be provided by connecting a variable resistor between the offset null pins as shown in Figure 12.

The  $\mu$ A748M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the  $\mu$ A748C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

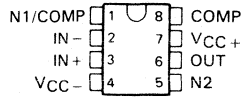
**symbol**



$\mu$ A748M . . . JG

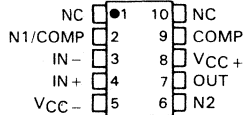
$\mu$ A748C . . . D, JG, OR P

DUAL-IN-LINE PACKAGE  
(TOP VIEW)



$\mu$ A748M . . . U FLAT PACKAGE

(TOP VIEW)

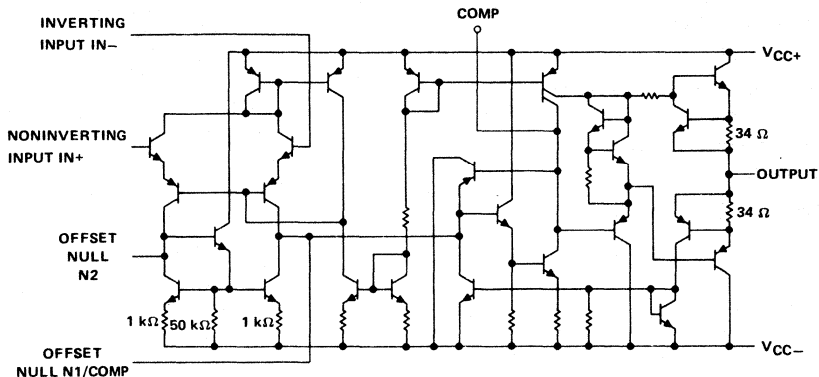


NC—No internal connection

# TYPES $\mu$ A748M, $\mu$ A748C

## GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

schematic



Resistor values shown are nominal.

### absolute maximum ratings over operating free-air temperature (unless otherwise noted)

	$\mu$ A748M	$\mu$ A748C	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	22	18	V
Supply voltage $V_{CC-}$ (see Note 1)	-22	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	V
Input voltage (either input, see Notes 1 and 3)	$\pm 15$	$\pm 15$	V
Voltage between either offset null terminal (N1/N2) and $V_{CC-}$	-0.5 to 2	-0.5 to 2	V
Duration of output short-circuit (see Note 4)	unlimited	unlimited	
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5)	500	500	mW
Operating free-air temperature range	-55 to 125	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	JG or U package		300
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or P package		260

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply. For the  $\mu$ A748M only, the unlimited duration of the short-circuit applies at (or below) 125°C case temperature or 75°C free-air temperature.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J and JG package,  $\mu$ A748M chips are alloy-mounted;  $\mu$ A748C chips are glass-mounted.

# TYPES $\mu$ A748M, $\mu$ A748C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $C_C = 30\text{ pF}$

PARAMETER	TEST CONDITIONS <sup>†</sup>	$\mu$ A748M			$\mu$ A748C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_O = 0$	25°C	1	5	1	6	mV	
		Full range		6		7.5		
$I_{IO}$ Input offset current	$V_O = 0$	25°C	20	200	20	200	nA	
		Full range		500		300		
$I_{IB}$ Input bias current	$V_O = 0$	25°C	80	500	80	500	nA	
		Full range		1500		800		
$V_{ICR}$ Common-mode input voltage range		25°C	$\pm 12$	$\pm 13$	$\pm 12$	$\pm 13$	V	
		Full range	$\pm 12$		$\pm 12$			
$V_{OM}$ Maximum peak output voltage swing	$R_L = 10\text{ k}\Omega$	25°C	$\pm 12$	$\pm 14$	$\pm 12$	$\pm 14$	V	
		Full range	$\pm 12$		$\pm 12$			
		$R_L \geq 2\text{ k}\Omega$	25°C	$\pm 10$	$\pm 13$	$\pm 10$		$\pm 13$
		Full range	$\pm 10$		$\pm 10$			
AVD Large-signal differential voltage amplification	$R_L \geq 2\text{ k}\Omega$ , $V_O = \pm 10\text{ V}$	25°C	50	200	20	200	V/mV	
		Full range	25		15			
$r_i$ Input resistance		25°C	0.3	2	0.3	2	M $\Omega$	
$r_o$ Output resistance	$V_O = 0$ , See Note 6	25°C		75		75	$\Omega$	
$C_i$ Input capacitance		25°C		1.4		1.4	pF	
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICR}\text{ min.}$ , $V_O = 0$	25°C	70	90	70	90	dB	
		Full range	70		70			
$k_{SVS}$ Supply voltage sensitivity ( $\Delta V_{IO}/\Delta V_{CC}$ )	$V_{CC} = \pm 9\text{ V to } \pm 15\text{ V}$ , $V_O = 0$	25°C	30	150	30	150	$\mu\text{V/V}$	
		Full range		150		150		
$I_{OS}$ Short-circuit output current		25°C	$\pm 25$	$\pm 40$	$\pm 25$	$\pm 40$	mA	
$I_{CC}$ Supply current	No load, $V_O = 0$	25°C	1.7	2.8	1.7	2.8	mA	
		Full range		3.3		3.3		
$P_D$ Total power dissipation	No load, $V_O = 0$	25°C	50	85	50	85	mW	
		Full range		100		100		

<sup>†</sup> All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for  $\mu$ A748M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for  $\mu$ A748C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

NOTE 6: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

operating characteristics,  $V_{CC+} = 15\text{ V}$ ,  $V_{CC-} = -15\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	$\mu$ A748M			$\mu$ A748C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$t_r$ Rise time	$V_I = 20\text{ mV}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , $C_C = 30\text{ pF}$ , See Figure 1	0.3			0.3			$\mu\text{s}$
		5%			5%			
SR Slew rate at unity gain	$V_I = 10\text{ V}$ , $C_L = 100\text{ pF}$ , $C_C = 30\text{ pF}$ , See Figure 1	0.5			0.5			V/ $\mu\text{s}$

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Operational Amplifiers

# TYPES $\mu$ A748M, $\mu$ A748C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

## PARAMETER MEASUREMENT INFORMATION

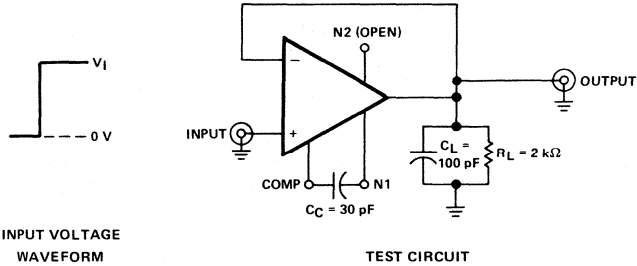


FIGURE 1—RISE TIME, OVERSHOOT, AND SLEW RATE

## TYPICAL CHARACTERISTICS

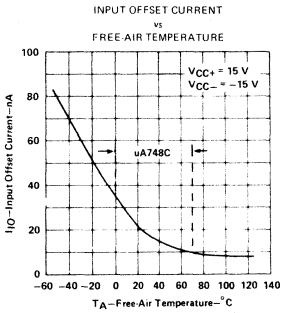


FIGURE 2

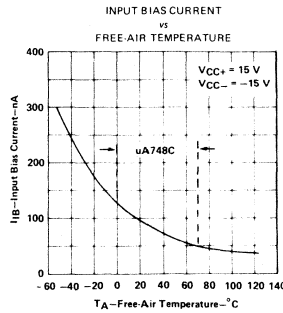


FIGURE 3

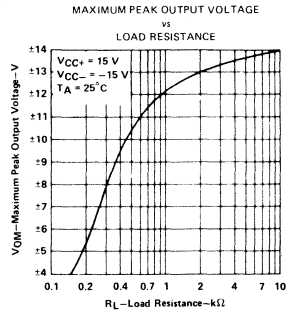


FIGURE 4

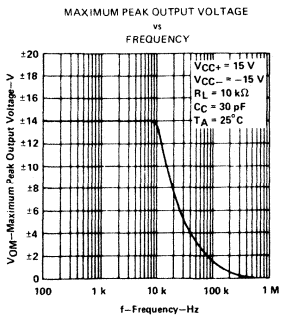


FIGURE 5

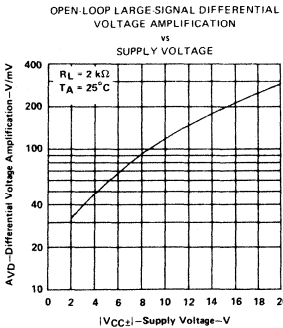


FIGURE 6

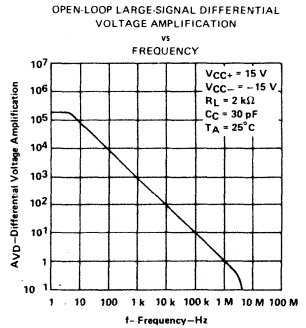


FIGURE 7

# TYPES $\mu$ A748M, $\mu$ A748C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

## TYPICAL CHARACTERISTICS

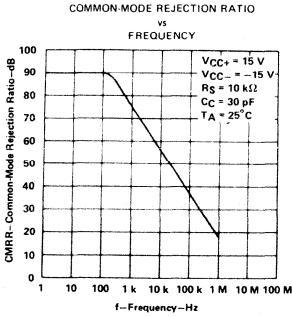


FIGURE 8

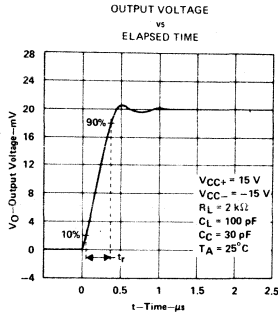


FIGURE 9

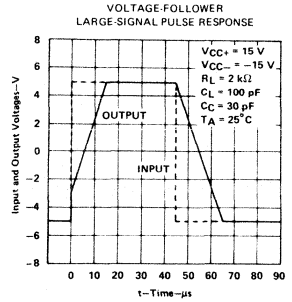


FIGURE 10

## TYPICAL APPLICATION DATA

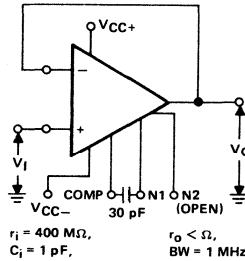
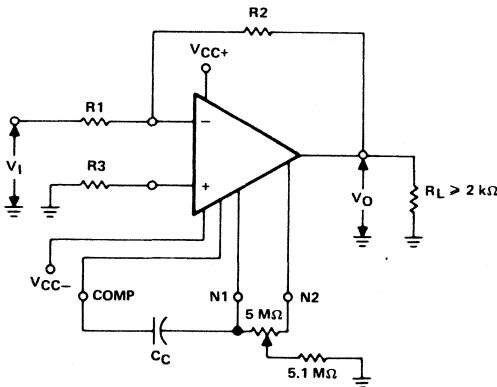


FIGURE 11—UNITY-GAIN VOLTAGE FOLLOWER



$$\frac{V_O}{V_I} = -\frac{R_2}{R_1}$$

$$C_C > \frac{R_1 \cdot 30 \text{ pF}}{R_1 + R_2}$$

$$R_3 = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

FIGURE 12—INVERTING CIRCUIT WITH ADJUSTABLE GAIN, COMPENSATION, AND OFFSET ADJUSTMENT



## Operational Amplifiers

**General Information**

**1**

**Thermal Information**

**2**

**Operational Amplifiers**

**3**

**Voltage Comparators**

**4**

**Special Functions**

**5**

**Voltage Regulators**

**6**

**Data Acquisition**

**7**

**Appendix**

**A**

# 4

## Voltage Comparators



VOLTAGE COMPARATORS

military temperature range

(values specified at  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	TYPE	REMARKS	V <sub>IO</sub> MAX (mV)	I <sub>B</sub> MAX (μA)	I <sub>OL</sub> MIN (mA)	RESPONSE TIME TYP (ns)	POWER SUPPLIES		PACKAGES	PAGE
							V <sub>CC+</sub> NOM (V)	V <sub>CC-</sub> NOM (V)		
μA710M	Single		2	20	2	40	12	-6	J,JG,U	4-85
LM106		Strobe	2	45	100	28	12	-6	J,JG,W	4-9
LM111		Strobe	3	0.1	8	115	15	-15	FK,J,JG,U	4-15
TL510M		Strobe	2	15	2	30			FK,JG,U	4-43
TL810M		Improved TL710M	2	15	2	30			JG,U	4-65
TL710M			5	75	1.6	40	15	-6	FK,JG,U	4-67
TL331M		V <sub>CC</sub> : 12 V to 36 V	5	-0.1	6	300	5	0	JG	4-35
TL506M		Strobes	2	20	100	28	12	-6	J,W	4-37
TL820M	Dual	Dual TL810M	2	15	2	30	12	-6	J	4-77
TL514M		Dual TL510M	2	15	2	30	12	-6	FK,J,W	4-49
μA711M		Strobes	3.5	75	0.5	40	12	-6	J,U	4-89
TL811M		Strobes	3.5	20	0.5	33	12	-6	J,U	4-71
LM193		V <sub>CC</sub> : 2 V to 36 V	5	0.1	6	300	5	0	FK,JG	4-29
TLC372M		LinCMOS	10			200	5	0	JG	4-81
LM139A		V <sub>CC</sub> : 2 V to 36 V	2	-0.1	6	300	5	0	D,J,N	4-25
LM139		V <sub>CC</sub> : 2 V to 36 V	5	-0.1	6	300	5	0	FK,J	4-25
TLC374M	LinCMOS	10			200	5	0	J	4-83	

automotive temperature range

(values specified at  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	TYPE	REMARKS	V <sub>IO</sub> MAX (mV)	I <sub>B</sub> MAX (μA)	I <sub>OL</sub> MIN (mA)	RESPONSE TIME TYP (ns)	POWER SUPPLIES		PACKAGES	PAGE
							V <sub>CC+</sub> NOM (V)	V <sub>CC-</sub> NOM (V)		
LM2903	Dual	V <sub>CC</sub> : 2 V to 36 V	7	0.25	6	300	5	0	D,JG,P	4-29
LM3302	Quad	V <sub>CC</sub> : 2 V to 36 V	20	-0.5	6	300	5	0	D,J,N	4-33
LM2901		V <sub>CC</sub> : 2 V to 36 V	15	-0.4	6	300	5	0	D,J,N	4-25

industrial temperature range

(values specified at  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	TYPE	REMARKS	V <sub>IO</sub> MAX (mV)	I <sub>B</sub> MAX (μA)	I <sub>OL</sub> MIN (mA)	RESPONSE TIME TYP (ns)	POWER SUPPLIES		PACKAGES	PAGE
							V <sub>CC+</sub> NOM (V)	V <sub>CC-</sub> NOM (V)		
LM206	Single	Strobe	2	45	100	28	12	-6	D,J,JG,N,P	4-9
LM211		Strobe	3	0.1	8	115	15	-15	D,JG,P	4-15
TL3311			5	-0.1	6	300	5	0	D,JG,P	4-35
LM293A			2	0.25	6	300	5	0	D,JG,P	4-29
LM293	Quad		5	0.25	6	300	5	0	D,JG,P	4-29
LM239A			4	-0.4	6	300	5	0	D,J,N	4-25
LM239			9	-0.4	6	300	5	0	D,J,N	4-25

## SELECTION GUIDE

commercial temperature range

(values specified at  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	TYPE	REMARKS	V <sub>IO</sub> MAX (mV)	I <sub>B</sub> MAX (μA)	I <sub>OL</sub> MIN (mA)	RESPONSE TIME TYP (ns)	POWER SUPPLIES		PACKAGES	PAGE
							V <sub>CC+</sub> NOM (V)	V <sub>CC-</sub> NOM (V)		
TL510C	Single	Strobe	3.5	20	1.6	30			JG,P	4-43
TL810C		Improved TL710C	3.5	20	1.6	30			JG,P	4-65
LM306		Strobe	5	40	100	28	12	-6	D,J,JG,N,P	4-9
TL331C		V <sub>CC</sub> : 2 V to 36 V	5	-0.25	6	300	5	0	D,JG,P	4-35
LM311		Strobe	7.5	0.25	8	115	15	-15	D,JG,P	4-15
TL710C			7.5	100		40	12	-6	J,JG,N,P,U	4-57
TL721			± 100			12 Max	0	-5.2	JG,P	4-63
TL712		Output enable				25			JG,P	4-61
LM393A		V <sub>CC</sub> : 2 V to 36 V	2	0.25	6	300	5	0	D,JG,P	4-29
TL820C		Dual TL810C	3.5	20	1.6	30	12	-6	J,N	4-77
TL514C	Dual TL510C	3.5	20	1.6	30	12	-6	J,N	4-49	
uA711C	Strobes	5	100	0.5	40	12	-6	J,N	4-89	
TL811C	Improved uA711C	5	30	0.5	33	12	-6	J,N	4-71	
TL506C	Strobes	5	25	100	28	12	-6	J,N	4-37	
LM393	V <sub>CC</sub> : 2 V to 36 V	5	0.25	6	300	5	0	D,JG,P	4-29	
TLC372C	LinCMOS	10			200	5	0	JG,P	4-81	
LM339		5	-0.15	6	300	5	0	D,J,N	4-25	
LM339A		2	-0.15	6	300	5	0	D,J,N	4-25	
TLC374C	LinCMOS	10			200	5	0	D,J,N	4-83	

4

Voltage Comparators

**Input Offset Voltage ( $V_{IO}$ )**

The d-c voltage that must be applied between the input terminals to force the quiescent d-c output voltage to the specified level.

**Average Temperature Coefficient of Input Offset Voltage ( $\alpha V_{IO}$ )**

The ratio of the change in input offset voltage to the change in free-air temperature. This is an average value for the specified temperature range.

$$\alpha V_{IO} = \left[ \frac{V_{IO} @ T_{A(1)} - V_{IO} @ T_{A(2)}}{T_{A(1)} - T_{A(2)}} \right] \text{ where } T_{A(1)} \text{ and } T_{A(2)} \text{ are the specified temperature extremes.}$$

**Input Offset Current ( $I_{IO}$ )**

The difference between the currents into the two input terminals with the output at the specified level.

**Average Temperature Coefficient of Input Offset Current ( $\alpha I_{IO}$ )**

The ratio of the change in input offset current to the change in free-air temperature. This is an average value for the specified temperature range.

$$\alpha I_{IO} = \left[ \frac{I_{IO} @ T_{A(1)} - I_{IO} @ T_{A(2)}}{T_{A(1)} - T_{A(2)}} \right] \text{ where } T_{A(1)} \text{ and } T_{A(2)} \text{ are the specified temperature extremes.}$$

**Input Bias Current ( $I_{IB}$ )**

The average of the currents into the two input terminals with the output at the specified level.

**High-Level Strobe Current ( $I_{IH(S)}$ )**

The current flowing into or out of\* the strobe at a high-level voltage.

**Low-Level Strobe Current ( $I_{IL(S)}$ )**

The current flowing out of\* the strobe at a low-level voltage.

**High-Level Strobe Voltage ( $V_{IH(S)}$ )**

For a device having an active-low strobe, a voltage within the range that is guaranteed not to interfere with the operation of the comparator.

**Low-Level Strobe Voltage ( $V_{IL(S)}$ )**

For a device having an active-low strobe, a voltage within the range that is guaranteed to force the output high or low, as specified, independently of the differential inputs.

**Input Voltage Range ( $V_I$ )**

The range of voltage that if exceeded at either input terminal will cause the comparator to cease functioning properly.

**Common-Mode Input Voltage ( $V_{IC}$ )**

The average of the two input voltages.

\*Current out of a terminal is given as a negative value.

## GLOSSARY

---

### Common-Mode Input Voltage Range ( $V_{ICR}$ )

The range of common-mode input voltage that if exceeded will cause the comparator to cease functioning properly.

### Differential Input Voltage ( $V_{ID}$ )

The voltage at the noninverting input with respect to the inverting input.

### Differential Input Voltage Range ( $V_{ID}$ )

The range of voltage between the two input terminals that if exceeded will cause the comparator to cease functioning properly.

### Differential Voltage Amplification ( $A_{VD}$ )

The ratio of the change in output to the change in differential input voltage producing it with the common-mode input voltage held constant.

### High-Level Output Voltage ( $V_{OH}$ )

The voltage at an output with input conditions applied that according to the product specification will establish a high level at the output.

### Low-Level Output Voltage ( $V_{OL}$ )

The voltage at an output with input conditions applied that according to the product specification will establish a low level at the output.

### High-Level Output Current, ( $I_{OH}$ )

The current into\* an output with input conditions applied that according to the product specification will establish a high level at the output.

### Low-Level Output Current, ( $I_{OL}$ )

The current into\* an output with input conditions applied that according to the product specification will establish a low level at the output.

### Output Resistance ( $r_o$ )

The resistance between an output terminal and ground.

### Common-Mode Rejection Ratio ( $k_{CMR}$ , $CMRR$ )

The ratio of differential voltage amplification to common-mode voltage amplification.

NOTE: This is measured by determining the ratio of a change in input common-mode voltage to the resulting change in input offset voltage.

### Supply Current ( $I_{CC+}$ , $I_{CC-}$ )

The current into\* the  $V_{CC+}$  or  $V_{CC-}$  terminal of an integrated circuit.

### Total Power Dissipation ( $P_D$ )

The total d-c power supplied to the device less any power delivered from the device to a load.

NOTE: At no load:  $P_D = V_{CC+} \cdot I_{CC+} + V_{CC-} \cdot I_{CC-}$ .

\*Current out of a terminal is given as a negative value.

---

### Response Time

The interval between the application of an input step function and the instant at which the output crosses the logic threshold voltage.

NOTE: The input step drives the comparator from some initial condition sufficient to saturate the output (or in the case of high-to-low-level response time, to turn the output off) to an input level just barely in excess of that required to bring the output back to the logic threshold voltage. This excess is referred to as the voltage overdrive.

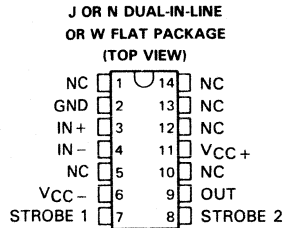
### Strobe Release Time

The time required for the output to rise to the logic threshold voltage after the strobe terminal has been driven from its active logic level to its inactive logic level.

# 4

## Voltage Comparators

- **Fast Response Times**
- **Improved Gain and Accuracy**
- **Fan-Out to 10 Series 54/74 TTL Loads**
- **Strobe Capability**
- **Short-Circuit and Surge Protection**
- **Designed to be Interchangeable with National Semiconductor LM106, LM206, and LM306**



NC—No internal connection

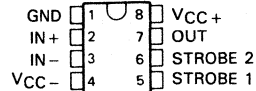
**description**

The LM106, LM206, and LM306 are high-speed voltage comparators with differential inputs, a low-impedance high-sink-current (100 mA) output, and two strobe inputs. These devices detect low-level analog or digital signals and can drive digital logic or lamps and relays directly. Short-circuit protection and surge-current limiting is provided.

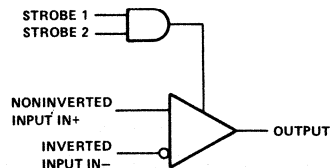
The circuit is similar to a TL810 with gated output. A low-level input at either strobe causes the output to remain high regardless of the differential input. When both strobe inputs are either open or at a high logic level, the output voltage is controlled by the differential input voltage. The circuit will operate with any negative supply voltage between -3 volts and -12 volts with little difference in performance.

The LM106 is characterized for operation over the full military temperature range of -55°C to 125°C, the LM206 is characterized for operation from -25°C to 85°C, and the LM306 from 0°C to 70°C.

**D, JG OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)**

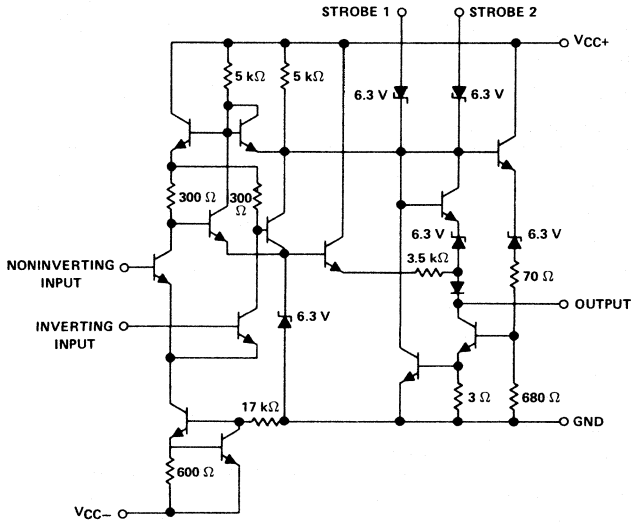


**functional block diagram**



# TYPES LM106, LM206, LM306 DIFFERENTIAL COMPARATORS WITH STROBES

schematic



Resistor values are nominal in ohms.

## absolute maximum ratings over operating free-air temperature (unless otherwise noted)

Supply voltage $V_{CC+}$ (see Note 1)	15 V
Supply voltage $V_{CC-}$ (see Note 1)	-15 V
Differential input voltage (see Note 2)	$\pm 5$ V
Input voltage (either input, see Notes 1 and 3)	$\pm 7$ V
Strobe voltage range (see Note 1)	0 V to $V_{CC+}$
Output voltage (see Note 1)	24 V
Voltage from output to $V_{CC-}$	30 V
Duration of output short-circuit (see Note 4)	10 s
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5)	600 mW
Operating free-air temperature range:	
LM106 Circuits	-55°C to 125°C
LM206 Circuits	-25°C to 85°C
LM306 Circuits	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J, JG or W package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, N, or P package	260°C

- NOTES:
1. All voltage values, except differential voltages and the voltage from the output to  $V_{CC-}$ , are with respect to the network ground terminal.
  2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
  3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 7 volts, whichever is less.
  4. The output may be shorted to ground or either power supply.
  5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J and JG packages, LM106 chips are alloy-mounted; LM206 and LM306 chips are glass-mounted.



# TYPES LM106, LM206, LM306 DIFFERENTIAL COMPARATORS WITH STROBES

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -3\text{ V to }12\text{ V}$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS†			LM106, LM206			LM306			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S \leq 200\ \Omega$ , See Note 6	25°C	0.5‡	2	1.6‡	5	mV			
			Full range			6.5				
$\alpha_{VIO}$ Average temperature coefficient of input offset voltage	$R_S = 50\ \Omega$ , See Note 6	Full range	3	10	5	20	$\mu\text{V}/^\circ\text{C}$			
$I_{IO}$ Input offset current	See Note 6	25°C	0.7‡	3	1.8‡	5	$\mu\text{A}$			
		MIN	2	7	1	7.5				
		MAX	0.4	3	0.5	5				
$\alpha_{IIO}$ Average temperature coefficient of input offset current	See Note 6	MIN to 25°C	15	75	24	100	nA/°C			
		25°C to MAX	5	25	15	50				
		MIN to 25°C	45		40					
$I_{IB}$ Input bias current	$V_O = 0.5\text{ V to }5\text{ V}$	25°C to MAX	7‡	20	16‡	25	$\mu\text{A}$			
		Full range			-1.7‡ -3.2					
$I_{IL(S)}$ Low-level strobe current	$V_{I(strobe)} = 0.4\text{ V}$	Full range	2.2		2.2		V			
$V_{IH(S)}$ High-level strobe voltage		Full range	0.9				V			
$V_{IL(S)}$ Low-level strobe voltage		Full range	0.9				V			
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V to }-12\text{ V}$	Full range	$\pm 5$			V				
$V_{ID}$ Differential input voltage range		Full range	$\pm 5$			V				
$A_{VD}$ Large-signal differential voltage amplification	No load, $V_O = 0.5\text{ V to }5\text{ V}$	25°C	40‡			V/mV				
$V_{OH}$ High-level output voltage	$I_{OH} = -400\ \mu\text{A}$	$V_{ID} = 5\text{ mV}$	Full range	2.5	5.5	V				
		$V_{ID} = 8\text{ mV}$	Full range	2.5 5.5						
$V_{OL}$ Low-level output voltage	$I_{OL} = 100\text{ mA}$	$V_{ID} = -5\text{ mV}$	25°C	0.8‡	1.5	V				
		$V_{ID} = -7\text{ mV}$	25°C	0.8‡ 2						
		$I_{OL} = 50\text{ mA}$	$V_{ID} = -5\text{ mV}$	Full range	1					
		$V_{ID} = -8\text{ mV}$	Full range	1						
		$I_{OL} = 16\text{ mA}$	$V_{ID} = -5\text{ mV}$	Full range	0.4					
		$V_{ID} = -8\text{ mV}$	Full range	0.4						
$I_{OH}$ High-level output current	$V_{OH} = 8\text{ V to }24\text{ V}$	$V_{ID} = 5\text{ mV}$	MIN to 25°C	0.02‡	1	$\mu\text{A}$				
		$V_{ID} = 8\text{ mV}$	25°C to MAX	100						
		$V_{ID} = 7\text{ mV}$	MIN to 25°C	0.02‡ 2						
		$V_{ID} = 8\text{ mV}$	25°C to MAX	100						
$I_{CC+}$ Supply current from $V_{CC+}$	$V_{ID} = -5\text{ mV}$ , No load	Full range	6.6‡	10	6.6‡	10	mA			
$I_{CC-}$ Supply current from $V_{CC-}$	No load	Full range	-1.9‡	-3.6	-1.9‡	-3.6	mA			

† Unless otherwise noted, all characteristics are measured with both strobos open.

‡ These typical values are at  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$ . Full range (MIN to MAX) for LM106 is  $-55^\circ\text{C to }125^\circ\text{C}$ ; for LM206 is  $-25^\circ\text{C to }85^\circ\text{C}$ ; and for LM306 is  $0^\circ\text{C to }70^\circ\text{C}$ .

NOTE 6: The offset voltages and offset currents given are the maximum values required to drive the output down to the low range ( $V_{OL}$ ) or up to the high range ( $V_{OH}$ ). Thus these parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance.

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS†	LM106, LM206			LM306			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Response time, low-to-high-level output	$R_L = 390\ \Omega$ to $5\text{ V}$ , $C_L = 15\text{ pF}$ , See Note 7	28		40	28		40	ns

NOTE 7: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

# TYPES LM106, LM206, LM306 DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS<sup>†</sup>

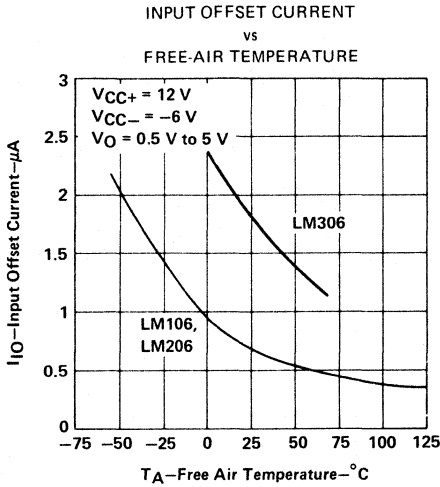


FIGURE 1

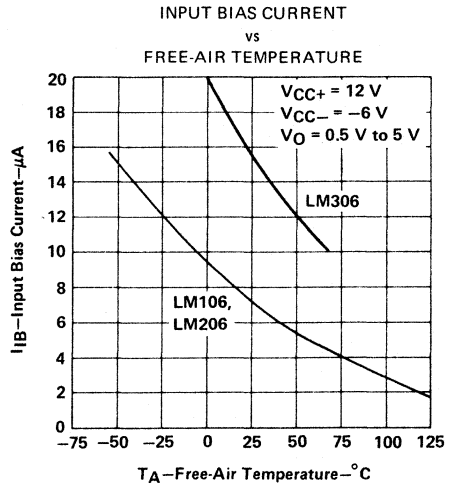


FIGURE 2

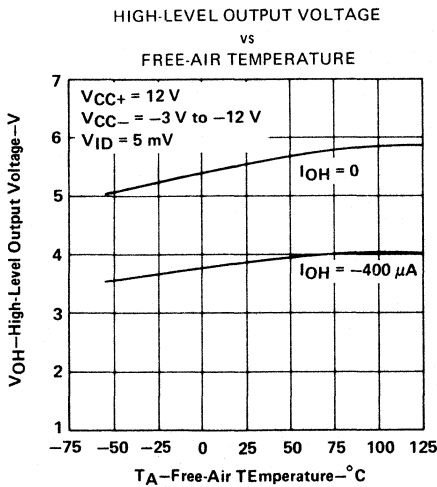


FIGURE 3

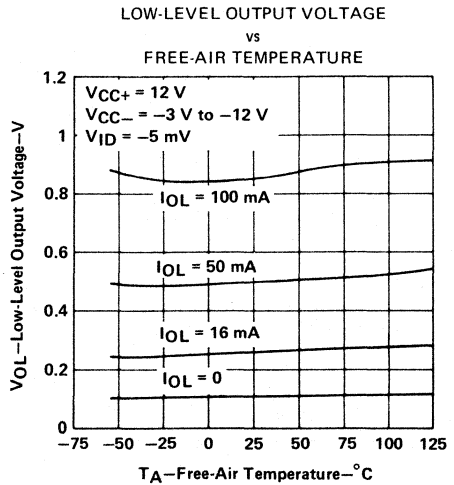


FIGURE 4

<sup>†</sup>Data for free-air temperature outside the range specified in the absolute maximum ratings for LM206 or LM306 is not applicable for those types.

# TYPES LM106, LM206, LM306 DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS<sup>†</sup>

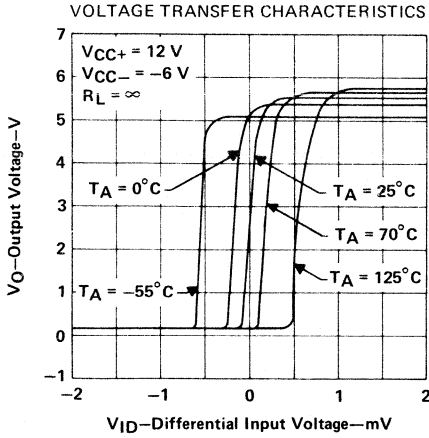


FIGURE 5

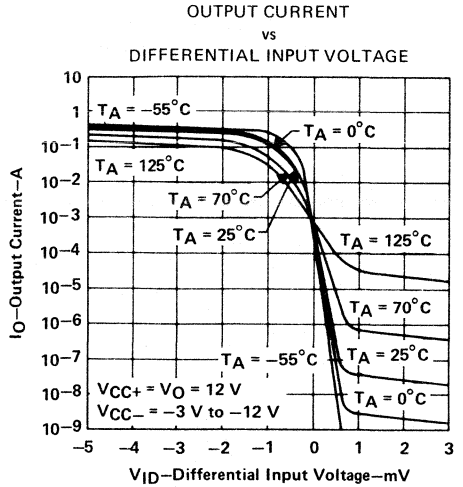


FIGURE 6

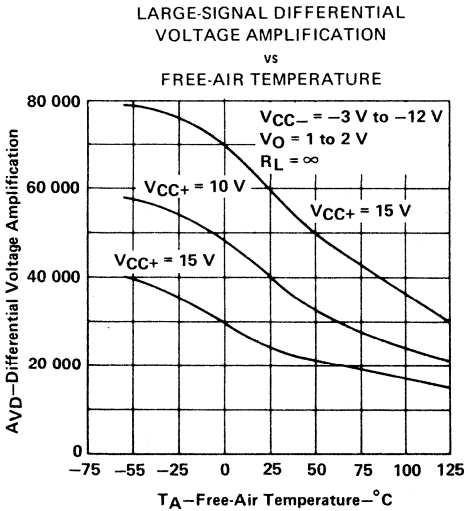


FIGURE 7

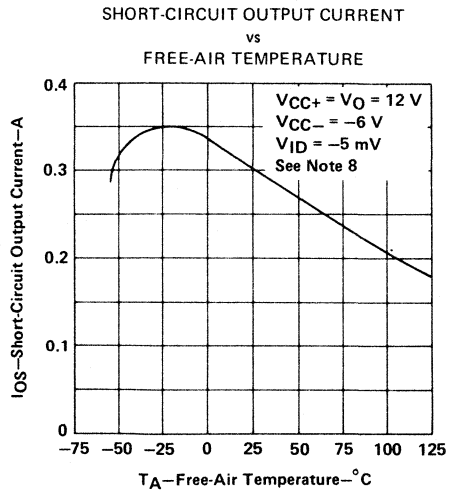


FIGURE 8

<sup>†</sup>Data for free-air temperature outside the range specified in the absolute maximum ratings for LM206 or LM306 is not applicable for those types.  
NOTE 8: This parameter was measured using a single 5-ms pulse.

# TYPES LM106, LM206, LM306 DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS<sup>‡</sup>

OUTPUT RESPONSE FOR  
VARIOUS INPUT OVERDRIVES

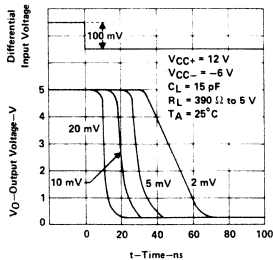


FIGURE 9

OUTPUT RESPONSE FOR  
VARIOUS INPUT OVERDRIVES

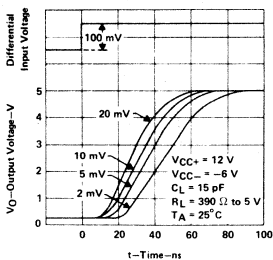


FIGURE 10

SUPPLY CURRENT FROM  $V_{CC+}$   
VS  
SUPPLY VOLTAGE  $V_{CC+}$

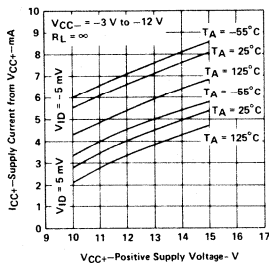


FIGURE 11

SUPPLY CURRENT FROM  $V_{CC-}$   
VS  
SUPPLY VOLTAGE  $V_{CC-}$

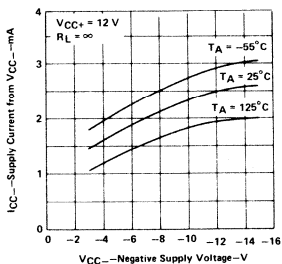


FIGURE 12

TOTAL POWER DISSIPATION  
VS  
FREE-AIR TEMPERATURE

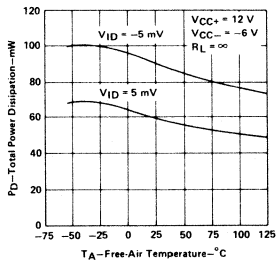


FIGURE 13

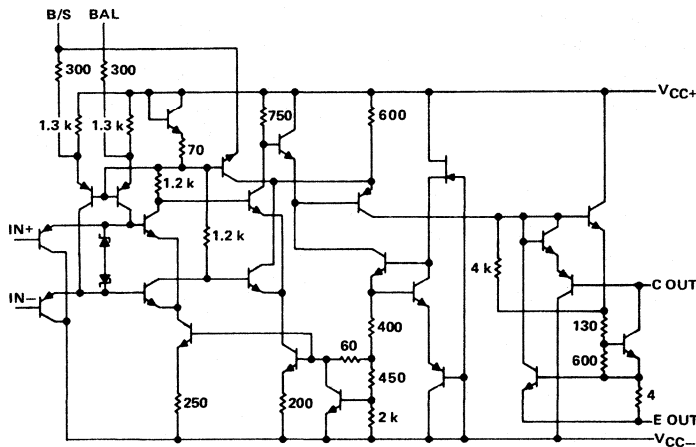
<sup>‡</sup>Data for free-air temperature outside the range specified in the absolute maximum ratings for LM206 or LM306 is not applicable for those types.



# TYPES LM111, LM211, LM311

## DIFFERENTIAL COMPARATORS WITH STROBES

schematic



- BAL Balance
- B/S Balance/Strobe
- C OUT Collector Output
- E OUT Emitter Output
- IN+ Noninverting Input
- IN- Inverting Input
- NC No Internal Connection
- VCC+ Positive Supply Voltage
- VCC- Negative Supply Voltage

Resistor values shown are nominal and in ohms.

4

Voltage Comparators

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	LM111	LM211	LM311	UNIT
Supply voltage, $V_{CC+}$ (see Note 1)	18	18	18	V
Supply voltage, $V_{CC-}$ (see Note 1)	-18	-18	-18	V
Differential input voltage (see Note 2)	$\pm 30$	$\pm 30$	$\pm 30$	V
Input voltage (either input, see Notes 1 and 3)	$\pm 15$	$\pm 15$	$\pm 15$	V
Voltage from emitter output to $V_{CC-}$	30	30	30	V
Voltage from collector output to $V_{CC-}$	50	50	40	V
Duration of output short-circuit (see Note 4)	10	10	10	s
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5)	500	500	500	mW
Operating free-air temperature range	-55 to 125	-25 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds J, JG, FH, FK, or U package	300	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds D or P package		260	260	°C

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or  $\pm 15$  volts, whichever is less.
4. The output may be shorted to ground or either power supply.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J and JG packages, LM111 chips are alloy mounted. LM211 and LM311 chips are glass mounted.

# TYPES LM111, LM211, LM311 DIFFERENTIAL COMPARATORS WITH STROBES

electrical characteristics at specified free-air temperature,  $V_{CC\pm} = \pm 15\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	LM111, LM211			LM311			UNIT
		MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	
$V_{IO}$ Input offset voltage	See Note 6	25°C	0.7	3	2	7.5	mV	
		Full range	4			10		
$I_{IO}$ Input offset current	See Note 6	25°C	4	10	6	50	nA	
		Full range	20			70		
$I_{IB}$ Input bias current	$V_O = 1\text{ V to }14\text{ V}$	25°C	75	100	100	250	nA	
		Full range	150			300		
$I_{IL(S)}$ Low-level strobe current (see Note 7)	$V_{(\text{strobe})} = 0.3\text{ V}, V_{ID} \leq -10\text{ mV}$	25°C	-3		-3		mA	
$V_{ICR}$ Common-mode input voltage range		Full range	13 to -14.5	13.8 to -14.7	13 to -14.5	13.8 to -14.7	V	
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 5\text{ V to }35\text{ V}, R_L = 1\text{ k}\Omega$	25°C	40	200	40	200	V/mV	
$I_{OH}$ High-level (collector) output current	$I_{\text{strobe}} = -3\text{ mA}, V_{ID} = 5\text{ mV}, V_{OH} = 35\text{ V}, V_{ID} = 10\text{ mV}, V_{OH} = 35\text{ V}$	25°C	0.2		10		nA	
		Full range	0.5				$\mu\text{A}$	
$V_{OL}$ Low-level (collector-to-emitter) output voltage	$I_{OL} = 50\text{ mA}, V_{CC+} = 4.5\text{ V}, V_{CC-} = 0, I_{OL} = 8\text{ mA}$	$V_{ID} = -5\text{ mV}$	25°C	0.75	1.5		V	
		$V_{ID} = -10\text{ mV}$	25°C	0.75				1.5
		Full range	0.23		0.4			
		Full range	0.23			0.4		
$I_{CC+}$ Supply current from $V_{CC+}$ , output low	$V_{ID} = -10\text{ mV}, \text{ No load}$	25°C	5.1	6	5.1	7.5	mA	
$I_{CC-}$ Supply current from $V_{CC-}$ , output high	$V_{ID} = 10\text{ mV}, \text{ No load}$	25°C	-4.1	-5	-4.1	-5	mA	

<sup>†</sup>Unless otherwise noted, all characteristics are measured with the balance and balance/strobe terminals open and the emitter output grounded. Full range for LM111 is -55°C to 125°C, for LM211 is -25°C to 85°C, and for LM311 is 0°C to 70°C.

<sup>‡</sup>All typical values are at  $T_A = 25^\circ\text{C}$ .

NOTES: 6. The offset voltages and offset currents given are the maximum values required to drive the collector output up to 14 V or down to 1 V with a pull-up resistor of 7.5 k $\Omega$  to  $V_{CC+}$ . Thus these parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance.

7. The strobe should not be shorted to ground; it should be current driven at -3 to -5 mA, e.g., see Figures 13 and 27.

switching characteristics,  $V_{CC+} = 15\text{ V}, V_{CC-} = -15\text{ V}, T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Response time, low-to-high-level output	$R_C = 500\ \Omega \text{ to } 5\text{ V}, C_L = 5\text{ pF}, \text{ See Note 8}$	115			ns
Response time, high-to-low-level output		165			ns

NOTE 8: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

# TYPES LM111, LM211, LM311 DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS

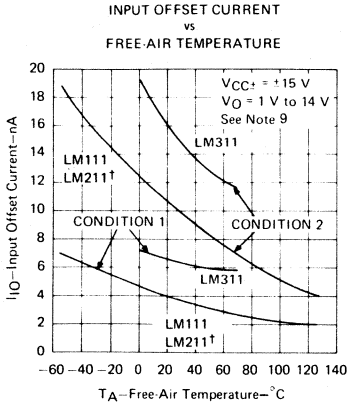


FIGURE 1

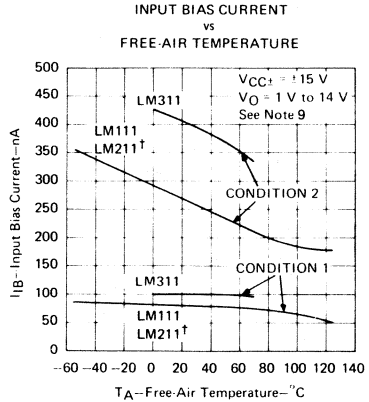


FIGURE 2

4

Voltage Comparators

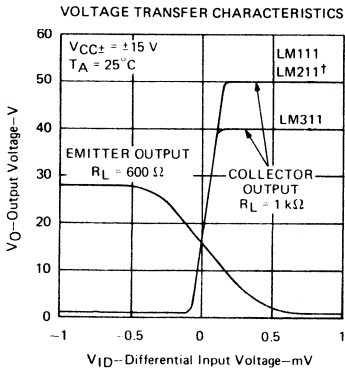
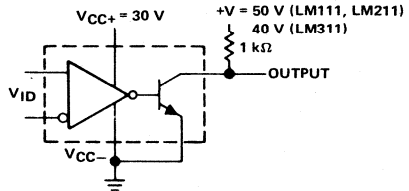
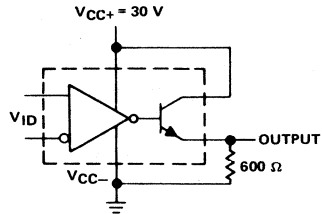


FIGURE 3



COLLECTOR OUTPUT TRANSFER CHARACTERISTIC TEST CIRCUIT FOR FIGURE 3



EMITTER OUTPUT TRANSFER CHARACTERISTIC TEST CIRCUIT FOR FIGURE 3

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

NOTE 9: Condition 1 is with the balance and balance/strobe terminals open. Condition 2 is with the balance and balance/strobe terminals connected to  $V_{CC+}$ .



## TYPICAL CHARACTERISTICS

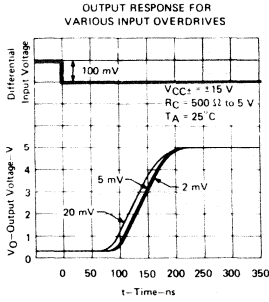


FIGURE 4

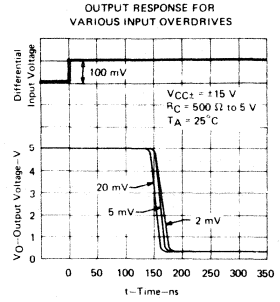
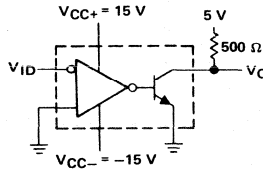


FIGURE 5

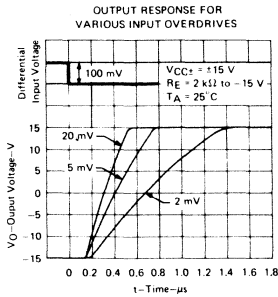
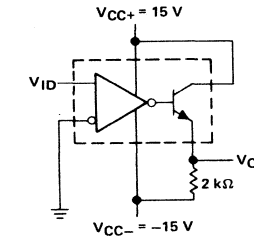


FIGURE 6



TEST CIRCUIT FOR FIGURES 6 AND 7

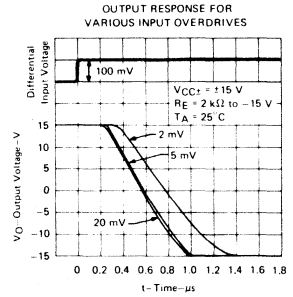


FIGURE 7

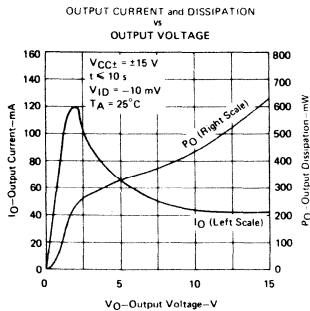


FIGURE 8

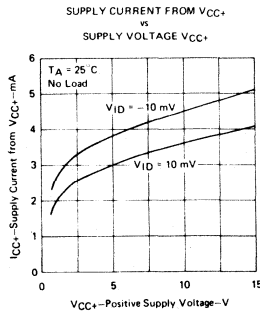


FIGURE 9

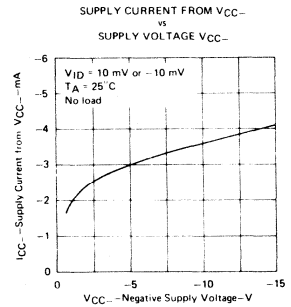


FIGURE 10

# TYPES LM111, LM211, LM311 DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL APPLICATION DATA

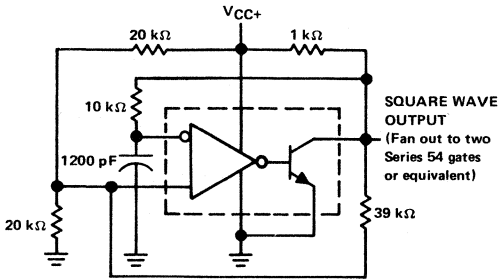


FIGURE 11—100-kHz  
FREE-RUNNING MULTIVIBRATOR

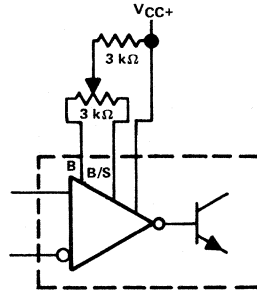


FIGURE 12  
OFFSET BALANCING

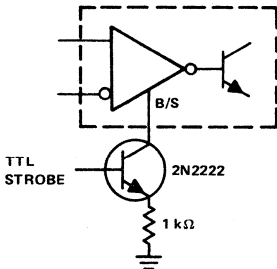


FIGURE 13—STROBING

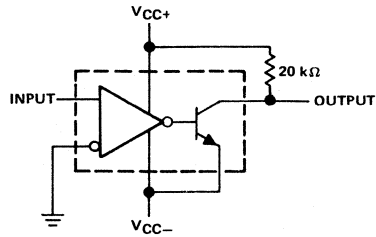
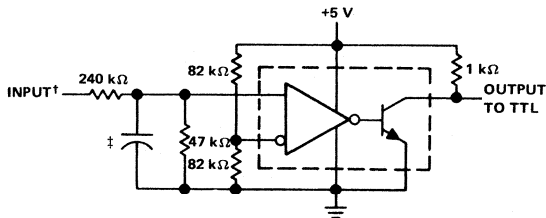


FIGURE 14—ZERO-CROSSING DETECTOR



† Resistor values shown are for a 0-to-30-V logic swing and a 15-V threshold.

‡ May be added to control speed and reduce susceptibility to noise spikes.

FIGURE 15—TTL INTERFACE WITH HIGH-LEVEL LOGIC

4

Voltage Comparators

TYPICAL APPLICATION DATA

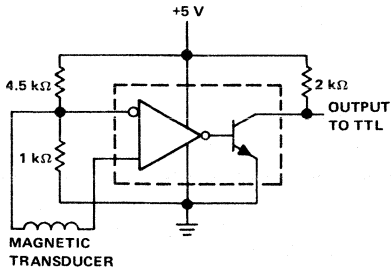


FIGURE 16—DETECTOR FOR MAGNETIC TRANSDUCER

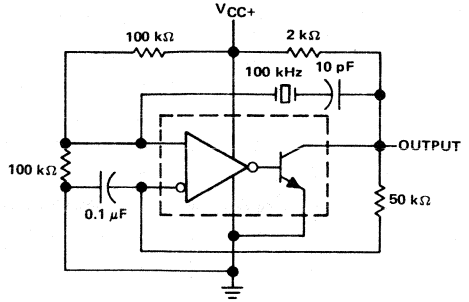


FIGURE 17—100-kHz CRYSTAL OSCILLATOR

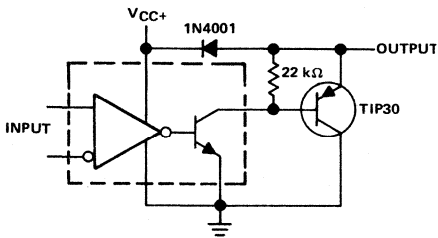
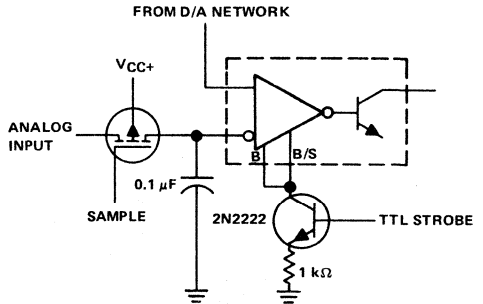


FIGURE 18—COMPARATOR AND SOLENOID DRIVER



Typical input current is 50 pA with inputs strobed off.  
FIGURE 19—STROBING BOTH INPUT AND OUTPUT STAGES SIMULTANEOUSLY

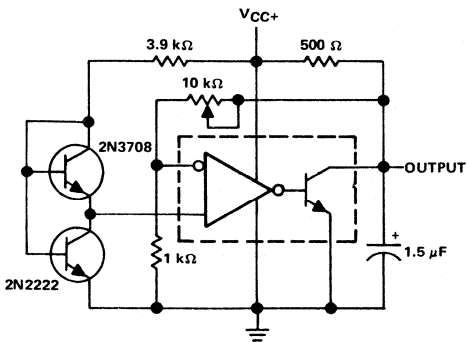


FIGURE 20—LOW-VOLTAGE ADJUSTABLE REFERENCE SUPPLY

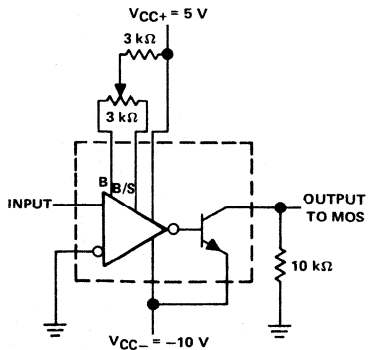
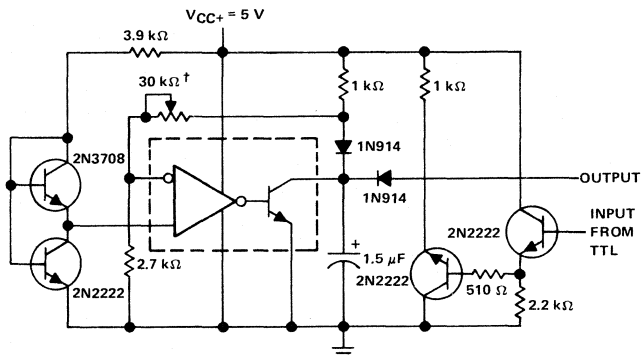


FIGURE 21—ZERO-CROSSING DETECTOR DRIVING MOS LOGIC

# TYPES LM111, LM211, LM311 DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL APPLICATION DATA



†Adjust to set clamp level.

FIGURE 22—PRECISION SQUARER

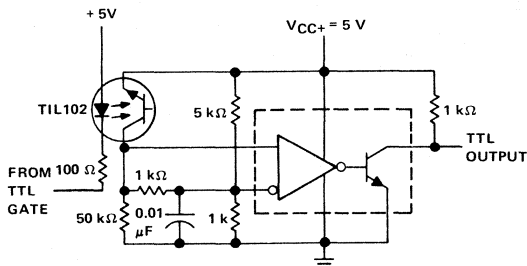


FIGURE 23—DIGITAL TRANSMISSION ISOLATOR

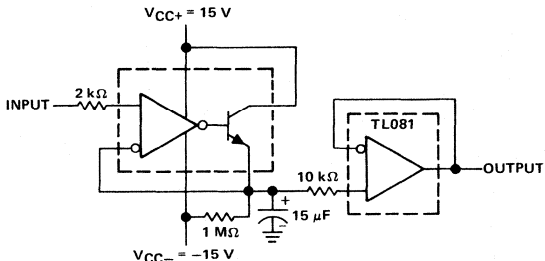


FIGURE 24—POSITIVE-PEAK DETECTOR

TYPICAL APPLICATION DATA

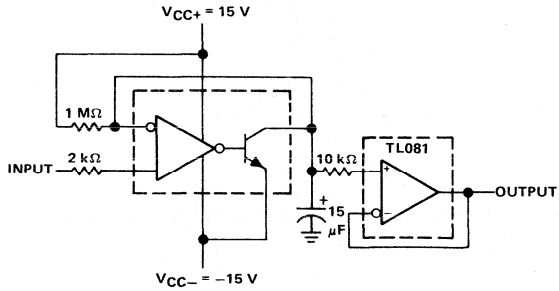
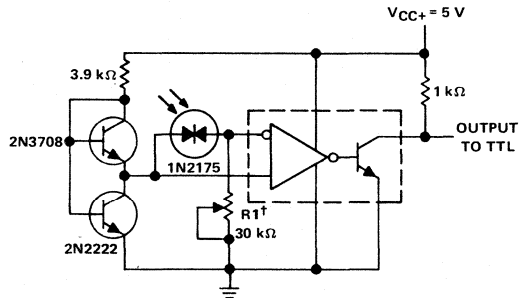
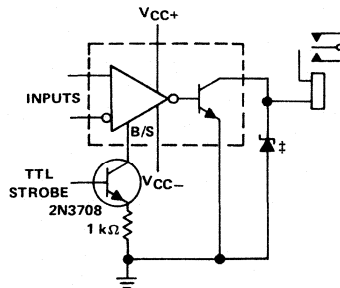


FIGURE 25—NEGATIVE-PEAK DETECTOR



†R1 sets the comparison level. At comparison, the photodiode has less than 5 mV across it decreasing dark current by an order of magnitude.

FIGURE 26—PRECISION PHOTODIODE COMPARATOR

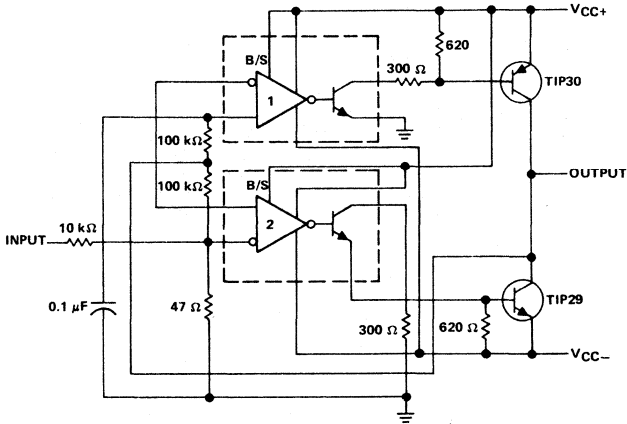


‡Transient voltage and inductive kickback protection

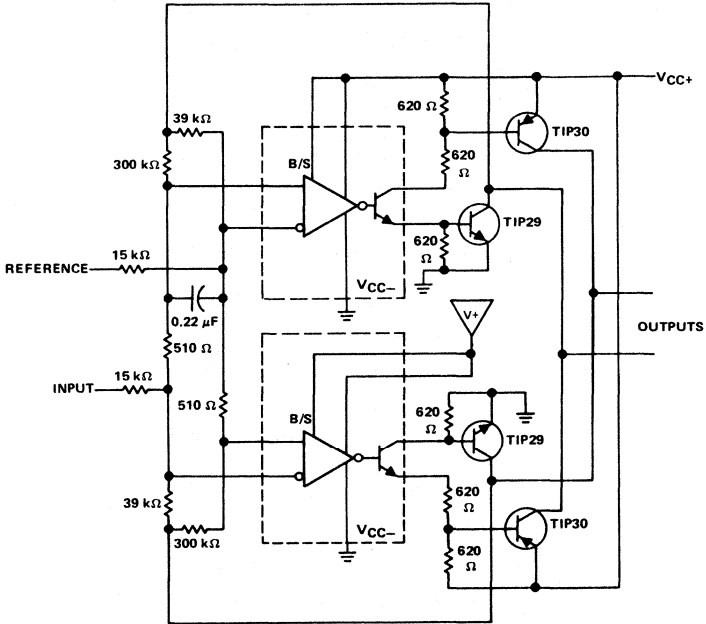
FIGURE 27—RELAY DRIVER WITH STROBE

**TYPES LM111, LM211, LM311  
DIFFERENTIAL COMPARATORS WITH STROBES**

**TYPICAL APPLICATION DATA**



**FIGURE 28—SWITCHING POWER AMPLIFIER**



**FIGURE 29—SWITCHING POWER AMPLIFIERS**

**4**

**Voltage Comparators**

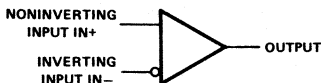
D1979, OCTOBER 1979—REVISED AUGUST 1983

- Single Supply or Dual Supplies
- Wide Range of Supply Voltage . . . 2 to 36 V
- Low Supply Current Drain Independent of Supply Voltage . . . . . 0.8 mA Typ
- Low Input Bias Current . . . . . 25 nA Typ
- Low Input Offset Current . . . . . 3 nA Typ (LM139)
- Low Input Offset Voltage . . . . . 2 mV Typ
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . ± 36 V
- Low Output Saturation Voltage
- Output Compatible with TTL, MOS, and CMOS

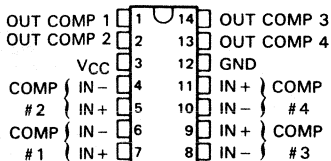
**description**

These devices consist of four independent voltage comparators that are designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 volts to 36 volts and pin 3 is at least 1.5 volts more positive than the input common-mode voltage. Current drain is independent of the supply voltage. The outputs can be connected to other open-collector outputs to achieve wired-AND relationships.

**symbol (each comparator)**

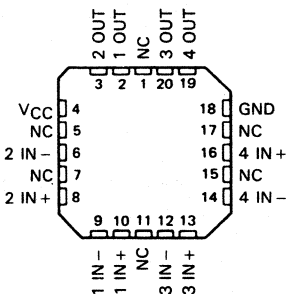


**D, J, OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



**LM139, LM139A**

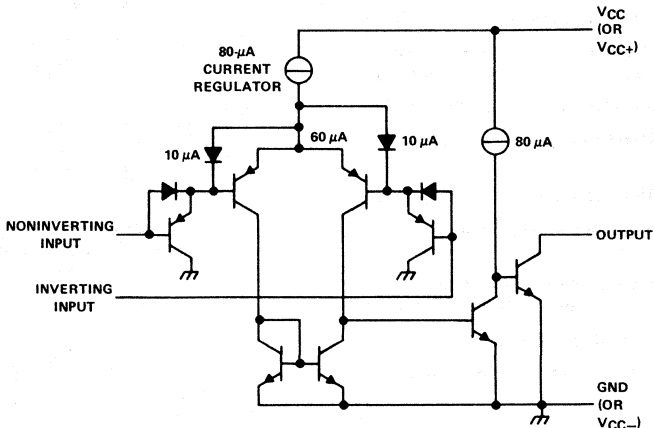
**FH, OR FK CHIP CARRIER PACKAGE  
(TOP VIEW)**



NC—No internal connection

**TYPES LM139, LM239, LM339, LM139A  
LM239A, LM339A, LM2901  
QUADRUPLE DIFFERENTIAL COMPARATORS**

schematic (each comparator)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	36 V
Differential input voltage (see Note 2)	$\pm 36$ V
Input voltage range (either input)	-0.3 V to 36 V
Output voltage	36 V
Output current	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4):	
D, FH, FK, or J package	900 mW
J package	875 mW
Operating free-air temperature range:	
LM139, LM139A	-55°C to 125°C
LM239, LM239A	-25°C to 85°C
LM339, LM339A	0°C to 70°C
LM2901	-40°C to 85°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: FH, FK, or J package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J package, LM139 and LM139A chips are alloy-mounted; LM239, LM239A, LM339, LM339A, and LM2901 chips are glass-mounted.



electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>1</sup>	LM139			LM139A			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{CC} = 5\text{ V to }30\text{ V}$ , $V_{IC} = V_{ICR\text{ min}}$ , $V_O = 1.4\text{ V}$		2	5	1	1	2	mV
$I_{IO}$ Input offset current	$V_O = 1.4\text{ V}$		3	25	3	3	25	nA
$I_{IB}$ Input bias current	$V_O = 1.4\text{ V}$		-25	-100	-25	-25	-100	nA
Common-mode input voltage range	25°C	0 to			0 to			V
	-55°C to 125°C	$V_{CC} - 1.5$			$V_{CC} - 1.5$			
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$ , $V_O = 1.4\text{ V to }11.4\text{ V}$ , $R_L \geq 15\text{ k}\Omega\text{ to }V_{CC}$	0 to	200		0 to	200		V/mV
$I_{OH}$ High-level output current	$V_{OH} = 5\text{ V}$	0 to	0.1		0 to	0.1		nA
$V_{OL}$ Low-level output voltage	$V_{OH} = 30\text{ V}$	150	150	400	150	150	400	$\mu\text{A}$
$I_{OL}$ Low-level output current	$V_{ID} = -1\text{ V}$ , $I_{OL} = 4\text{ mA}$	6	16	700	6	16	700	mV
$I_{CC}$ Supply current (four comparators)	$V_O = 2.5\text{ V}$ , No load	0.8	0.8	2	0.8	0.8	2	mA

<sup>1</sup>All characteristics are measured with zero common-mode input voltage unless otherwise specified.

switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
	$R_L$ connected to 5 V through 5.1 k $\Omega$ , $C_L = 15\text{ pF}$ , <sup>§</sup> See Note 5	100-mV input step with 5-mV overdrive TTL-level input step				
Response time				1.3		$\mu\text{s}$
					C-3	

<sup>§</sup> $C_L$  includes probe and jig capacitance.

NOTE 5: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

## TYPES LM239, LM339, LM239A, LM339A, LM2901 QUADRUPLE DIFFERENTIAL COMPARATORS

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	LM239, LM339			LM239A, LM339A			LM2901			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{CC} = 5\text{ V}$ to $30\text{ V}$ , $V_{IC} = V_{ICR}$ min, $V_O = 1.4\text{ V}$	2	5	9	1	2	4	2	7	15	mV
	Full range										
$I_{IO}$ Input offset current	$V_O = 1.4\text{ V}$	5	50	150	5	50	150	5	50	200	nA
	Full range										
$I_{IB}$ Input bias current	$V_O = 1.4\text{ V}$	-25	-250	-250	-25	-250	-250	-25	-250	-250	nA
	Full range										
$V_{ICR}$ Common-mode input voltage range	25°C	0 to $V_{CC} - 1.5$	0 to $V_{CC} - 1.5$	0 to $V_{CC} - 1.5$	0 to $V_{CC} - 1.5$	0 to $V_{CC} - 1.5$	0 to $V_{CC} - 1.5$	0 to $V_{CC} - 1.5$	0 to $V_{CC} - 1.5$	0 to $V_{CC} - 1.5$	V
	Full range										
Large-signal $A_{VD}$ differential voltage amplification	$V_{CC} = 15\text{ V}$ , $V_O = 1.4\text{ V}$ to $11.4\text{ V}$ , $R_L \geq 15\text{ k}\Omega$ to $V_{CC}$	200	200	200	50	200	200	25	100	200	V/mV
	25°C										
$I_{OH}$ High-level output current	$V_{OH} = 5\text{ V}$ , $V_{OH} = 30\text{ V}$	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	nA
	Full range										
$V_{OL}$ Low-level output voltage	$V_{ID} = 1\text{ V}$ , $V_{ID} = 4\text{ mA}$	150	400	700	150	400	700	150	500	700	mV
	Full range										
$I_{OL}$ Low-level output current	$V_{ID} = -1\text{ V}$ , $V_{OL} = 1.5\text{ V}$	6	16	16	6	16	16	6	16	16	mA
	25°C										
$I_{CC}$ Supply current (four comparators)	$V_O = 2.5\text{ V}$ , No load $V_{CC} = 30\text{ V}$ , $V_O = 15\text{ V}$ , No load	0.8	2	2	0.8	2	2	0.8	2	2	mA
	25°C										

<sup>†</sup> Full range (MIN to MAX) for LM239 and LM239A is -25°C to 85°C, for LM339 and LM339A is 0°C to 70°C, and for LM2901 is -40°C to 85°C. All characteristics are measured with zero common-mode input voltage unless otherwise specified.

switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
		Response time			1.3
	$R_L$ connected to 5 V through 5.1 k $\Omega$ , $C_L = 15\text{ pF}$ . See Note 5			0.3	

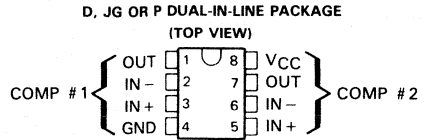
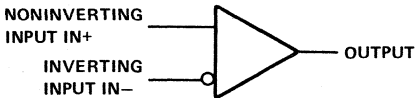
$C_L$  includes probe and jig capacitance.  
NOTE 5: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

- **Single Supply or Dual Supplies**
- **Wide Range of Supply Voltage** . . . . . **2 to 36 Volts**
- **Low Supply Current Drain Independent of Supply Voltage** . . . . . **0.5 mA Typ**
- **Low Input Bias Current** . . . . . **25 nA Typ**
- **Low Input Offset Current** . . . . . **3 nA Typ (LM193)**
- **Low Input Offset Voltage** . . . . . **2 mV Typ**
- **Common-Mode Input Voltage Range Includes Ground**
- **Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage** . . . . . **±36 V**
- **Low Output Saturation Voltage**
- **Output Compatible with TTL, MOS, and CMOS**

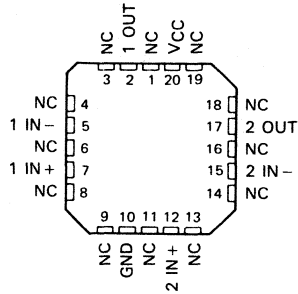
**description**

These devices consist of two independent voltage comparators that are designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 volts to 36 volts and pin 8 is at least 1.5 volts more positive than the input common-mode voltage. Current drain is independent of the supply voltage. The outputs can be connected to other open-collector outputs to achieve wired-AND relationships.

**symbol (each comparator)**



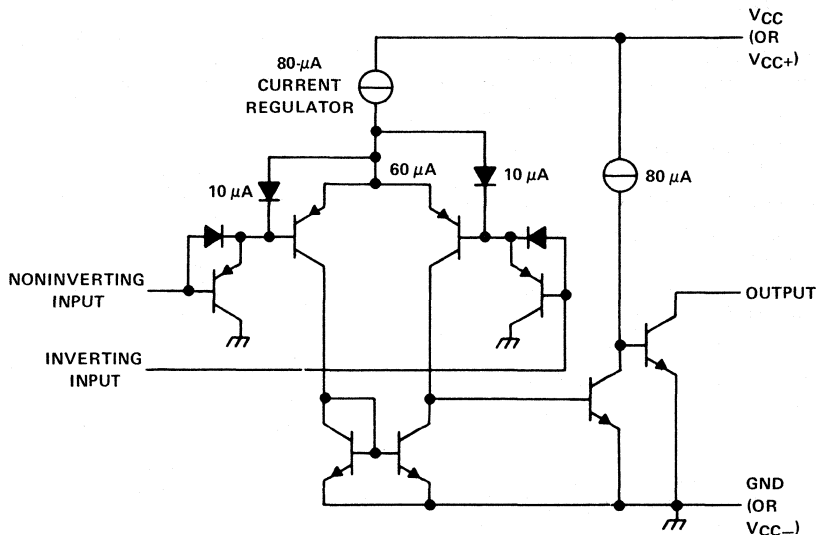
**LM193  
FH OR FK CHIP CARRIER PACKAGE  
(TOP VIEW)**



NC—No internal connection

# TYPES LM193, LM293, LM393, LM293A, LM393A, LM2903 DUAL DIFFERENTIAL COMPARATORS

schematic (each comparator)



Current values shown are nominal.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	36 V
Differential input voltage (see Note 2)	$\pm 36$ V
Input voltage range (either input)	-0.3 V to 36 V
Output voltage	36 V
Output current	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4):	
D or P package	725 mW
JG package (glass-mounted chip)	825 mW
FH, FK, or JG (alloy mounted chip) package	900 mW
Operating free-air temperature range: LM193	-55°C to 125°C
LM293, LM293A	-25°C to 85°C
LM393, LM393A	0°C to 70°C
LM2903	-40°C to 85°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the JG package, LM193 chips are alloy-mounted; LM293, LM293A, LM393, LM393A, and LM2903 chips are glass-mounted.

# TYPES LM193, LM293, LM393, LM293A, LM393A, LM2903 DUAL DIFFERENTIAL COMPARATORS

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	LM193			LM293, LM393			LM293A, LM393A			LM2903		
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX
$V_{IO}$ Input offset voltage	$V_{CC} = 5\text{ V}$ to $30\text{ V}$ ,												
	$V_{IC} = V_{ICR}$ , $V_{O}^* = 1.4\text{ V}$	2	5	9	2	5	9	1	2	4	2	7	15
$I_{IO}$ Input offset current	25°C	3	25	50	5	50	150	5	50	150	5	50	200
	Full range	100			250			250			250		
$I_{IB}$ Input bias current	25°C	25	100	300	25	100	400	25	250	400	25	250	500
	Full range	300			400			400			500		
Common-mode input voltage range*	25°C	0 to $V_{CC}-1.5$			0 to $V_{CC}-1.5$			0 to $V_{CC}-1.5$			0 to $V_{CC}-1.5$		
	Full range	0 to $V_{CC}-2$			0 to $V_{CC}-2$			0 to $V_{CC}-2$			0 to $V_{CC}-2$		
Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$ ,												
	$V_O = 1.4\text{ V}$ to $11.4\text{ V}$ , $R_L \geq 15\text{ k}\Omega$ to $V_{CC}$	50	200	200	50	200	200	50	200	200	50	100	100
$I_{OH}$ High-level output current	$V_{OH} = 5\text{ V}$ , $V_{ID} = 1\text{ V}$	0.1			0.1			0.1			0.1		
	$V_{OH} = 30\text{ V}$ , $V_{ID} = 1\text{ V}$	1			1			1			1		
$V_{OL}$ Low-level output voltage	25°C	150	400	700	150	400	700	150	400	700	150	400	700
	Full range	400			700			700			700		
$I_{OL}$ Low-level output current	25°C	6			6			6			6		
	Full range	6			6			6			6		
$I_{CC}$ Supply current	$V_{CC} = 5\text{ V}$ ,	0.8	1	2.5	0.8	1	2.5	0.8	1	2.5	0.8	1	2.5
	$V_O = 2.5\text{ V}$ , $V_{CC} = 30\text{ V}$ , $V_O = 15\text{ V}$	2.5			2.5			2.5			2.5		

† Full range (MIN to MAX) for LM193 is -55°C to 125°C, for the LM293 and LM293A is -25°C to 85°C, for the LM393 and LM393A is 0°C to 70°C, and for LM2903 is -40°C to 85°C. All characteristics are measured with zero common-mode input voltage unless otherwise specified.  
 \* The voltage at either input or common-mode should not be allowed to go negative by more than 0.3 V. The upper end of the common-mode voltage range is  $V_{CC} + 1.5\text{ V}$ , but either or both inputs can go to 30 V without damage.

switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN			MAX		
		MIN	TYP	MAX	MIN	TYP	MAX
Response time	$R_L$ connected to 5 V through 5.1 k $\Omega$ , $C_L = 15\text{ pF}$ , See Note 5						
	TTL-level input step				1.3		
					0.3		

\*  $C_L$  includes probe and jig capacitance.  
 NOTE 5: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

# 4

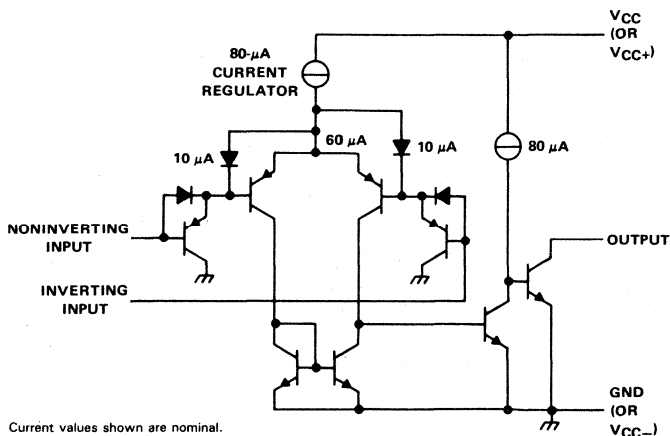
## Voltage Comparators

- Single Supply or Dual Supplies
- Wide Range of Supply Voltage . . . 2 to 28 Volts
- Low Supply Current Drain Independent of Supply Voltage . . . 0.8 mA Typ
- Low Input Bias Current . . . 25 nA Typ
- Low Input Offset Current . . . 3 nA Typ
- Low Input Offset Voltage . . . 3 mV Typ
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . .  $\pm 28$  V
- Low Output Saturation Voltage
- Output Compatible with TTL, MOS, and CMOS

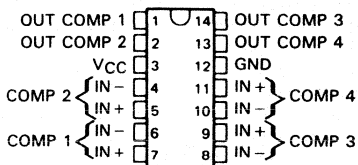
**description**

This device consists of four independent voltage comparators that are designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 volts to 28 volts and pin 3 is at least 1.5 volts more positive than the input common-mode voltage. Current drain is independent of the supply voltage. The outputs can be connected to other open-collector outputs to achieve wired-AND relationships.

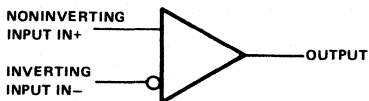
**schematic (each comparator)**



**D, J, OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



**symbol (each comparator)**



# TYPE LM3302

## QUADRUPLE DIFFERENTIAL COMPARATOR

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	28 V
Differential input voltage (see Note 2)	$\pm 28$ V
Input voltage range (either input)	-0.3 V to 28 V
Output voltage	28 V
Output current	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	500 mW
Operating free-air temperature range	-40°C to 85°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from the output to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J package, LM3302 chips are glass-mounted.

### electrical characteristics at specified free-air temperature, $V_{CC} = 5$ V (unless otherwise noted)

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
$V_{IO}$	Input offset voltage	$V_{CC} = 5$ V to 28 V, $V_{IC} = V_{ICR}$ min, $V_O = 1.4$ V	25°C		3	20	mV
			-40°C to 85°C			40	
$I_{IO}$	Input offset current	$V_O = 1.4$ V	25°C		3	100	nA
			-40°C to 85°C			300	
$I_B$	Input bias current		25°C		-25	-500	nA
			-40°C to 85°C			-1000	
$V_{ICR}$	Common-mode input voltage range		25°C		0 to $V_{CC} - 1.5$		V
			-40°C to 85°C			0 to $V_{CC} - 2$	
$A_{VD}$	Large-signal differential voltage amplification	$V_{CC} = 15$ V, $V_O = 1.4$ V to 11.4 V, $R_L = 15$ k $\Omega$ to $V_{CC}$	25°C		2	30	V/mV
$I_{OH}$	High-level output current	$V_{ID} = 1$ V, $V_{OH} = 5$ V	25°C			0.1	nA
			-40°C to 85°C				1
$V_{OL}$	Low-level output voltage	$V_{ID} = -1$ V, $I_{OL} = 4$ mA	25°C		150	500	mV
			-40°C to 85°C				
$I_{OL}$	Low-level output current	$V_{ID} = 1$ V, $V_{OL} = 1.5$ V	25°C		6	16	mA
$I_{CC}$	Supply current (four comparators)	$V_O = 2.5$ V, No load	25°C		0.8	2	mA

†All characteristics are measured with zero common-mode input voltage unless otherwise specified.

### switching characteristics, $V_{CC} = 5$ V, $T_A = 25$ °C

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	$R_L = 5.1$ k $\Omega$ to 5 V, $C_L = 15$ pF <sup>‡</sup> , See Note 5	100-mV input step with 5 mV overdrive		1.3		$\mu$ s
		TTL-level input step		0.3		

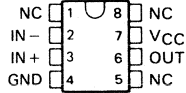
<sup>‡</sup> $C_L$  includes probe and jig capacitance.

NOTE 5: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.



- Single Supply or Dual Supplies
- Wide Range of Supply Voltage . . . 2 to 36 Volts
- Low Supply Current Drain Independent of Supply Voltage . . . 0.8 mA Typ
- Low Input Bias Current . . . 25 nA Typ
- Low Input Offset Current . . . 3 nA Typ (TL331M)
- Low Input Offset Voltage . . . 2 mV Typ
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated-Supply Voltage . . .  $\pm 36$  V
- Low Output Saturation Voltage
- Output Compatible with TTL, MOS, and CMOS

D, JG OR P  
DUAL-IN-LINE PACKAGE  
(TOP VIEW)



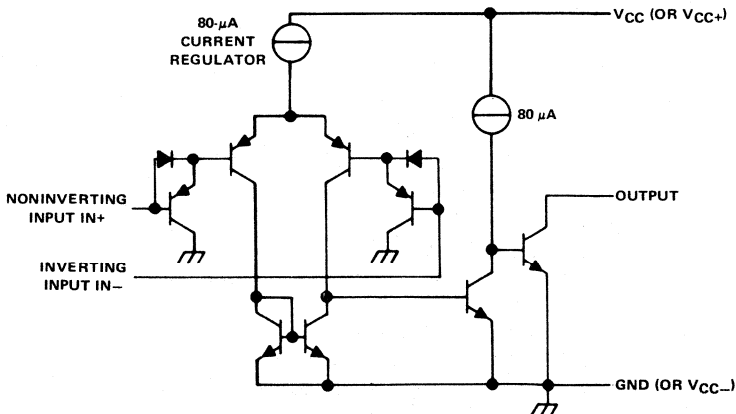
NC—No internal connection

**description**

The TL331 is a voltage comparator that is designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 volts to 36 volts and pin 7 is at least 1.5 volts more positive than the input common-mode voltage. Current drain is independent of the supply voltage.

The TL331M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The TL331I is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The TL331C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**schematic**



Current values shown are nominal.

# TYPES TL331M, TL331I, TL331C DIFFERENTIAL COMPARATORS

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	36 V
Differential input voltage (see Note 2)	$\pm 36$ V
Input voltage range (either input)	-0.3 V to 36 V
Output voltage	36 V
Output current	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	680 mW
Operating free-air temperature range: TL331M	-55°C to 125°C
TL331I	-25°C to 85°C
TL331C	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from the output to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the JG package, TL331M chips are alloy-mounted; TL331I and TL331C chips are glass-mounted.

## electrical characteristics at specified free-air temperature, $V_{CC} = 5$ V (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL331M, TL331I			TL331C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{CC} = 5$ V to 30 V, $V_{IC} = V_{ICR}$ min, $V_O = 1.4$ V	25°C	2	5	2	5	mV	
		Full range	9			9		
$I_{IO}$ Input offset current	$V_O = 1.4$ V	25°C	3	25	5	50	nA	
		Full range	100			150		
$I_{IB}$ Input bias current		25°C	-25	-100	-25	-250	nA	
		Full range	-300			-400		
$V_{ICR}$ Common-mode input voltage range	$V_{CC} = 5$ V to 30 V	25°C	0 to $V_{CC}-1.5$		0 to $V_{CC}-1.5$		V	
		Full range	0 to $V_{CC}-2$		0 to $V_{CC}-2$			
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} = 15$ V, $V_O = 1.4$ V to 11.4 V, $R_L = 15$ k $\Omega$ to $V_{CC}$	25°C	200		200		V/mV	
$I_{OH}$ High-level output current	$V_{ID} = 1$ V	$V_{OH} = 5$ V	25°C	0.1		0.1		nA
		$V_{OH} = 30$ V	Full range	1			$\mu$ A	
$V_{OL}$ Low-level output voltage	$V_{ID} = -1$ V, $I_{OL} = 4$ mA	25°C	150	400	150	400	mV	
		Full range	700			700		
$I_{OL}$ Low-level output current	$V_{ID} = -1$ V, $V_{OL} = 1.5$ V	25°C	6		6		mA	
$I_{CC}$ Supply current	$V_O = 2.5$ V, No load	25°C	0.5	0.8	0.5	0.8	mA	

† Full range (MIN to MAX) for TL331M is -55°C to 125°C, for the TL331I is -25°C to 85°C, and for the TL331C is 0°C to 70°C. All characteristics are measured with zero common-mode input voltage unless otherwise specified.

## switching characteristics, $V_{CC} = 5$ V, $T_A = 25$ °C

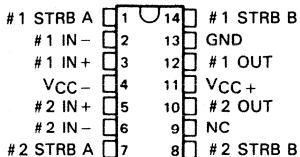
PARAMETER	TEST CONDITIONS			MIN	TYP	MAX	UNIT
Response time	$R_L$ connected to 5 V through 5.1 k $\Omega$ , $C_L = 15$ pF, ‡ See Note 5	100-mV input step with 5-mV overdrive			1.3		$\mu$ s
		TTL-level input step			0.3		

‡  $C_L$  includes probe and jig capacitance.

NOTE 5: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

- Each Comparator Identical to LM106 or LM306 with Common  $V_{CC+}$ ,  $V_{CC-}$ , and Ground Connections
- Improved Gain and Accuracy
- Fan-Out to 10 Series 54/74 TTL Loads
- Strobe Capability
- Short-Circuit and Surge Protection
- Fast Response Times

TL506M . . . J OR W PACKAGE  
TL506C . . . J OR N PACKAGE  
(TOP VIEW)



NC—No internal connection

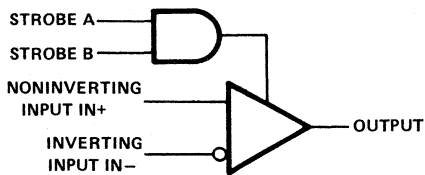
**description**

The TL506 is a dual high-speed comparator, with each half having differential inputs, a low-impedance output with high-sink-current capability (100 mA), and two strobe inputs. This device detects low-level analog or digital signals and can drive digital logic or lamps and relays directly. Short-circuit protection and surge-current limiting is provided.

The circuit is similar to a TL810 with gated output. A low-level input at either strobe causes the output to remain high regardless of the differential input. When both strobe inputs are either open or at a high logic level, the output voltage is controlled by the differential input voltage. The circuit will operate with any negative supply voltage between  $-3\text{ V}$  and  $-12\text{ V}$  with little difference in performance.

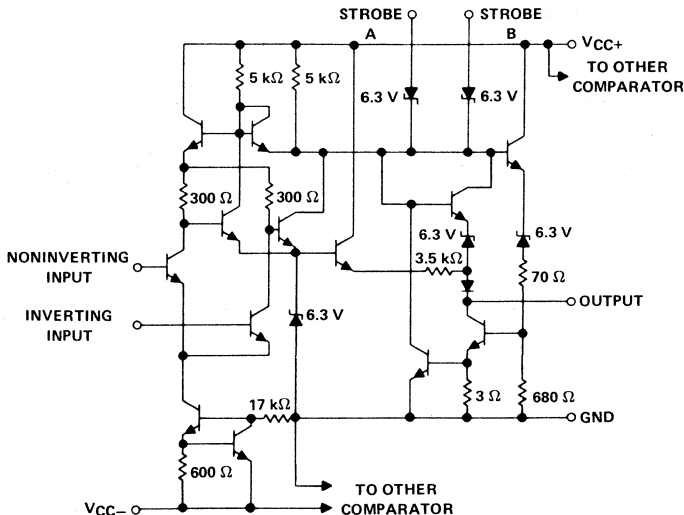
The TL506M is characterized for operation over the full military temperature range of  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ ; the TL506C is characterized for operation from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

**functional block diagram (each comparator)**



# TYPES TL506M, TL506C DUAL DIFFERENTIAL COMPARATORS WITH STROBES

schematic (each comparator)



absolute maximum ratings over operating free-air temperature (unless otherwise noted)

Supply voltage $V_{CC+}$ (see Note 1)	15 V
Supply voltage $V_{CC-}$ (see Note 1)	-15 V
Differential input voltage (see Note 2)	$\pm 5$ V
Input voltage (any input, see Notes 1 and 3)	$\pm 7$ V
Strobe voltage range (see Note 1)	0 V to $V_{CC+}$
Output voltage (see Note 1)	24 V
Voltage from output to $V_{CC-}$	30 V
Duration of output short-circuit (see Note 4)	10 s
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 5):	
J package (TL506MJ)	1375 mW
J package (TL506CJ)	1025 mW
N package	875 mW
W package	1000 mW
Operating free-air temperature range:	
TL506M	-55°C to 125°C
TL506C	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J or W package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N package	260°C

- NOTES: 1. All voltage values, except differential voltages and the voltage from the output to  $V_{CC-}$ , are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 7 V, whichever is less.  
 4. One output at a time may be shorted to ground or either power supply.  
 5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J package, TL506M chips are alloy mounted; TL506C chips are glass mounted.

4

Voltage Comparators

# TYPES TL506M, TL506C DUAL DIFFERENTIAL COMPARATORS WITH STROBES

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -3\text{ V to } -12\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL506M			TL506C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	See Note 6	25°C	0.5‡	2	1.6‡	5	mV	
		Full range	3			6.5		
$\alpha V_{IO}$ Average temperature coefficient of input offset voltage	See Note 6	Full range	3	10	5	20	$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$ Input offset current	See Note 6	25°C	0.7‡	3	1.8‡	5	$\mu\text{A}$	
		MIN	2	7	1	7.5		
		MAX	0.4	3	0.5			
$\alpha I_{IO}$ Average temperature coefficient of input offset current	See Note 6	MIN to 25°C	15	75	24	100	nA/°C	
		25°C to MAX	5	25	15	50		
$I_{IB}$ Input bias current	$V_O = 0.5\text{ V to } 5\text{ V}$	25°C	7‡	20	16‡	25	$\mu\text{A}$	
		Full range	45			40		
$I_{L(S)}$ Low-level strobe current	$V_{(\text{strobe})} = 0.4\text{ V}$	Full range	-1.7‡	-3.3	-1.7‡	-3.3	mA	
$V_{IH(S)}$ High-level strobe voltage		Full range	2.5		2.5		V	
$V_{IL(S)}$ Low-level strobe voltage		Full range		0.9		0.9	V	
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V to } -12\text{ V}$	Full range	$\pm 5$			$\pm 5$	V	
$V_{ID}$ Differential input voltage range		Full range	$\pm 5$			$\pm 5$	V	
$A_{VD}$ Large-signal differential voltage amplification	No load, $V_O = 0.5\text{ V to } 5\text{ V}$	25°C	40 000‡			40 000‡		
$V_{OH}$ High-level output voltage	$V_{ID} = 5\text{ mV}$ , $I_{OH} = -400\ \mu\text{A}$	Full range	2.5	5.5	2.5	5.5	V	
	$V_{ID} = -5\text{ mV}$ , $I_{OL} = 100\text{ mA}$	25°C	0.8‡	1.5	0.8‡	2		
$V_{OL}$ Low-level output voltage	$V_{ID} = -5\text{ mV}$ , $I_{OL} = 50\text{ mA}$	Full range	1			1	V	
	$V_{ID} = -5\text{ mV}$ , $I_{OL} = 16\text{ mA}$	Full range	0.4			0.4		
	$V_{ID} = 5\text{ mV}$ , $V_{OH} = 8\text{ V to } 24\text{ V}$	25°C	0.02‡	1	0.02‡	2		
$I_{OH}$ High-level output current	$V_{OH} = 8\text{ V to } 24\text{ V}$	Full range	100			100	$\mu\text{A}$	
$I_{CC+}$ Supply current from $V_{CC+}$	$V_{ID} = -5\text{ mV}$ , See Note 7	Full range	13.9‡	20	13.9‡	20	mA	
$I_{CC-}$ Supply current from $V_{CC-}$	See Note 7	Full range	3.2‡	7.2	3.2‡	7.2	mA	

† Unless otherwise noted, all characteristics are measured with the strobe open. Full range (MIN to MAX) for TL506M is  $-55^\circ\text{C to } 125^\circ\text{C}$  and for the TL506C is  $0^\circ\text{C to } 70^\circ\text{C}$ .

‡ These typical values are at  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

NOTES: 6. The offset voltages and offset currents given are the maximum values required to drive the output down to the low range ( $V_{OL}$ ) or up to the high range ( $V_{OH}$ ). Thus these parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance.

7. Power supply currents are measured with the respective noninverting inputs and inverting inputs of both comparators connected in parallel. The outputs are open.

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS†	TL506M			TL506C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Response time, low-to-high-level output	$R_L = 390\ \Omega\text{ to } 5\text{ V}$ , $C_L = 15\text{ pF}$ , See Note 8		28	40		28		ns

NOTE 8: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

# TYPES TL506M, TL506C DUAL DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS<sup>§</sup>

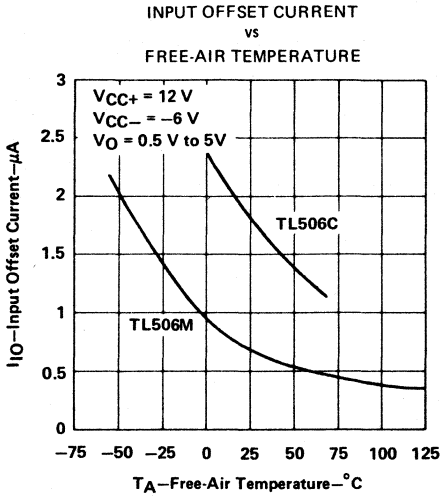


FIGURE 1

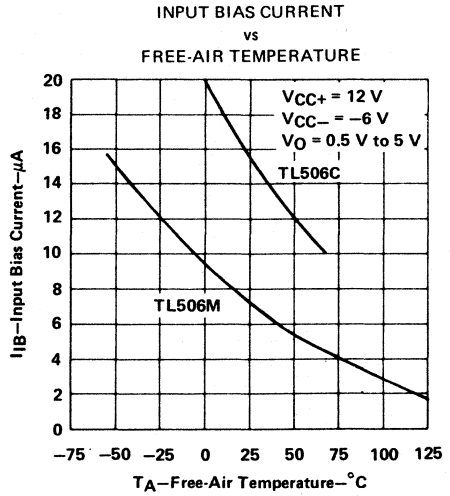


FIGURE 2

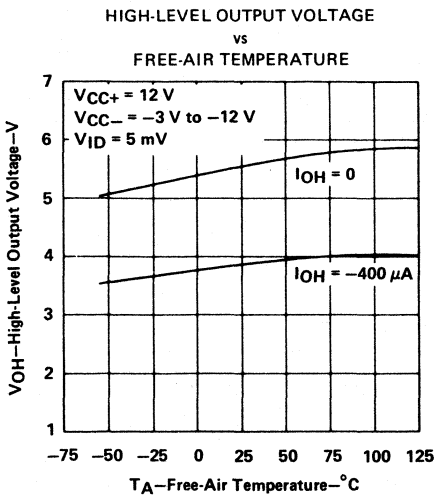


FIGURE 3

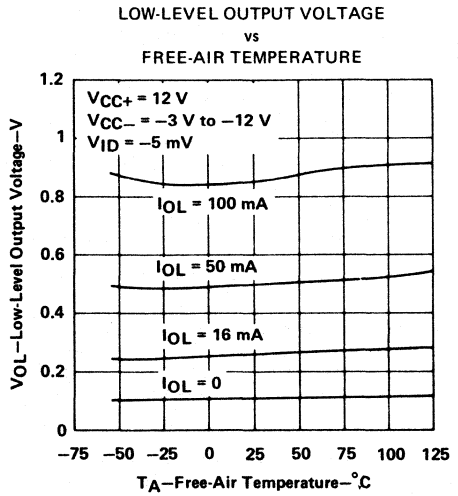


FIGURE 4

<sup>§</sup>Data for temperatures below  $0^{\circ}\text{C}$  and above  $70^{\circ}\text{C}$  is applicable to TL506M circuits only.

# TYPES TL506M, TL506C DUAL DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS<sup>§</sup>

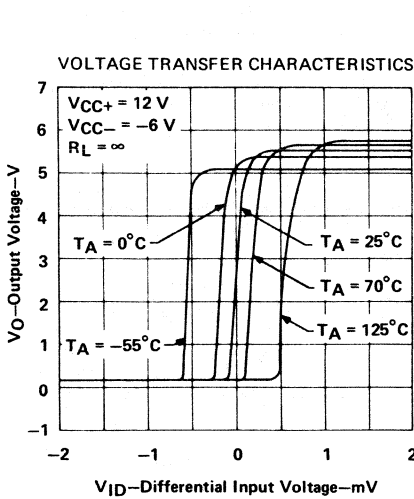


FIGURE 5

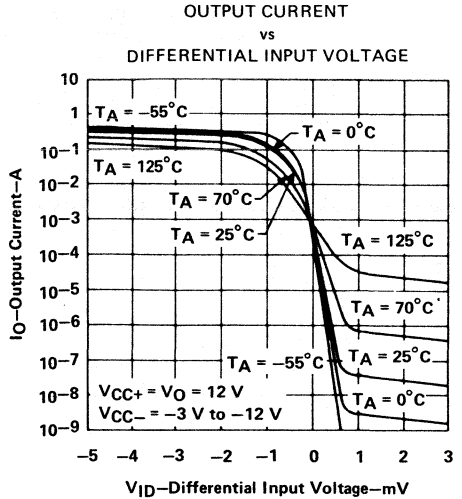


FIGURE 6

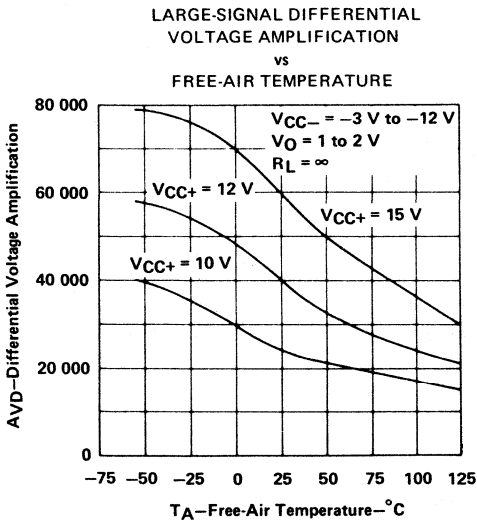


FIGURE 7

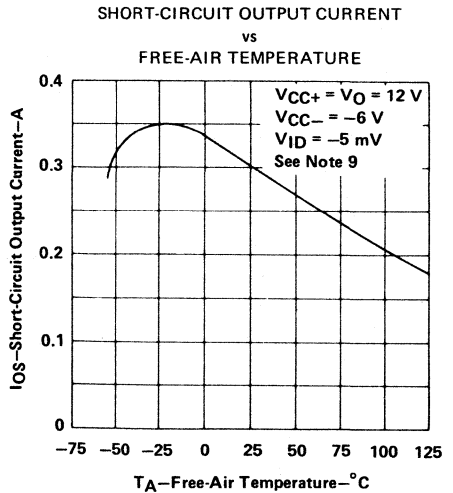


FIGURE 8

<sup>§</sup>Data for temperatures below  $0^\circ\text{C}$  and above  $70^\circ\text{C}$  is applicable to TL506M circuits only.  
NOTE 9: This parameter was measured using a single 5-ms pulse.

# TYPES TL506M, TL506C DUAL DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS

OUTPUT RESPONSE FOR  
VARIOUS INPUT OVERDRIVES

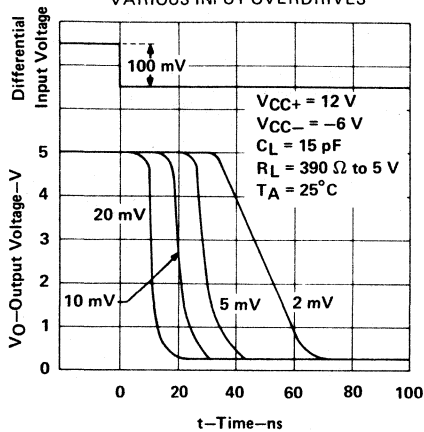


FIGURE 9

OUTPUT RESPONSE FOR  
VARIOUS INPUT OVERDRIVES

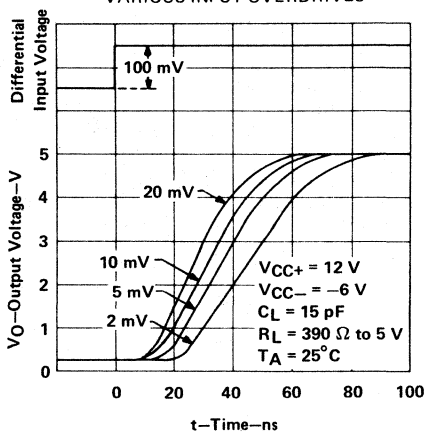


FIGURE 10

SUPPLY CURRENT FROM  $V_{CC+}$   
VS  
SUPPLY VOLTAGE  $V_{CC+}$

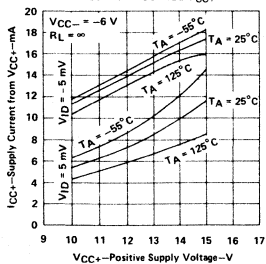


FIGURE 11

SUPPLY CURRENT FROM  $V_{CC-}$   
VS  
SUPPLY VOLTAGE  $V_{CC-}$

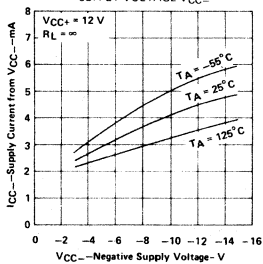


FIGURE 12

TOTAL POWER DISSIPATION  
VS  
FREE-AIR TEMPERATURE

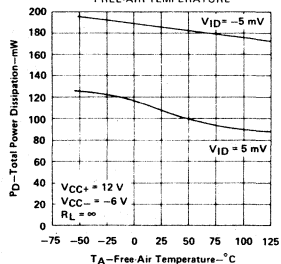


FIGURE 13

§Data for temperatures below 0°C and above 70°C is applicable to TL506M circuits only.

4

Voltage Comparators

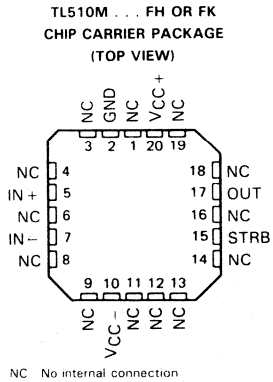
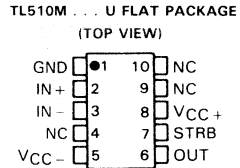
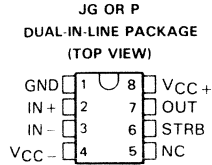


- Low Offset Characteristics
- High Differential Voltage Amplification
- Fast Response Times
- Output Compatible with Most TTL Circuits

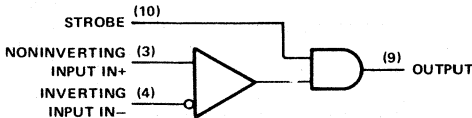
**description**

The TL510 monolithic high-speed voltage comparator is an improved version of the TL710 with an extra stage added to increase voltage amplification and accuracy, and a strobe input for greater flexibility. Typical voltage amplification is 33,000. Since the output cannot be more positive than the strobe, a low-level input at the strobe will cause the output to go low regardless of the differential input. Component matching, inherent in integrated circuit fabrication techniques, produces a comparator with low-drift and low-offset characteristics. These circuits are particularly useful for applications requiring an amplitude discriminator, memory sense amplifier, or a high-speed limit detector.

The TL510M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL510C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

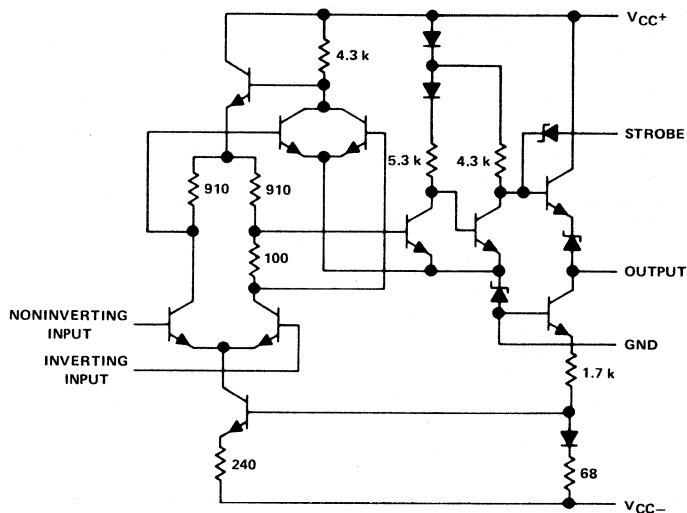


**functional block diagram (positive logic)**



# TYPES TL510M, TL510C DIFFERENTIAL COMPARATORS WITH STROBE

schematic



Resistor values shown are nominal in ohms.  
Component values shown are nominal.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage $V_{CC+}$ (see Note 1)	14 V
Supply voltage $V_{CC-}$ (see Note 1)	-7 V
Differential input voltage (see Note 2)	$\pm 5$ V
Input voltage (either input, see Note 1)	$\pm 7$ V
Strobe voltage (see Note 1)	6 V
Peak output current ( $t_W \leq 1$ s)	10 mA
Continuous total power dissipation at (or below) 70°C free-air temperature (see Note 3)	300 mW
Operating free-air temperature range: TL510M Circuits	-55°C to 125°C
TL510C Circuits	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: FH, FK, JG, or U package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: P package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
3. For operation of the TL510M above 70°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the JG package, TL510M chips are alloy mounted and TL510C chips are glass mounted.

4 Voltage Comparators

# TYPES TL510M, TL510C DIFFERENTIAL COMPARATORS WITH STROBE

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS†		TL510M			TL510C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S \leq 200\ \Omega$ , See Note 4	25 °C	0.6	2	1.6	3.5		mV	
		Full range			3	4.5			
$\alpha_{VIO}$ Average temperature coefficient of input offset voltage	$R_S = 50\ \Omega$ , See Note 4	MIN to 25 °C	3	10	3	20		$\mu\text{V}/^\circ\text{C}$	
		25 °C to MAX	3	10	3	20			
$I_{IO}$ Input offset current	See Note 4	25 °C	0.75	3	1.8	5		$\mu\text{A}$	
		MIN	1.8	7		7.5			
		MAX	0.25	3					
$\alpha_{IIO}$ Average temperature coefficient of input offset current	See Note 4	MIN to 25 °C	15	75	24	100		nA/°C	
		25 °C to MAX	5	25	15	50			
$I_{IB}$ Input bias current	See Note 4	25 °C	7	15	7	20		$\mu\text{A}$	
		MIN	12	25	9	30			
$I_{IH(S)}$ High-level strobe current	$V_{I(strobe)} = 5\text{ V}$ , $V_{ID} = -5\text{ mV}$	25 °C		$\pm 100$		$\pm 100$		$\mu\text{A}$	
$I_{IL(S)}$ Low-level strobe current	$V_{I(strobe)} = -100\text{ mV}$ , $V_{ID} = 5\text{ mV}$	25 °C	-1	-2.5	-1	-2.5		mA	
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V}$	Full range	$\pm 5$		$\pm 5$			V	
$V_{ID}$ Differential input voltage range		Full range	$\pm 5$		$\pm 5$			V	
$AVD$ Large-signal differential voltage amplification	No load, $V_O = 0$ to 2.5 V	25 °C	12.5	33	10	33		V/mV	
		Full range	10		8				
$V_{OH}$ High-level output voltage	$V_{ID} = 5\text{ mV}$ , $I_{OH} = 0$	Full range	4‡	5	4‡	5		V	
	$V_{ID} = 5\text{ mV}$ , $I_{OH} = -5\text{ mA}$	Full range	2.5	3.6‡	2.5	3.6‡		V	
$V_{OL}$ Low-level output voltage	$V_{ID} = -5\text{ mV}$ , $I_{OL} = 0$	Full range	-1	-0.5‡	0‡	-1	-0.5‡	0‡	V
	$V_{I(strobe)} = 0.3\text{ V}$ , $V_{ID} = 5\text{ mV}$ , $I_{OL} = 0$	Full range	-1	0‡	-1	0‡		V	
$I_{OL}$ Low-level output current	$V_{ID} = -5\text{ mV}$ , $V_O = 0$	25 °C	2	2.4	1.6	2.4		mA	
		MIN	1	2.3	0.5	2.4			
		MAX	0.5	2.3	0.5	2.4			
$r_o$ Output resistance	$V_O = 1.4\text{ V}$	25 °C		200		200		$\Omega$	
CMRR Common-mode rejection ratio	$R_S \leq 200\ \Omega$	Full range	80	100‡	70	100‡		dB	
$I_{CC+}$ Supply current from $V_{CC+}$	No load	Full range	5.5‡	9	5.5‡	9		mA	
$I_{CC-}$ Supply current from $V_{CC-}$		Full range	-3.5‡	-7	-3.5‡	-7			
$P_D$ Total power dissipation		Full range	90‡	150	90‡	150			mW

† Unless otherwise noted, all characteristics are measured with the strobe open. Full range (MIN to MAX) for TL510M is -55 °C to 125 °C and for the TL510C is 0 °C to 70 °C.

‡ These typical values are at  $T_A = 25\text{ }^\circ\text{C}$ .

§ The algebraic convention, where the most-positive (least negative) limit is designated as maximum, is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL510M,  $V_O = 1.8\text{ V}$  at  $T_A = -55\text{ }^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25\text{ }^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125\text{ }^\circ\text{C}$ ; for TL510C,  $V_O = 1.5\text{ V}$  at  $T_A = 0\text{ }^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at 25 °C, and  $V_O = 1.2\text{ V}$  at  $T_A = 70\text{ }^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

# TYPES TL510M, TL510C

## DIFFERENTIAL COMPARATORS WITH STROBE

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	$R_L = \infty$	$C_L = 5\text{ pF}$ , See Note 5		30	80	ns
Strobe release time	$R_L = \infty$	$C_L = 5\text{ pF}$ , See Note 6		5	25	ns

NOTES: 5. The response time specified is for a 100-mV input step with 5-mV overdrive.

6. For testing purposes, the input bias conditions are selected to produce an output voltage of 1.4 V. A 5-mV overdrive is then added to the input bias voltage to produce an output voltage that rises above 1.4 V. The time interval is measured from the 50% point of the strobe voltage curve to the point where the overdriven output voltage crosses the 1.4 V level.

### TYPICAL CHARACTERISTICS

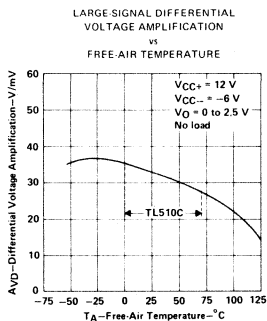


FIGURE 1

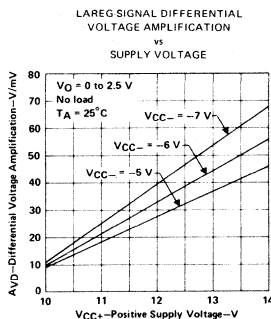


FIGURE 2

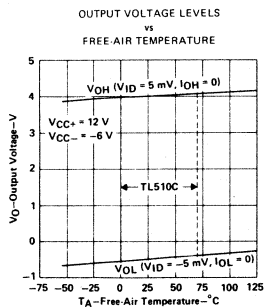


FIGURE 3

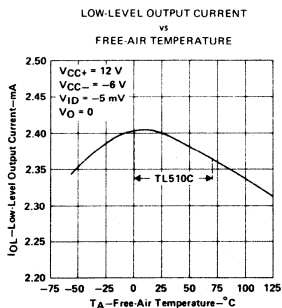


FIGURE 4

4

Voltage Comparators

# TYPES TL510M, TL510C DIFFERENTIAL COMPARATORS WITH STROBE

## TYPICAL CHARACTERISTICS

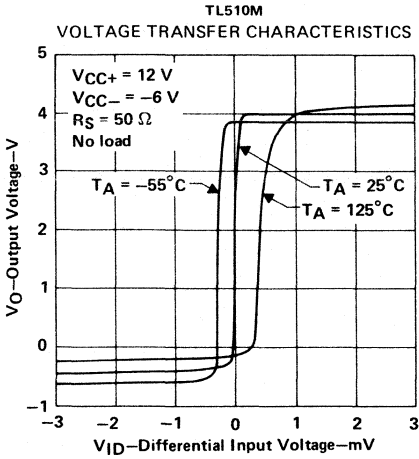


FIGURE 5

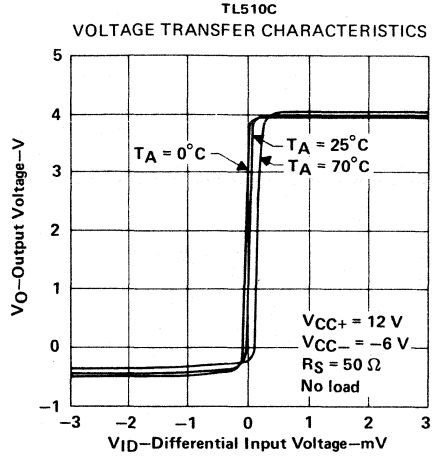


FIGURE 6

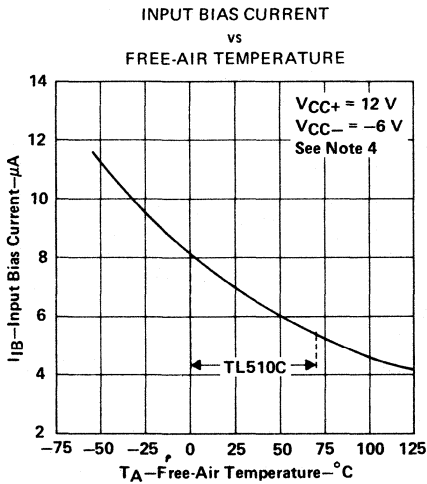


FIGURE 7

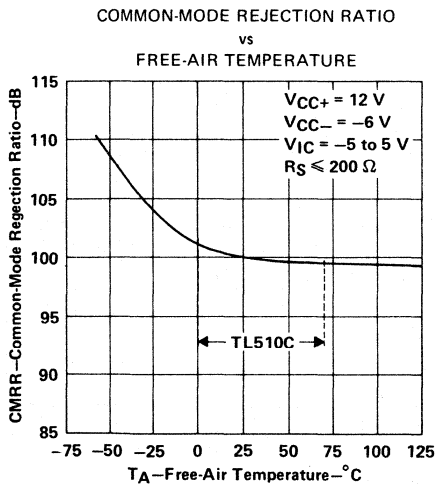


FIGURE 8

# TYPES TL510M, TL510C DIFFERENTIAL COMPARATORS WITH STROBE

## TYPICAL CHARACTERISTICS

OUTPUT RESPONSE FOR  
VARIOUS INPUT OVERDRIVES

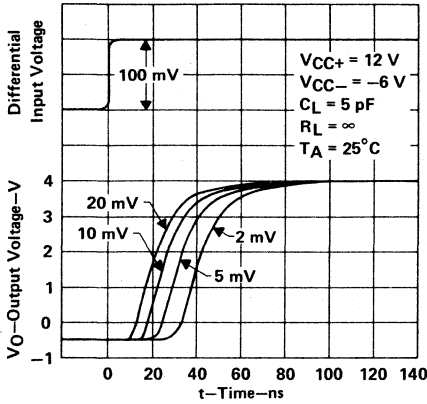


FIGURE 9

STROBE RELEASE TIME  
FOR VARIOUS INPUT OVERDRIVES

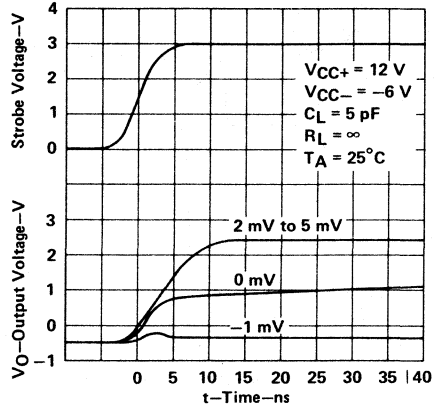


FIGURE 10

COMMON-MODE PULSE RESPONSE

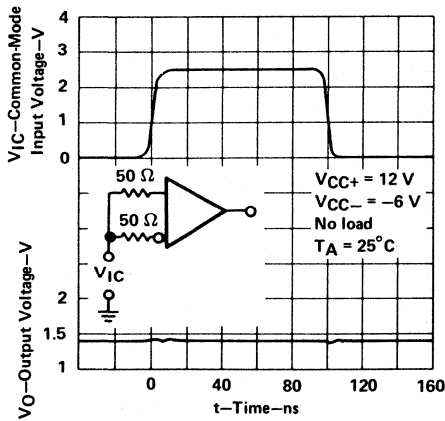


FIGURE 11

TOTAL POWER DISSIPATION  
vs  
FREE-AIR TEMPERATURE

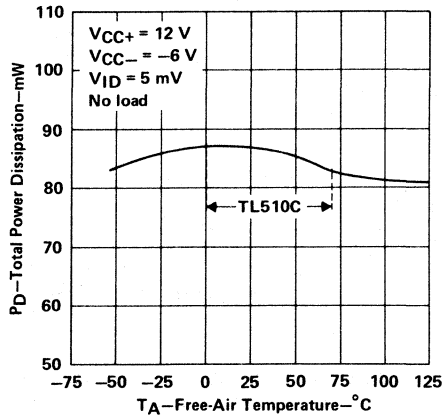


FIGURE 12

Voltage Comparators

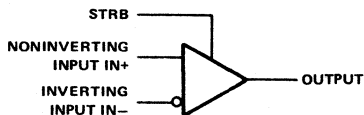
- **Fast Response Times**
- **High Differential Voltage Amplification**
- **Low Offset Characteristics**
- **Outputs Compatible with Most TTL Circuits**

**description**

The TL514 is an improved version of the TL720 dual high-speed voltage comparator. When compared with the TL720, these circuits feature higher amplification (typically 33,000) due to an extra amplification stage, increased accuracy because of lower offset characteristics, and greater flexibility with the addition of a strobe to each comparator. Since the output cannot be more positive than the strobe, a low-level input at the strobe will cause the output to go low regardless of the differential input.

These circuits are especially useful in applications requiring an amplitude discriminator, memory sense amplifier, or a high-speed limit detector. The TL514M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the TL514C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

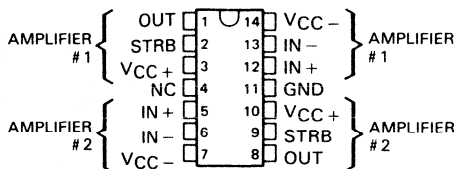
**symbol (each comparator)**



TL514M . . . J OR W PACKAGE

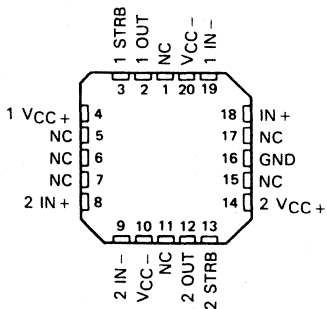
TL514C . . . J OR N PACKAGE

(TOP VIEW)



TL514M  
FH OR FK CHIP CARRIER

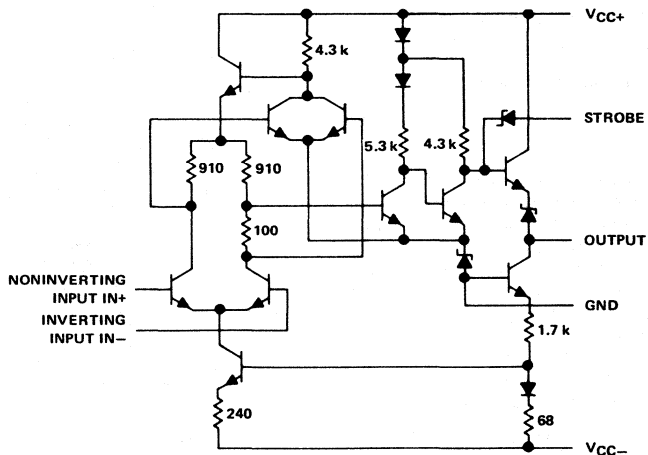
(TOP VIEW)



NC—No internal connection

# TYPES TL514M, TL514C DUAL DIFFERENTIAL COMPARATORS WITH STROBES

schematic (each comparator)



Resistor values shown are nominal in ohms.  
Component values shown are nominal.

4

Voltage Comparators

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage $V_{CC+}$ (see Note 1)	14 V
Supply voltage $V_{CC-}$ (see Note 1)	-7 V
Differential input voltage (see Note 2)	$\pm 5$ V
Input voltage (any input, see Note 1)	$\pm 7$ V
Strobe voltage (see Note 1)	6 V
Peak output current ( $t_W \leq 1$ s)	10 mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 3):	
each comparator	300 mW
total package	600 mW
Operating free-air temperature range:	
TL514M Circuits	-55°C to 125°C
TL514C Circuits	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: FH, FK, J, or W package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N package	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
3. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J package, TL514M chips are alloy mounted and TL514C chips are glass mounted.



# TYPES TL514M, TL514C DUAL DIFFERENTIAL COMPARATORS WITH STROBES

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$

PARAMETER	TEST CONDITIONS <sup>†</sup>	TL514M			TL514C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S \leq 200\ \Omega$ , See Note 4	25°C	0.6	2	1.6	3.5	mV	
		Full range		3		4.5		
$\alpha V_{IO}$ Average temperature coefficient of input offset voltage	$R_S = 50\ \Omega$ , See Note 4	MIN to 25°C	3	10	3	20	$\mu\text{V}/^\circ\text{C}$	
		25°C to MAX	3	10	3	20		
$I_{IO}$ Input offset current	See Note 4	25°C	0.75	3	1.8	5	$\mu\text{A}$	
		MIN	1.8	7	7.5			
		MAX	0.25	3	7.5			
$\alpha I_{IO}$ Average temperature coefficient of input offset current	See Note 4	MIN to 25°C	15	75	24	100	nA/°C	
		25°C to MAX	5	25	15	50		
$I_{IB}$ Input bias current	See Note 4	25°C	7	15	7	20	$\mu\text{A}$	
		MIN	12	25	9	30		
$I_{L(S)}$ High-level strobe current	$V_{(\text{strobe})} = 5\text{ V}$ , $V_{ID} = -5\text{ mV}$	25°C	±100		±100		$\mu\text{A}$	
$I_{L(S)}$ Low-level strobe current	$V_{(\text{strobe})} = -100\text{ mV}$ , $V_{ID} = 5\text{ mV}$	25°C	-1	-2.5	-1	-2.5	mA	
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V}$	Full range	±5		±5		V	
$V_{ID}$ Differential input voltage range		Full range	±5		±5		V	
		25°C	12.5	33	10	33	V/mV	
$A_{VD}$ Large-signal differential voltage amplification	No load, $V_O = 0\text{ to }2.5\text{ V}$	Full range	10		8		V/mV	
		25°C	12.5	33	10	33		
$V_{OH}$ High-level output voltage	$V_{ID} = 5\text{ mV}$ , $I_{OH} = 0$	Full range	4 <sup>§</sup> 5		4 <sup>§</sup> 5		V	
	$V_{ID} = 5\text{ mV}$ , $I_{OH} = -5\text{ mA}$	Full range	2.5	3.6 <sup>§</sup>	2.5	3.6 <sup>§</sup>		
$V_{OL}$ Low-level output voltage	$V_{ID} = -5\text{ mV}$ , $I_{OL} = 0$	Full range	-1	-0.5 <sup>§</sup> 0 <sup>‡</sup>	-1	-0.5 <sup>§</sup> 0 <sup>‡</sup>	V	
	$V_{(\text{strobe})} = 0.3\text{ V}$ , $V_{ID} = 5\text{ mV}$ , $I_{OL} = 0$	Full range	-1	0 <sup>‡</sup>	-1	0 <sup>‡</sup>	V	
$I_{OL}$ Low-level output current	$V_{ID} = -5\text{ mV}$ , $V_O = 0$	25°C	2	2.4	1.6	2.4	mA	
		MIN	1	2.3	0.5	2.4		
		MAX	0.5	2.3	0.5	2.4		
$r_o$ Output resistance	$V_O = 1.4\text{ V}$	25°C	200		200		$\Omega$	
CMRR Common-mode rejection ratio	$R_S \leq 200\ \Omega$	Full range	80	100 <sup>§</sup>	70	100 <sup>§</sup>	dB	
$I_{CC+}$ Supply current from $V_{CC+}$ <sup>†</sup>	$V_{ID} = -5\text{ mV}$	Full range	5.5 <sup>§</sup> 9		5.5 <sup>§</sup> 9		mA	
$I_{CC-}$ Supply current from $V_{CC-}$ <sup>†</sup>		Full range	-3.5 <sup>§</sup> -7		-3.5 <sup>§</sup> -7		mA	
$P_D$ Total power dissipation <sup>†</sup>	No load	Full range	90 <sup>§</sup>	150	90 <sup>§</sup>	150	mW	

<sup>†</sup> Unless otherwise noted, all characteristics are measured with the strobe open. Full range (MIN to MAX) for TL514M is -55°C to 125°C and for the TL514C is 0°C to 70°C.

<sup>‡</sup> The algebraic convention where the most-positive (least-negative) limit is designated as maximum, is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

<sup>§</sup> These typical values are at  $T_A = 25^\circ\text{C}$ .

<sup>¶</sup> Supply current and power dissipation limits apply for each comparator.

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL514M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ ; for TL514C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $T_A = 70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

4

Voltage Comparators

# TYPES TL514M, TL514C DUAL DIFFERENTIAL COMPARATORS WITH STROBES

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS			MIN	TYP	MAX	UNIT
Response time	$R_L = \infty$	$C_L = 5\text{ pF}$	See Note 5		30	80	ns
Strobe release time	$R_L = \infty$	$C_L = 5\text{ pF}$	See Note 6		5	25	ns

- NOTES: 5. The response time specified is for a 100-mV input step with 5 mV overdrive.  
6. For testing purposes, the input bias conditions are selected to produce an output voltage of 1.4 V. A 5-mV overdrive is then added to the input bias voltage to produce an output voltage that rises above 1.4 V. The time interval is measured from the 50% point of the strobe voltage curve to the point where the overdriven output voltage crosses the 1.4 V level.

## TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
FREE-AIR TEMPERATURE

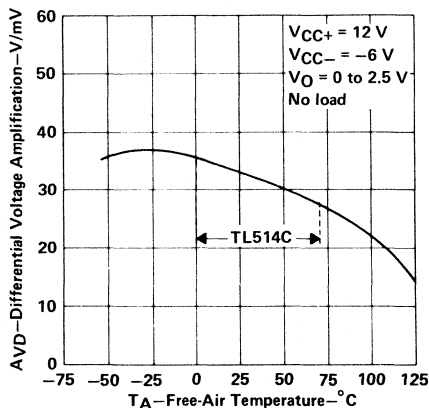


FIGURE 1

LARGE-SIGNAL DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
SUPPLY VOLTAGE

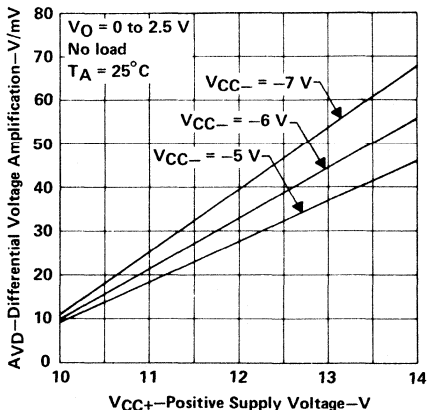


FIGURE 2

4

Voltage Comparators

# TYPES TL514M, TL514C DUAL DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS

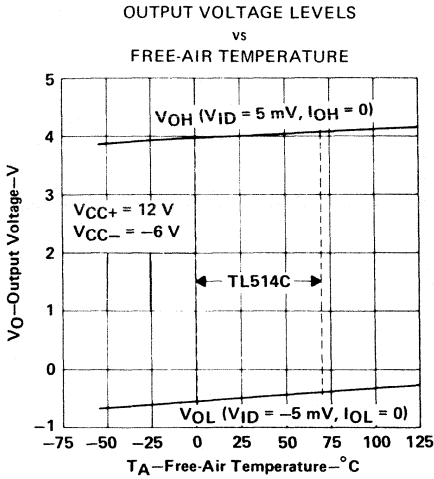


FIGURE 3

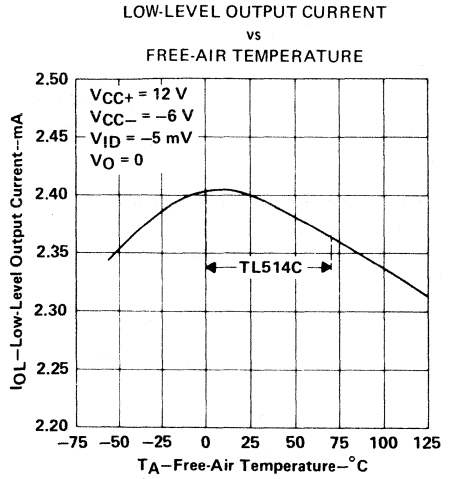


FIGURE 4

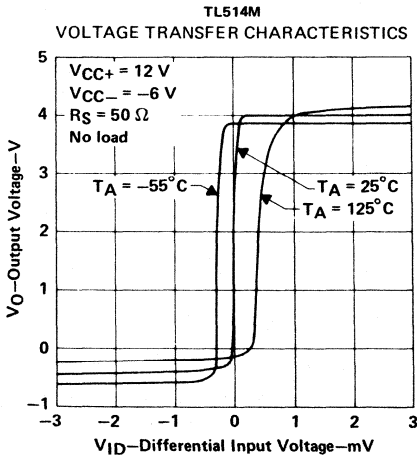


FIGURE 5

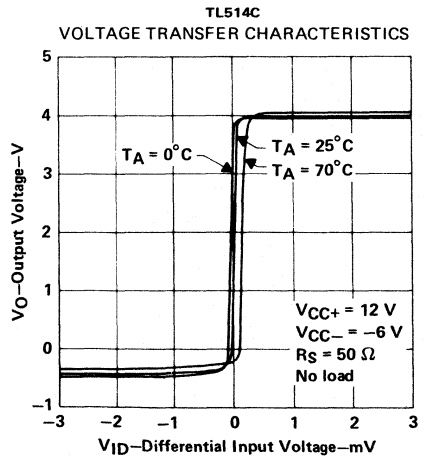


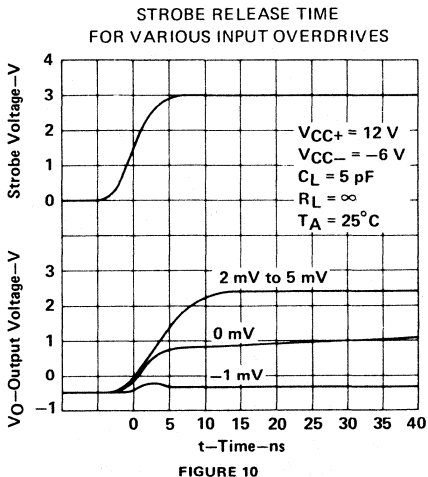
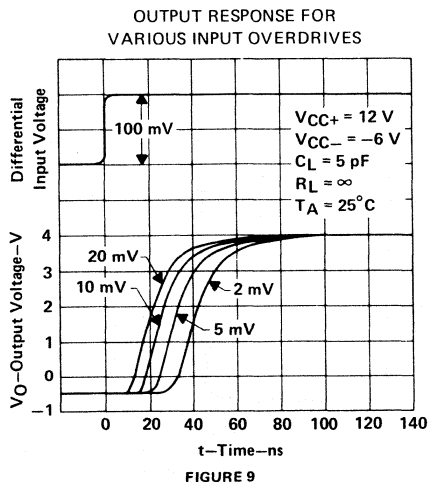
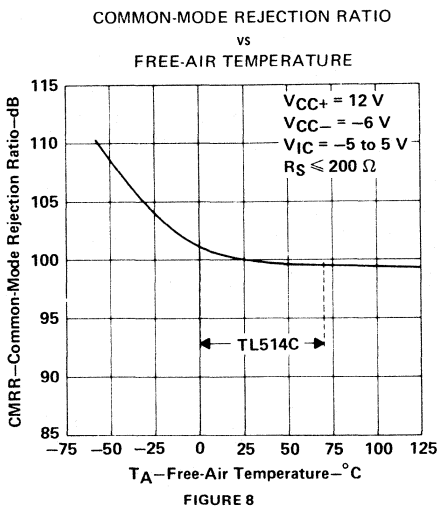
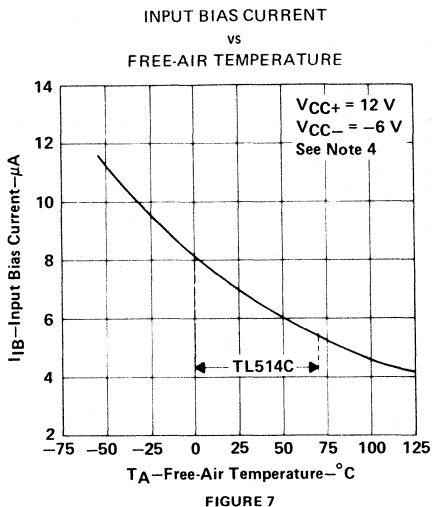
FIGURE 6

4

Voltage Comparators

# TYPES TL514M, TL514C DUAL DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS



NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL514M,  $V_O = 1.8$  V at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4$  V at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1$  V at  $T_A = 125^\circ\text{C}$ ; for TL514C,  $V_O = 1.5$  V at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4$  V at  $25^\circ\text{C}$ , and  $V_O = 1.2$  V at  $T_A = 70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

# TYPES TL514M, TL514C DUAL DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS

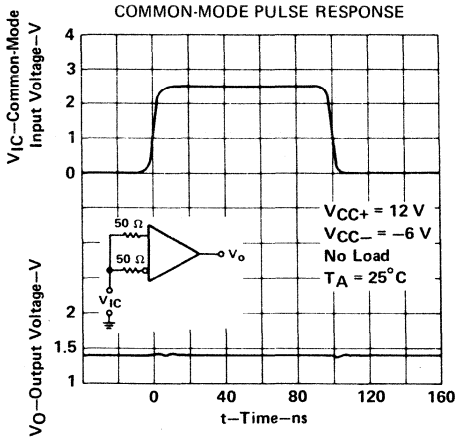


FIGURE 11

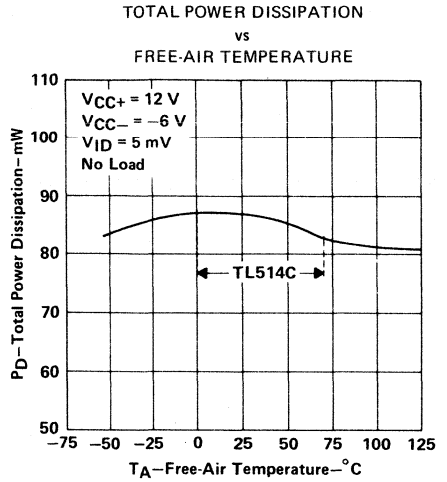


FIGURE 12

# 4

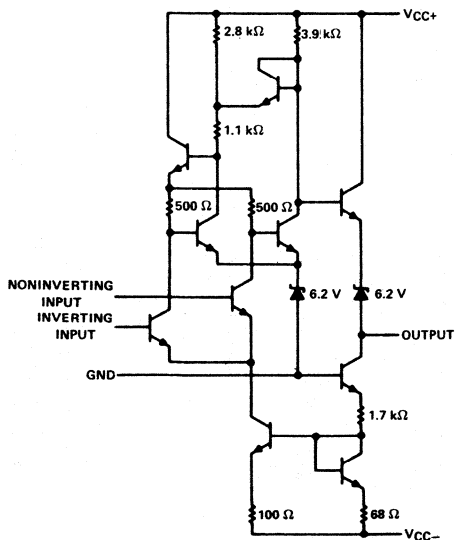
## Voltage Comparators

- Fast Response Times
- Low Offset Characteristics
- Output Compatible with Most TTL Circuits

**description**

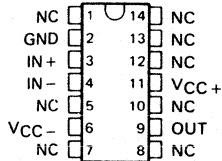
The TL710 is a monolithic high-speed comparator having differential inputs and a low-impedance output. Component matching, inherent in silicon integrated circuit fabrication techniques, produces a comparator with a low-drift and low-offset characteristics. These circuits are especially useful for applications requiring an amplitude discriminator, memory sense amplifier, or a high-speed voltage comparator. The TL710M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL710C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**schematic**

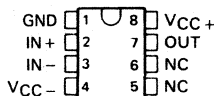


Component values shown are nominal.

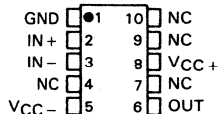
**J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



**JG OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)**

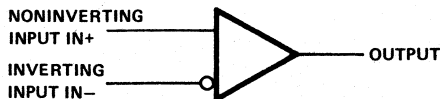


**U FLAT PACKAGE  
(TOP VIEW)**



NC—No internal connection

**symbol**



# TYPES TL710M, TL710C DIFFERENTIAL COMPARATORS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TL710M	TL710C	UNIT	
Supply voltage $V_{CC+}$ (see Note 1)	14	14	V	
Supply voltage $V_{CC-}$ (see Note 1)	-7	-7	V	
Differential input voltage (see Note 2)	$\pm 5$	$\pm 5$	V	
Input voltage (either input, see Note 1)	$\pm 7$	$\pm 7$	V	
Peak output current ( $t_w \leq 1$ s)	10	10	mA	
Continuous total power dissipation at (or below) 70°C free-air temperature (see Note 3)	300	300	mW	
Operating free-air temperature range	-55 to 125	0 to 70	°C	
Storage temperature range	-65 to 150	-65 to 150	°C	
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J, JG or U package	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	N or P package		260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. For operation of the TL710M above 70°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J and JG packages, TL710M chips are alloy-mounted; TL710C chips are glass-mounted.

electrical characteristics at specified free-air temperature.  $V_{CC+} = 12$  V,  $V_{CC-} = -6$  V

PARAMETER	TEST CONDITIONS <sup>†</sup>	TL710M			TL710C			UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$R_S \leq 200 \Omega$ , See Note 4	25°C	2	5	2	7.5	mV		
		Full range	6			10			
$\alpha_{VIO}$ Average temperature coefficient of input offset voltage	$R_S \leq 200 \Omega$ , See Note 4	Full range	5		7.5		$\mu\text{V}/^\circ\text{C}$		
$I_{IO}$ Input offset current	See Note 4	25°C	1	10	1	15	$\mu\text{A}$		
		Full range	20			25			
$I_{IB}$ Input bias current	See Note 4	25°C	25		25	100	$\mu\text{A}$		
		Full range	150			150			
$V_{ICR}$ Common-mode input voltage range	$V_{CC} = -7$ V	25°C	$\pm 5$		$\pm 5$		V		
$V_{ID}$ Differential input voltage range		25°C	$\pm 5$		$\pm 5$		V		
AVD Large-signal differential voltage amplification	No load, See Note 4	25°C	750	1500	700	1500	V/V		
		Full range	500			500			
$V_{OH}$ High-level output voltage	$V_{ID} = 15$ mV, $I_{OH} = -0.5$ mA	25°C	2.5	3.2	4	2.5	3.2	4	V
$V_{OL}$ Low-level output voltage	$V_{ID} = -15$ mV, $I_{OL} = 0$	25°C	-1	-0.5	0 <sup>‡</sup>	-1	-0.5	0 <sup>‡</sup>	V
$I_{OL}$ Low-level output current	$V_{ID} = -15$ mV, $V_O = 0$	25°C	1.6		2.5		mA		
$r_o$ Output resistance	$V_O = 1.4$ V	25°C	200			200		$\Omega$	
CMRR Common-mode rejection ratio	$R_S \leq 200 \Omega$	25°C	70	90	65	90	dB		
$I_{CC+}$ Supply current from $V_{CC+}$	$V_{ID} = -5$ V to 5 V (-10 mV for typ)	25°C	5.4		10.1		5.4	mA	
$I_{CC-}$ Supply current from $V_{CC-}$		25°C	-3.8		-8.9		-3.8	mA	
$P_D$ Total power dissipation		25°C	88	175	88		mW		

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL710M,  $V_O = 1.8$  V at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4$  V at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1$  V at  $T_A = 125^\circ\text{C}$ ; for TL710C,  $V_O = 1.5$  V at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4$  V at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1.2$  V at  $T_A = 70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

<sup>†</sup>Full range for TL710M is -55°C to 125°C and for TL710C is 0°C to 70°C.

<sup>‡</sup>The algebraic convention where the most-positive (least-negative) limit is designated as maximum is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.



# TYPES TL710M, TL710C DIFFERENTIAL COMPARATORS

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL710M	TL710C	UNIT
		TYP	TYP	
Response time	No load, See Note 5	40	40	ns

NOTE 5: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

## TYPICAL CHARACTERISTICS

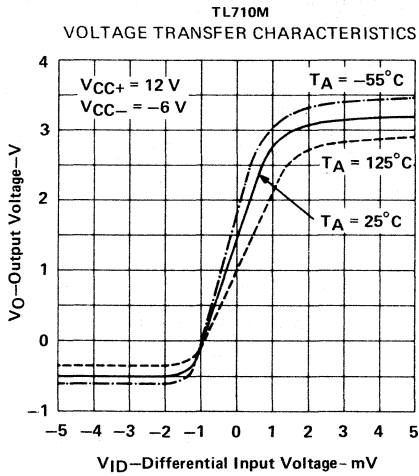


FIGURE 1

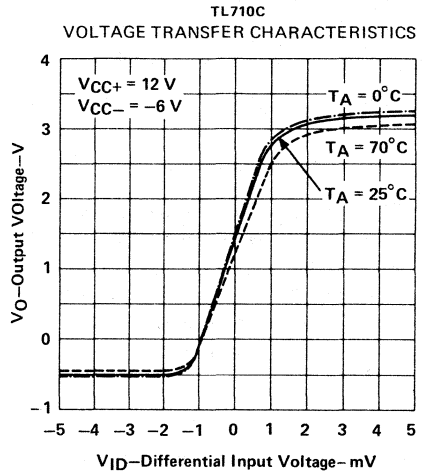


FIGURE 2

# TYPES TL710M, TL710C DIFFERENTIAL COMPARATORS

## TYPICAL CHARACTERISTICS

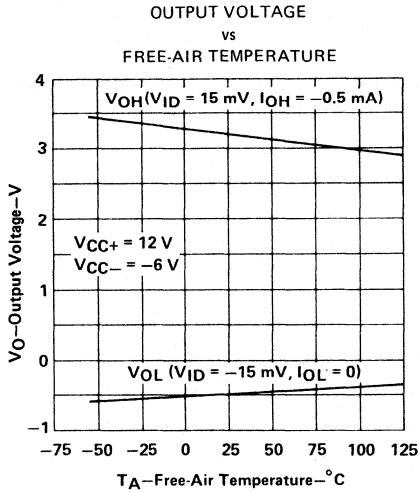


FIGURE 3

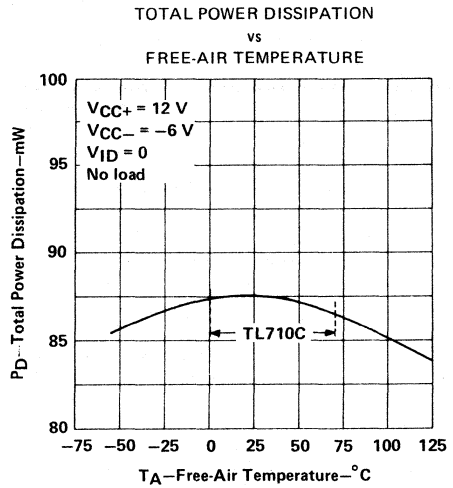


FIGURE 4

OUTPUT RESPONSE FOR VARIOUS  
INPUT OVERDRIVES

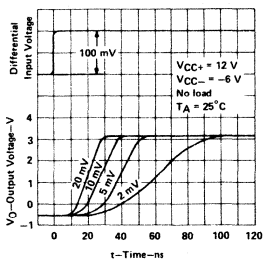


FIGURE 5

OUTPUT RESPONSE FOR VARIOUS  
INPUT OVERDRIVES

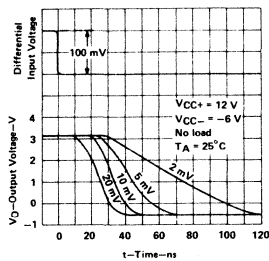


FIGURE 6

COMMON-MODE PULSE RESPONSE  
vs  
ELAPSED TIME

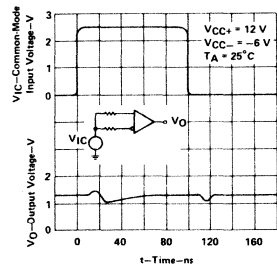


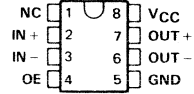
FIGURE 7

4

Voltage Comparators

- Operates from a Single 5-V Supply
- 0 to 5 V Common-Mode Input Voltage Range
- Self-Biased Inputs
- Complementary 3-State Outputs
- Enable Capability
- 5-mV Typical Hysteresis
- 25-ns Typical Response Times

JG OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



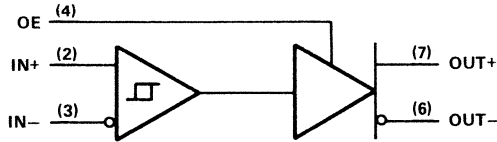
NC - No Internal connection

**description**

The TL712 is a single high-speed voltage comparator fabricated with bipolar Schottky process technology. The circuit has differential analog inputs and complementary 3-state TTL-compatible logic outputs with symmetrical switching characteristics. When the output enable, OE, is low, both outputs are in the high-impedance state. This device operates from a single 5-V supply and is useful as a disk memory read-chain data comparator.

The TL712 is characterized for operation from 0°C to 70°C.

**functional block diagram**



**PRODUCT PREVIEW**

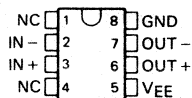
This page contains information on a product under development. Texas Instruments reserves the right to change or discontinue this product without notice.

# 4

## Voltage Comparators

- Operates From a Single  $-5.2\text{-V}$  Power Supply
- Self-Biased Inputs
- Common-Mode Input Voltage Range  
0 to  $-5.2\text{ V}$
- MECL III and MECL 10 000 Compatible
- Complementary ECL-Compatible Outputs
- Hysteresis . . .  $5\text{ mV Typ}$
- Response Times . . .  $10\text{ ns Typ}$

JG OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



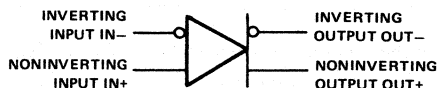
NC—No internal connection

**description**

The TL721 is a single high-speed voltage comparator fabricated with bipolar Schottky† process technology. The circuit has differential analog inputs and complementary ECL-compatible logic outputs with symmetrical switching characteristics. The device operates from a single  $-5.2\text{-volt}$  supply and is useful as a disk memory read-chain data comparator.

The TL721 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**symbol**



†Integrated Schottky-Barrier diode-clamped transistor is patented by Texas Instruments. U.S. Patent Number 3,463,975.

**PRODUCT PREVIEW**

This page contains information on a product under development. Texas Instruments reserves the right to change or discontinue this product without notice.

# TYPE TL721 DIFFERENTIAL COMPARATOR

electrical characteristics at  $T_A = 25^\circ\text{C}$ ,  $V_{EE} = -5.2\text{ V}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_T$	Threshold voltage ( $V_{T+}$ and $V_{T-}$ )	$-100^\dagger$		100	mV
$V_{T+} - V_{T-}$	Hysteresis		5	10	mV
$V_{OH}$	High-level output voltage	$V_{ID} = 100\text{ mV}$ , $R_L = 50\ \Omega$ to $-2\text{ V}$		$-0.81$	V
$V_{OL}$	Low-level output voltage	$V_{ID} = -100\text{ mV}$ , $R_L = 50\ \Omega$ to $-2\text{ V}$		$-1.65$	V
$V_{ICR}$	Common-mode input voltage range		0 to $-5.2$		V
$r_{in}$	Input resistance		4		k $\Omega$
$I_{EE}$	Supply current	$V_{ID} = 0$ , No load		$-13$ $-17$	mA

<sup>†</sup>The algebraic convention, where the more-negative limit is designated as minimum, is used in this data sheet for input threshold and output voltage levels only.

switching characteristics at  $T_A = 25^\circ\text{C}$ ,  $V_{EE} = -5.2\text{ V}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$	Propagation delay time, low-to-high-level output	$\Delta V_{ID} = +200\text{ mV}$ to $-200\text{ mV}$ or $-200\text{ mV}$ to $+200\text{ mV}$ , $R_L = 50\ \Omega$ to $-2\text{ V}$		12	ns
$t_{PHL}$	Propagation delay time, high-to-low-level output			12	ns

4

Voltage Comparators

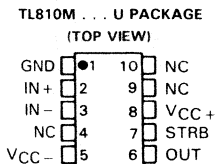
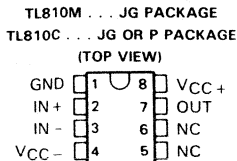
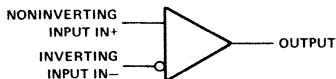
- Low Offset Characteristics
- High Differential Voltage Amplification
- Fast Response Times
- Output Compatible with Most TTL Circuits

**description**

The TL810 is an improved version of the TL710 high-speed voltage comparator with an extra stage added to increase voltage amplification and accuracy. Typical amplification is 33,000. Component matching, inherent in monolithic integrated circuit fabrication techniques, produces a comparator with low-drift and low-offset characteristics. These circuits are particularly useful for applications requiring an amplitude discriminator, memory sense amplifier, or a high-speed limit detector.

The TL810M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL810C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

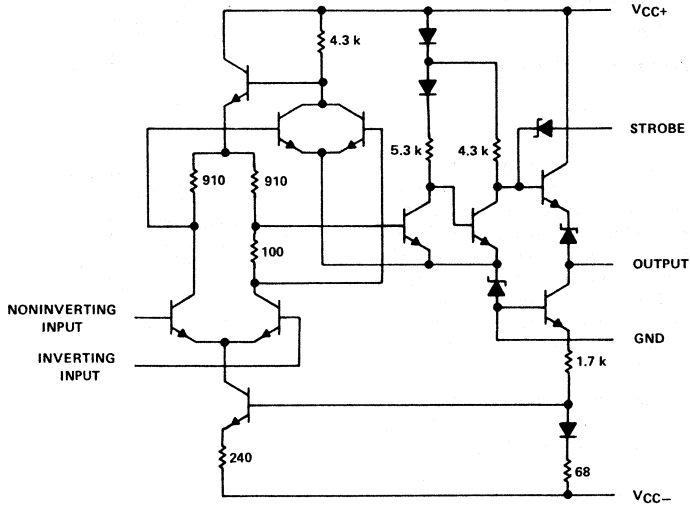
**symbol**



NC — No internal connection

# TYPES TL810M, TL810C DIFFERENTIAL COMPARATORS

schematic



Resistor values shown are nominal in ohms.

4 Voltage Comparators

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage $V_{CC+}$ (see Note 1)	14 V
Supply voltage $V_{CC-}$ (see Note 1)	-7 V
Differential input voltage (see Note 2)	$\pm 5$ V
Input voltage (either input, see Note 1)	$\pm 7$ V
Peak output current ( $t_w \leq 1$ s)	10 mA
Continuous total power dissipation at (or below) 70°C free-air temperature (see Note 3)	300 mW
Operating free-air temperature range: TL810M Circuits	-55°C to 125°C
TL810C Circuits	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or U package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: P package	260°C

- NOTES:
- All voltage values, except differential voltages, are with respect to the network ground terminal.
  - Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
  - For operation of the TL810M above 70°C free-air temperature, refer to dissipation Derating Curves, Section 2. In the JG package, TL810M chips are alloy-mounted; TL810C chips are glass-mounted.



# TYPES TL810M, TL810C DIFFERENTIAL COMPARATORS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		TL810M			TL810C			UNIT		
			MIN	TYP	MAX	MIN	TYP	MAX			
$V_{IO}$ Input offset voltage	$R_S \leq 200\ \Omega$ , See Note 4	25 °C	0.6		2	1.6		3.5	mV		
		Full range			3			4.5			
$\alpha_{VIO}$ Average temperature coefficient of input offset voltage	$R_S = 50\ \Omega$ , See Note 4	MIN to 25 °C	3		10	3		20	$\mu\text{V}/^\circ\text{C}$		
		25 °C to MAX	3		10	3		20			
$I_{IO}$ Input offset current	See Note 4	25 °C	0.75		3	1.8		5	$\mu\text{A}$		
		MIN	1.8		7	7.5					
		MAX	0.25		3	7.5					
$\alpha_{IIO}$ Average temperature coefficient of input offset current	See Note 4	MIN to 25 °C	15		75	24		100	nA/°C		
		25 °C to MAX	5		25	15		50			
$I_{IB}$ Input bias current	See Note 4	25 °C	7		15	7		20	$\mu\text{A}$		
		MIN	12		25	9		30			
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V}$	Full range	$\pm 5$			$\pm 5$		V			
$AVD$ Large-signal differential voltage amplification	No load, $V_O = 0$ to 2.5 V	25 °C	12.5	33		10	33		V/mV		
		Full range	10			8					
$V_{OH}$ High-level output voltage	$V_{ID} = 5\text{ mV}$ , $I_{OH} = 0$	Full range	4 $\S$		5	4 $\S$		5	V		
		$V_{ID} = 5\text{ mV}$ , $I_{OH} = -5\text{ mA}$	Full range	2.5	3.6 $\S$		2.5	3.6 $\S$			
$V_{OL}$ Low-level output voltage	$V_{ID} = -5\text{ mV}$ , $I_{OL} = 0$	Full range	-1	-0.5 $\S$		0 $\ddagger$	-1	-0.5 $\S$		0 $\ddagger$	V
$I_{OL}$ Low-level output current	$V_{ID} = -5\text{ mV}$ , $V_O = 0$	25 °C	2		2.4	1.6		2.4	mA		
		MIN	1		2.3	0.5		2.4			
		MAX	0.5		2.3	0.5		2.4			
$r_o$ Output resistance	$V_O = 1.4\text{ V}$	25 °C	200			200		$\Omega$			
CMRR Common-mode rejection ratio	$R_S \leq 200\ \Omega$	Full range	80	100 $\S$		70	100 $\S$		dB		
$I_{CC+}$ Supply current from $V_{CC+}$	$V_{ID} = -5\text{ mV}$ , No load	Full range	5.5 $\S$		9	5.5 $\S$		9	mA		
$I_{CC-}$ Supply current from $V_{CC-}$		Full range	-3.5 $\S$		-7	-3.5 $\S$		-7	mA		
$P_D$ Total power dissipation		Full range	90 $\S$		150	90 $\S$		150	mW		

<sup>†</sup>Full range (MIN to MAX) for TL810M is -55 °C to 125 °C and for the TL810C is 0 °C to 70 °C.

<sup>‡</sup>The algebraic convention, where the most-positive (least-negative) limit is designated as maximum, is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

<sup>§</sup>These typical values are at  $T_A = 25^\circ\text{C}$ .

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL810M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ ; for TL810C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $T_A = 70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS			MIN	TYP	MAX	UNIT
Response time	$R_L = \infty$ ,	$C_L = 5\text{ pF}$ ,	See Note 5		30	80	ns

NOTE 5: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

4  
Voltage Comparators

# TYPES TL810M, TL810C DIFFERENTIAL COMPARATORS

## TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
FREE-AIR TEMPERATURE

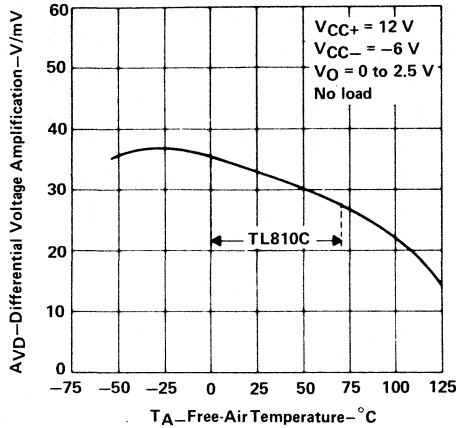


FIGURE 1

LARGE-SIGNAL DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
SUPPLY VOLTAGE

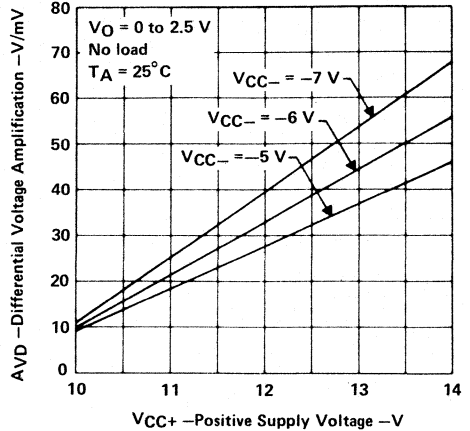


FIGURE 2

OUTPUT VOLTAGE LEVELS  
vs  
FREE-AIR TEMPERATURE

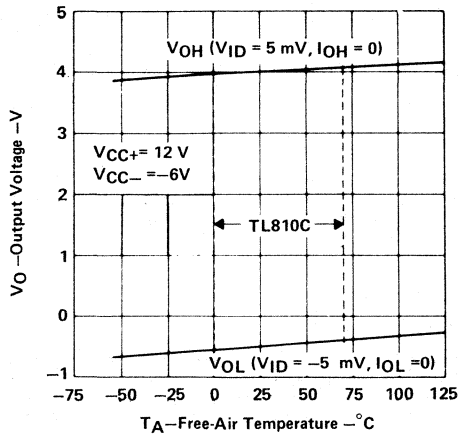


FIGURE 3

LOW-LEVEL OUTPUT CURRENT  
vs  
FREE-AIR TEMPERATURE

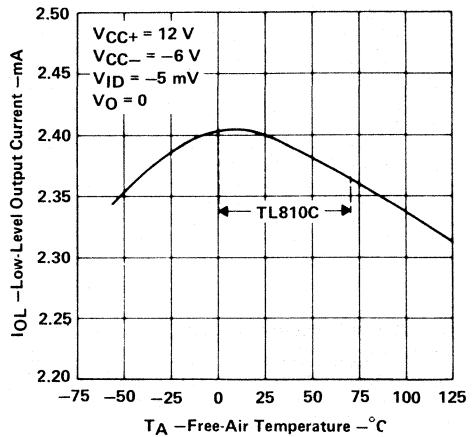
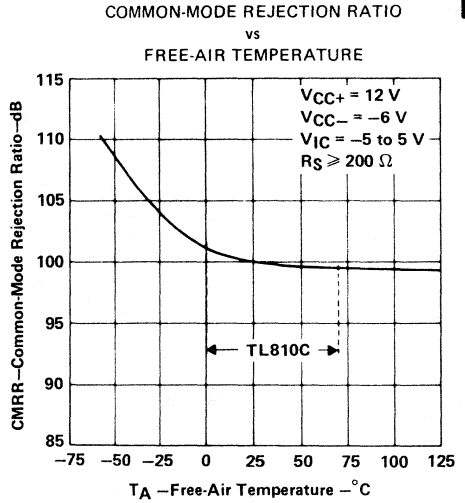
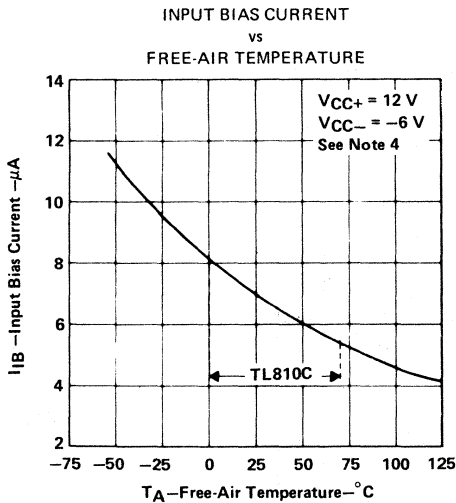
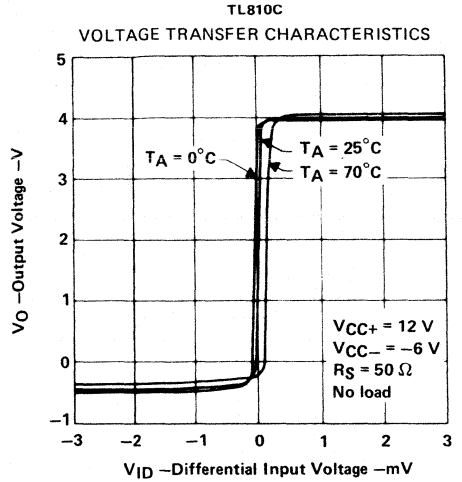
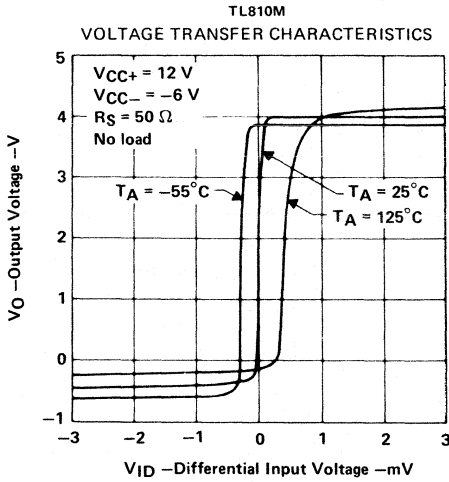


FIGURE 4

4

Voltage Comparators

TYPICAL CHARACTERISTICS



NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL810M,  $V_O = 1.8$  V at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4$  V at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1$  V at  $T_A = 125^\circ\text{C}$ ; for TL810C,  $V_O = 1.5$  V at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4$  V at  $25^\circ\text{C}$ , and  $V_O = 1.2$  V at  $T_A = 70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

4  
Voltage Comparators

# TYPES TL810M, TL810C DIFFERENTIAL COMPARATORS

## TYPICAL CHARACTERISTICS

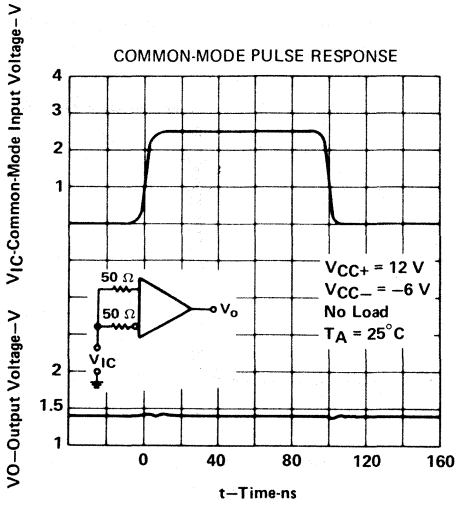


FIGURE 9

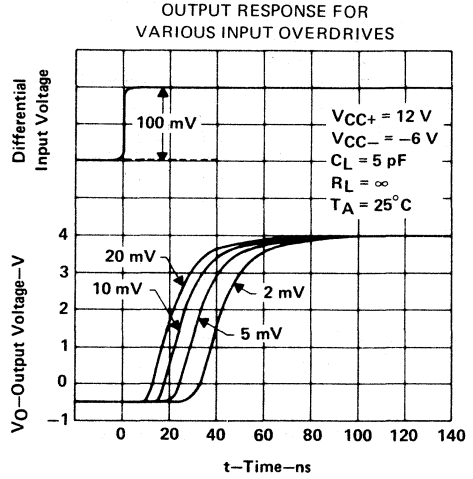


FIGURE 10

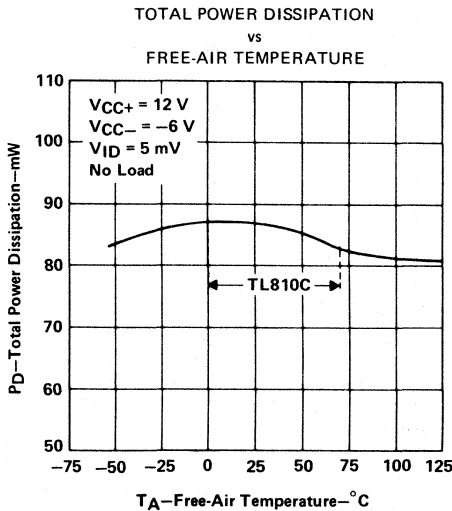


FIGURE 11

4

Voltage Comparators

- Fast Response Times
- Improved Voltage Amplification and Offset Characteristics
- Output Compatible with Most TTL Circuits

**description**

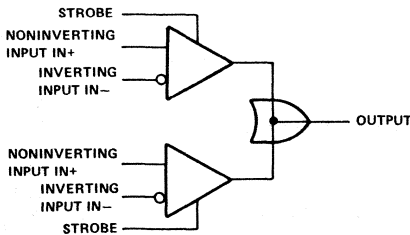
The TL811 is an improved version of the TL711 high-speed dual-channel voltage comparator. Voltage amplification is higher (typically 17,500) due to an extra stage, increasing the temperature accuracy. The output pulse width may be "stretched" by varying the capacitive loading.

Each channel has differential inputs, a strobe input, and an output in common with the other channel. When either strobe is taken low, it inhibits the associated channel. If both strobes are simultaneously low, the output will be low regardless of the conditions applied to the differential inputs.

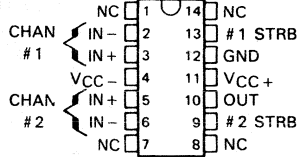
These dual-channel voltage comparators are particularly attractive for applications requiring an amplitude-discriminating sense amplifier with an adjustable threshold voltage.

The TL811M is characterized for operation over the full military range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL811C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

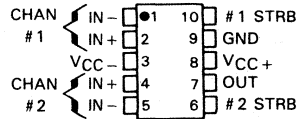
**functional block diagram**



TL811M . . . J DUAL-IN-LINE PACKAGE  
TL811C . . . J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



TL811M . . . U FLAT PACKAGE  
(TOP VIEW)



NC—No internal connection



## TYPES TL811M, TL811C DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	TL811M			TL811C			UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$V_{IC} = 0$ , See Note 4	25°C	1	3.5	1	5	mV		
		Full range	4.5		6				
	See Note 4	25°C	1	5	1	7.5			
		Full range	6		10				
$\alpha V_{IO}$ Average temperature coefficient of input offset voltage	$V_{IC} = 0$ , See Note 4	Full range	5		5		$\mu\text{V}/^\circ\text{C}$		
$I_{IO}$ Input offset current	See Note 4	25°C	0.5	3	0.5	5	$\mu\text{A}$		
		Full range	5		10				
$I_{IB}$ Input bias current	See Note 4	25°C	7	20	7	30	$\mu\text{A}$		
		Full range	30		50				
$I_{L(S)}$ Low-level strobe current	$V_{(strobe)} = -100\text{ mV}$	25°C	-1.2	-2.5	-1.2	-2.5	mA		
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V}$	25°C	±5		±5		V		
$V_{ID}$ Differential input voltage range		25°C	±5		±5		V		
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 0$ to 2.5 V, No load	25°C	12.5	17.5	10	17.5	V/mV		
		Full range	8		5				
$V_{OH}$ High-level output voltage	$V_{ID} = 10\text{ mV}$ , $I_{OH} = 0$	25°C	4	5	4	5	V		
	$V_{ID} = 10\text{ mV}$ , $I_{OH} = -5\text{ mA}$	25°C	2.5	3.6	2.5	3.6			
$V_{OL}$ Low-level output voltage	$V_{ID} = -10\text{ mV}$ , $I_{OL} = 0$	25°C	-1	-0.4	0 <sup>‡</sup>	-1	-0.4	0 <sup>‡</sup>	V
	$V_{ID} = 10\text{ mV}$ , $V_{(strobe)} = 0.3\text{ V}$ , $I_{OL} = 0$	25°C	-1	0 <sup>‡</sup>	1	0 <sup>‡</sup>			
$I_{OL}$ Low-level output current	$V_{ID} = -10\text{ mV}$ , $V_O = 0$	25°C	0.5	0.8	0.5	0.8	mA		
$r_O$ Output resistance	$V_O = 1.4\text{ V}$	25°C	200		200		$\Omega$		
CMRR Common-mode rejection ratio		25°C	70	90	65	90	dB		
$I_{CC+}$ Supply current from $V_{CC+}$	$V_{ID} = -5$ to 5 V (10 mV for typl).	25°C	6.5		6.5		mA		
$I_{CC-}$ Supply current from $V_{CC-}$		25°C	-2.7		-2.7		mA		
$P_D$ Total power dissipation	No load, See Note 5	25°C	94	150	94	200	mW		

<sup>†</sup> Unless otherwise noted, all characteristics are measured with the strobe of the channel under test open, the strobe of the other channel is grounded. Full range for TL811M is -55°C to 125°C and for the TL811C is 0°C to 70°C.

<sup>‡</sup> The algebraic convention, where the most-positive (least-negative) limit is designated as maximum, is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

NOTES: 4. These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL811M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ ; for TL811C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

5. The strobes are alternately grounded.

4

Voltage Comparators

# TYPES TL811M, TL811C

## DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL811M			TL811C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Response time	$R_L = \infty$ , $C_L = 5\text{ pF}$ , See Note 6		33	80		33		ns
Strobe release time	$R_L = \infty$ , $C_L = 5\text{ pF}$ , See Note 7		6	25		5		ns

NOTES: 6. The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

7. For testing purposes, the input bias conditions are selected to produce an output voltage of 1.4 V. A 5-mV overdrive is then added to the input bias voltage to produce an output voltage that rises above 1.4 V. The time interval is measured from the 50% point on the strobe voltage waveform to the instant when the overdriven output voltage crosses the 1.4-V level.

### TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
FREE-AIR TEMPERATURE

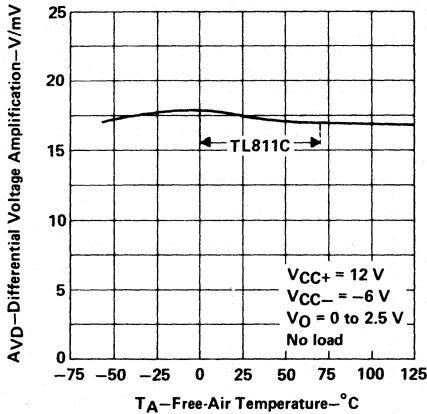


FIGURE 1

LARGE-SIGNAL DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
SUPPLY VOLTAGE

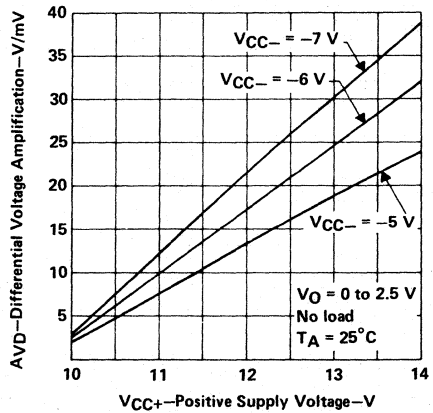


FIGURE 2



# TYPES TL811M, TL811C DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS

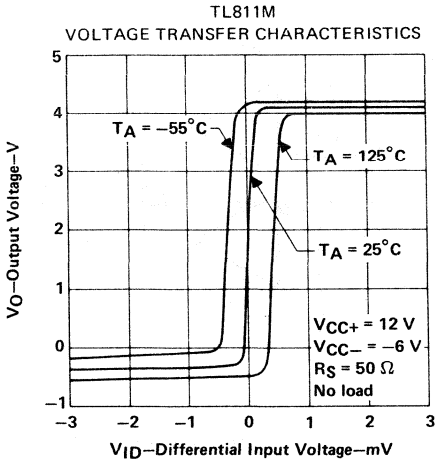


FIGURE 3

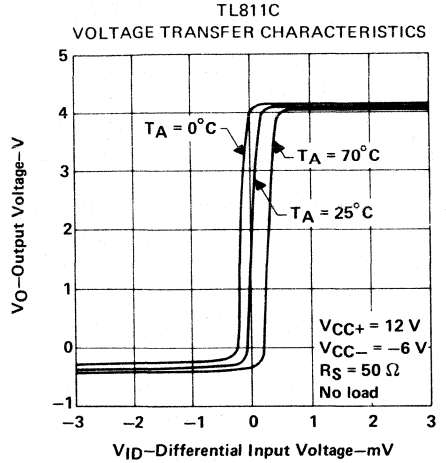


FIGURE 4

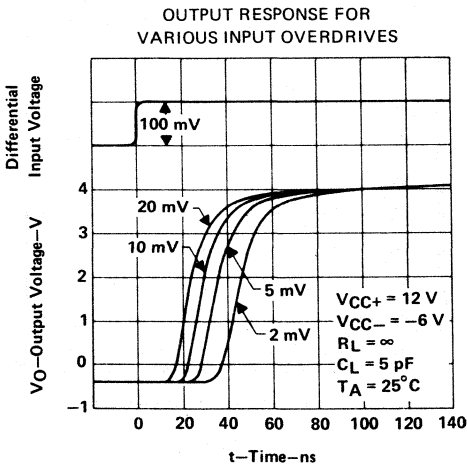


FIGURE 5

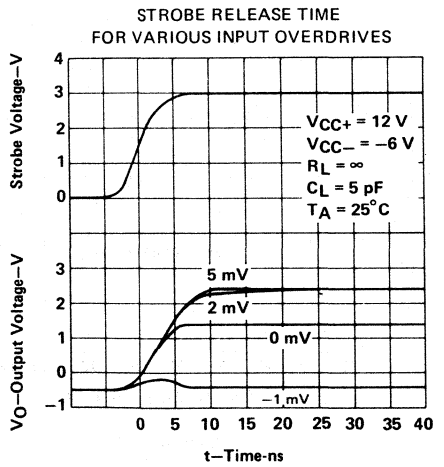


FIGURE 6

# TYPES TL811M, TL811C DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS

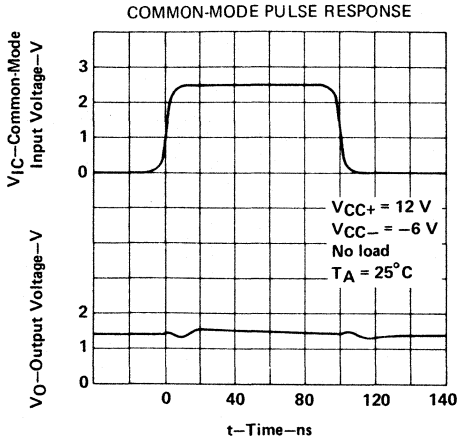
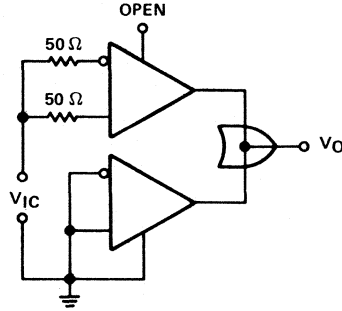


FIGURE 7



TEST CIRCUIT  
FOR FIGURE 7

### INPUT BIAS CURRENT vs FREE-AIR TEMPERATURE

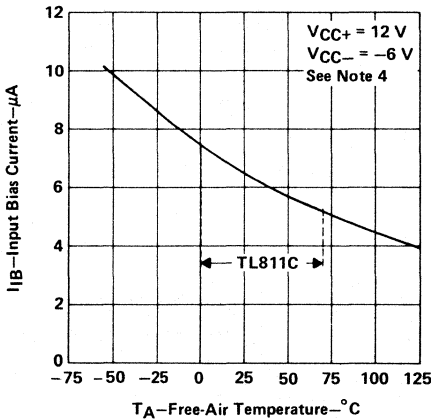


FIGURE 8

### TOTAL POWER DISSIPATED vs FREE-AIR TEMPERATURE

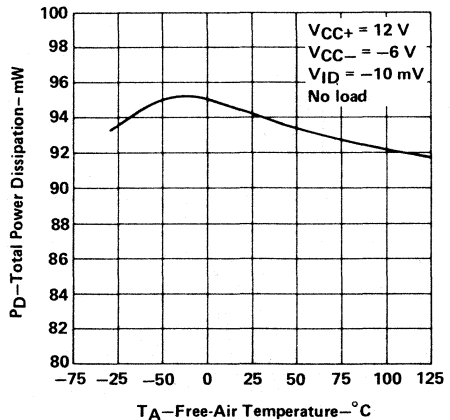


FIGURE 9

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL811M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ ; for TL811C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

4 Voltage Comparators

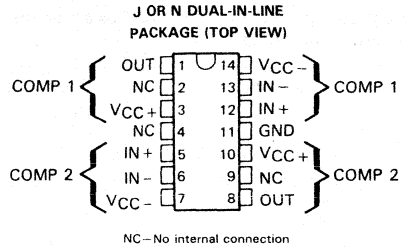
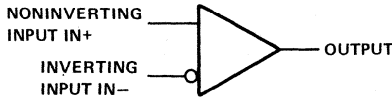
- Fast Response Times
- High Differential Voltage Amplification
- Low Offset Characteristics
- Outputs Compatible with Most TTL Circuits

**description**

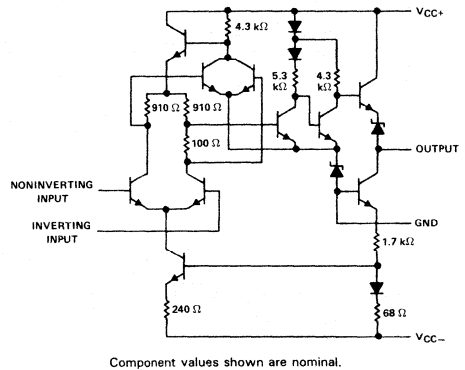
The TL820 is an improved version of the TL720 dual high-speed voltage comparator. Each comparator has differential inputs and a low-impedance output. When compared with the TL720, these circuits feature high amplification (typically 33,000) due to an extra amplification stage and increased accuracy because of lower offset characteristics. They are particularly useful in applications requiring an amplitude discriminator, memory sense amplifier, or a high-speed limit detector.

The TL820M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TL820C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**symbol (each comparator)**



**schematic (each comparator)**



**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage $V_{CC+}$ (see Note 1)	14 V
Supply voltage $V_{CC-}$ (see Note 1)	-7 V
Differential input voltage (see Note 2)	$\pm 5$ V
Input voltage (any input, see Note 1)	$\pm 7$ V
Peak output current ( $t_W \leq 1$ s)	10 mA
Continuous total power dissipation at (or below) $70^{\circ}\text{C}$ free-air temperature: each comparator	300 mW
total package (see Note 3)	600 mW
Operating free-air temperature range: TL820M Circuits	$-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$
TL820C Circuits	$0^{\circ}\text{C}$ to $70^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	$300^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N package	$260^{\circ}\text{C}$

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. For operation of the TL820M above  $70^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J package, TL820M chips are alloy-mounted, TL820C chips are glass-mounted.

**4**  
Voltage Comparators

# TYPES TL820M, TL820C DUAL DIFFERENTIAL COMPARATORS

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS†	TL820M			TL820C			UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$R_S < 200\ \Omega$ , See Note 4	25°C Full range	0.6	2	1.6	3.5	4.5	mV	
$\alpha_{VIO}$ Average temperature coefficient of input offset voltage	$R_S = 50\ \Omega$ , See Note 4	MIN to 25°C 25°C to MAX	3	10	3	20	20	$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$ Input offset current	See Note 4	25°C MIN MAX	0.75	3	1.8	5	7.5	$\mu\text{A}$	
$\alpha_{IIO}$ Average temperature coefficient of input offset current	See Note 4	MIN to 25°C 25°C to MAX	15	75	24	100	100	$\text{nA}/^\circ\text{C}$	
$I_{IB}$ Input bias current	See Note 4	25°C MIN	7	15	7	20	30	$\mu\text{A}$	
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V}$	Full range	$\pm 5$		$\pm 5$			V	
$V_{ID}$ Differential input voltage range		Full range	$\pm 5$		$\pm 5$			V	
$A_{VD}$ Large-signal differential voltage amplification	No load, $V_O = 0$ to 2.5 V	25°C Full range	12.5	33	10	33	8	V/mV	
$V_{OH}$ High-level output voltage	$V_{ID} = 5\text{ mV}$ $I_{OH} = 0$	Full range	4§ 5		4§ 5			V	
	$V_{ID} = 5\text{ mV}$ , $I_{OH} = -5\text{ mA}$	Full range	2.5	3.6§	2.5	3.6§			
$V_{OL}$ Low-level output voltage	$V_{ID} = -5\text{ mV}$ , $I_{OL} = 0$	Full range	-1	-0.5§	0‡	-1	-0.5§	0‡	V
$I_{OL}$ Low-level output current	$V_{ID} = -5\text{ mV}$ , $V_O = 0$	25°C MIN MAX	2	2.4	1.6	2.4	2.4	2.4	mA
$r_o$ Output resistance	$V_O = 1.4\text{ V}$	25°C	200		200			$\Omega$	
CMRR Common-mode rejection ratio	$R_S < 200\ \Omega$	Full range	80	100§	70	100§		dB	
$I_{CC+}$ Supply current from $V_{CC+}$ (each comparator)	$V_{ID} = -5\text{ mV}$ , No load	Full range	5.5§ 9		5.5§ 9			mA	
$I_{CC-}$ Supply current from $V_{CC-}$ (each comparator)		Full range	-3.5§ -7		-3.5§ -7			mA	
$P_D$ Total power dissipation (each comparator)		Full range	90§	150	90§	150		mW	

†Full range (MIN to MAX) for TL820M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for the TL820C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

‡The algebraic convention where the most-positive (least-negative) limit is designated as maximum is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

§These typical values are at  $T_A = 25^\circ\text{C}$ .

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL820M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ ; for TL820C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $T_A = 70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

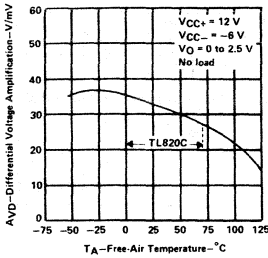
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Response time	$R_L = \infty$ , $C_L = 5\text{ pF}$ See Note 5		30	80	ns

NOTE 5: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

4 Voltage Comparators

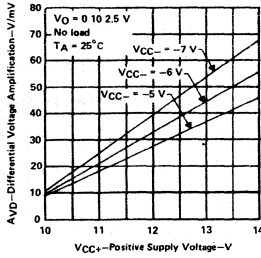
**TYPICAL CHARACTERISTICS**

**LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION**  
VS  
**FREE-AIR TEMPERATURE**



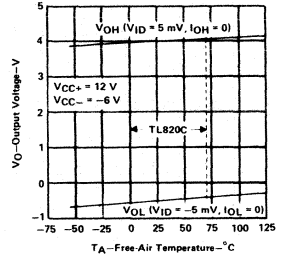
**FIGURE 1**

**LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION**  
VS  
**SUPPLY VOLTAGE**



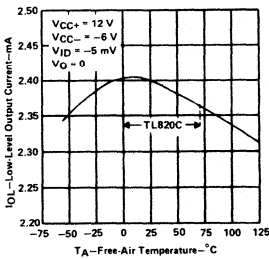
**FIGURE 2**

**OUTPUT VOLTAGE LEVELS**  
VS  
**FREE-AIR TEMPERATURE**



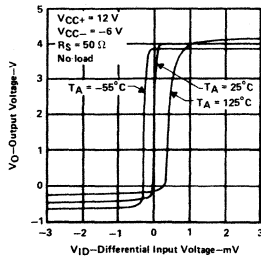
**FIGURE 3**

**LOW-LEVEL OUTPUT CURRENT**  
VS  
**FREE-AIR TEMPERATURE**



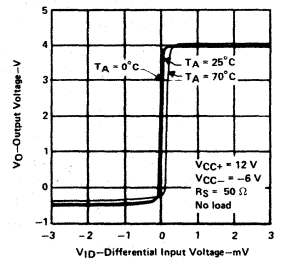
**FIGURE 4**

**TL820M**  
**VOLTAGE TRANSFER CHARACTERISTICS**



**FIGURE 5**

**TL820C**  
**VOLTAGE TRANSFER CHARACTERISTICS**



**FIGURE 6**

# TYPES TL820M, TL820C DUAL DIFFERENTIAL COMPARATORS

## TYPICAL CHARACTERISTICS

INPUT BIAS CURRENT  
VS  
FREE-AIR TEMPERATURE

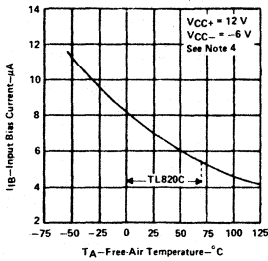


FIGURE 7

COMMON-MODE REJECTION RATIO  
VS  
FREE-AIR TEMPERATURE

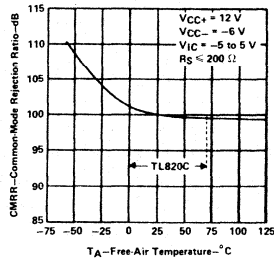


FIGURE 8

COMMON-MODE PULSE RESPONSE

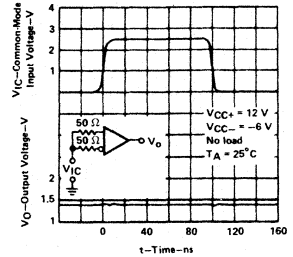


FIGURE 9

OUTPUT RESPONSE FOR  
VARIOUS INPUT OVERDRIVES

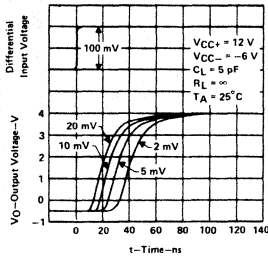


FIGURE 10

TOTAL POWER DISSIPATION  
VS  
FREE-AIR TEMPERATURE

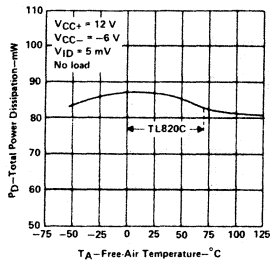


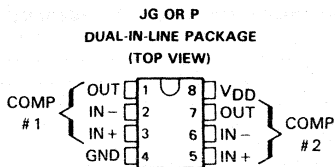
FIGURE 11

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for TL820M,  $V_O = 1.8$  V at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4$  V at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1$  V at  $T_A = 125^\circ\text{C}$ ; for TL820C,  $V_O = 1.5$  V at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4$  V at  $25^\circ\text{C}$ , and  $V_O = 1.2$  V at  $T_A = 70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

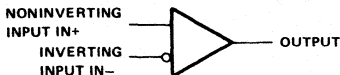
4

Voltage Comparators

- Single- or Dual-Supply Operation
- Wide Range of Supply Voltages  
2 to 18 Volts
- Very Low Supply Current Drain  
0.2 mA Typ
- Fast Response Time . . . 200 ns Typ for  
TTL-Level Input Step
- Built-In ESD Protection
- High Input Impedance . . .  $10^{12} \Omega$  Typ
- Extremely Low Input Bias Current  
1 pA Typ
- Ultra-Stable Low Input Offset Voltage
- Common-Mode Input Voltage Range  
Includes Ground
- Output Compatible with TTL, MOS, and  
CMOS



symbol (each comparator)



**description**

This device is fabricated using LinCMOST™ technology and consists of two independent voltage comparators designed to operate from a single power supply. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 to 18 volts. Each of these devices features extremely high input impedance (typically greater than  $10^{12}$  ohms) allowing direct interfacing with high-impedance sources. The outputs are n-channel open-drain configurations, and can be connected to achieve positive-logic wired-AND relationships.

These devices have internal electrostatic discharge (ESD) protection circuits that will prevent catastrophic failures at voltages up to 2000 volts as tested under MIL-STD-883B, Method 3015.1. However, care should be exercised in handling these devices as exposure to ESD may result in a degradation of the device parametric performance.

The TLC372M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The TLC372C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

# TYPES TLC372M, TLC372C

## DUAL LinCMOS™ DIFFERENTIAL COMPARATORS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TLC374M	TLC374C	UNIT
Supply voltage, $V_{DD}$ (see Note 1)	18	18	V
Differential input voltage (see Note 2)	$\pm 18$	$\pm 18$	V
Input voltage, $V_I$	18	18	V
Output voltage, $V_O$	18	18	V
Output current, $I_O$	20	20	mA
Duration of output short-circuit to ground (see Note 3)	unlimited	unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	500	500	mW
Operating free-air temperature range	-55 to 125	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	JG package	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or P package	260	°C

NOTES: 1. All voltage values, except differential voltages, are with respect to network ground terminal.

2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.

3. Short circuits from outputs to  $V_{DD}$  can cause excessive heating and eventual destruction.

4. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J package, TLC374C chips are glass mounted and TLC374M chips are alloy mounted.

electrical characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		TLC372M			TLC372C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{IC} = V_{ICR}$ min, See Note 5	25°C	2	10		2	10	mV	
		Full range		12			12		
$I_{IO}$ Input offset current	See Note 5	25°C		1			1	pA	
		Full range		10			0.3	nA	
$I_{IB}$ Input bias current		25°C		1				pA	
		Full range		20			0.6	nA	
$V_{ICR}$ Common-mode input voltage range		25°C	0 to $V_{CC}-1.5$			0 to $V_{CC}-1.5$		V	
		Full range	0 to $V_{CC}-2$			0 to $V_{CC}-2$			
$A_{VD}$ Large-signal differential voltage amplification	$V_{DD} = 15\text{ V}$ , $R_L \geq 15\text{ k}\Omega$ to $V_{DD}$	25°C		200			200	v/mV	
$I_{OH}$ High-level output current	$V_{ID} = 1\text{ V}$ , $V_{OH} = 5\text{ V}$	25°C		0.1			0.1	nA	
		Full range			1			1	$\mu\text{A}$
$V_{OL}$ Low-level output voltage	$V_{ID} = -1\text{ V}$ , $I_{OL} 4\text{ mA}$	25°C		150	400		150	400	mV
		Full range			700			700	
$I_{OL}$ Low-level output current	$V_{ID} = -1\text{ V}$ , $V_{OL} = 1.5\text{ V}$	25°C	6	16		6	16	mA	
$I_{DD}$ Supply current (two comparators)	$V_{ID} = 1\text{ V}$ , No load	25°C		0.2			0.2	mA	

†All characteristics are measured with zero common-mode input voltage unless otherwise specified.

NOTE 5: The offset voltages and offset currents given are the maximum values required to drive the output up to 4 V or down to 400 mV with a pull-up resistor of 2.5 k $\Omega$  to  $V_{DD}$ . Thus, these parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance. Full range for  $T_A$  is -55°C to 125°C for TLC372M, 0°C to 70°C for TLC372C.

switching characteristics,  $V_{DD} = 5\text{ V}$ ,  $T_A = 25\text{ }^\circ\text{C}$

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	$R_L$ connected to 5 V through 5.1 k $\Omega$ , $C_L = 15\text{ pF}$ †, See Note 6	100-mV input step with 5-mV overdrive		650		ns
		TTL-level input step		200		

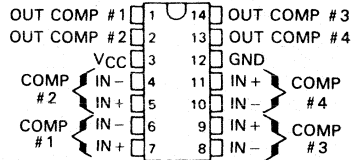
† $C_L$  includes probe and jig capacitance.

NOTE 6: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

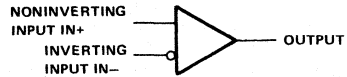


- Single- or Dual-Supply Operation
- Wide Range of Supply Voltages  
2 to 18 volts
- Very Low Supply Current Drain  
0.4 mA Typ
- Fast Response Time . . . 200 ns Typ for  
TTL-Level Input Step
- Built-In ESD Protection
- High Input Impedance . . . 10<sup>12</sup> Ω Typ
- Extremely Low Input Bias Current  
1 pA Typ
- Ultra-Stable Low Input Offset Voltage
- Common-Mode Input Voltage Range  
Includes Ground
- Output Compatible with TTL, MOS, and  
CMOS

TLC374M . . . J DUAL-IN-LINE PACKAGE  
TLC374C . . . D, J, OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



symbol (each comparator)



**description**

This device is fabricated using LinCMOST™ technology and consists of four independent voltage comparators designed to operate from a single power supply. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 to 18 volts. Each of these devices features extremely high input impedance (typically greater than 10<sup>12</sup> ohms) allowing direct interfacing with high-impedance sources. The outputs are n-channel open-drain configurations, and can be connected to achieve positive-logic wired-AND relationships. The TLC374C is designed as a pin-compatible, functional replacement for the LM339, offering twice the speed while consuming typically one-half of the power.

These devices have internal electrostatic discharge (ESD) protection circuits that will prevent catastrophic failures at voltages up to 2000 volts as tested under MIL-STD-883B, Method 3015.1. However, care should be exercised in handling these devices as exposure to ESD may result in a degradation of the device parametric performance.

The TLC374M is characterized for operation over the full military temperature range of -55°C to 125°C. The TLC374C is characterized for operation from 0°C to 70°C

# TYPES TLC374M, TLC374C

## QUADRUPLE LinCMOS™ DIFFERENTIAL COMPARATORS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TLC374M	TLC374C	UNIT
Supply voltage (see Note 1)	18	18	V
Differential input voltage (see Note 2)	± 18	± 18	V
Input voltage, $V_I$	18	18	V
Output voltage, $V_O$	18	18	V
Output current, $I_O$	20	20	mA
Duration of output short-circuit to ground (see Note 3)	unlimited	unlimited	
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 4)	500	500	mW
Operating free-air temperature range	-55 to 125	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	JG package	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D or P package	260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.  
 4. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J package, TLC374C chips are glass mounted and TLC374M chips are alloy mounted.

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	TLC374M			TLC374C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$V_{IC} = V_{ICR}$ min, See Note 5	25°C	2	10	2	10		mV
		Full range		12		12		
$I_{IO}$ Input offset current	See Note 5	25°C		1		1		pA
		Full range		10		0.3		
$I_{IB}$ Input bias current		25°C		1		1		pA
		Full range		20		0.6		
$V_{ICR}$ Common-mode input voltage range		25°C	0 to $V_{CC} - 1.5$		0 to $V_{CC} - 1.5$			V
		Full range	0 to $V_{CC} - 2$		0 to $V_{CC} - 2$			
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$ , $R_L \geq 15\text{ k}\Omega$ to $V_{CC}$	25°C		200		200		v/mV
$I_{OH}$ High-level output current	$V_{ID} = 1\text{ V}$ , $V_{OH} = 15\text{ V}$	25°C		0.1		0.1		nA
		Full range		1		1		
$V_{OL}$ Low-level output voltage	$V_{ID} = -1\text{ V}$ , $I_{OL} = 4\text{ mA}$	25°C		150	400	150	400	mV
		Full range			700		700	
$I_{OL}$ Low-level output current	$V_{ID} = -1\text{ V}$ , $V_{OL} = 1.5\text{ V}$	25°C	6	16	6	16		mA
$I_{CC}$ Supply current (four comparators)	$V_{ID} = -1\text{ V}$ , No load	25°C		0.4	1	0.4	1	mA

<sup>†</sup>All characteristics are measured with zero common-mode input voltage unless otherwise specified.

NOTE 5: The offset voltages and offset currents given are the maximum values required to drive the output up to 4 V or down to 400 mV with a pull-up resistor of 2.5 k $\Omega$  to  $V_{CC}$ . Thus, these parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance. Full range for  $T_A$  is -55°C to 125°C for TLC374M, 0°C to 70°C for TLC374C.

switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Response time	$R_L$ connected to 5 V through 5.1 k $\Omega$ , $C_L = 15\text{ pF}$ , See Note 6			0.9	$\mu\text{s}$
				0.2	

<sup>†</sup> $C_L$  includes probe and jig capacitance.

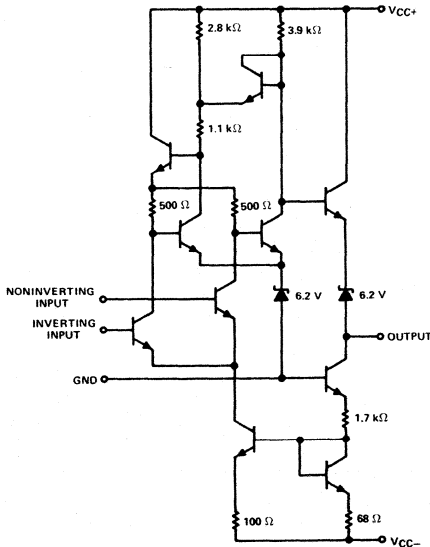
NOTE 6: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

- **Fast Response Times**
- **Low Offset Characteristics**
- **Output Compatible with Most TTL Circuits**
- **Designed to be Interchangeable with Fairchild  $\mu$ A710**

**description**

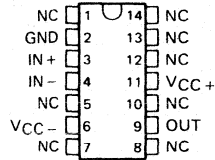
The  $\mu$ A710 is a monolithic high-speed comparator having differential inputs and a low-impedance output. Component matching, inherent in silicon integrated circuit fabrication techniques, produces a comparator with low-drift and low-offset characteristics. This circuit is especially useful for applications requiring an amplitude discriminator, memory sense amplifier, or a high-speed voltage comparator. The  $\mu$ A710M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

**schematic**

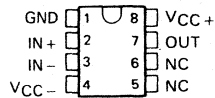


Component values shown are nominal.

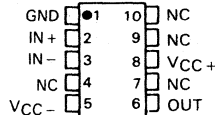
**J DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



**JG DUAL-IN-LINE PACKAGE  
(TOP VIEW)**

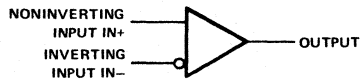


**U FLAT PACKAGE  
(TOP VIEW)**



NC—No internal connection

**symbol**



# TYPE $\mu$ A710M

## DIFFERENTIAL COMPARATOR

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage $V_{CC+}$ (see Note 1)	14 V
Supply voltage $V_{CC-}$ (see Note 1)	-7 V
Differential input voltage (see Note 2)	$\pm 5$ V
Input voltage at either input (see Note 1)	$\pm 7$ V
Peak output current ( $t_W \leq 1$ s)	10 mA
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 3)	300 mW
Operating free-air temperature range	-55°C to 125°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	300°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. For operation above 25°C free-air temperature, refer to the Dissipation Derating Curves in Section 2. In the J and JG packages,  $\mu$ A710M chips are alloy mounted.

### electrical characteristics at specified free-air temperature, $V_{CC+} = 12$ V, $V_{CC-} = -6$ V (unless otherwise noted)

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT	
$V_{IO}$	Input offset voltage	$R_S \leq 200 \Omega$ ,	See Note 4	25°C	0.6	2	mV	
				Full range		3		
$\alpha V_{IO}$	Average temperature coefficient of input offset voltage	$R_S \leq 50 \Omega$ ,	See Note 4	Full range	3	10	$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$	Input offset current	See Note 4	See Note 4	25°C	0.75	3	$\mu\text{A}$	
				Full range		7		
$\alpha I_{IO}$	Average temperature coefficient of input offset current	See Note 4	See Note 4	-55°C to 25°C	5	25	$\text{nA}/^\circ\text{C}$	
				25°C to 125°C	15	75		
				25°C	13	20		
$I_{IB}$	Input bias current	See Note 4	See Note 4	25°C		45	$\mu\text{A}$	
				Full range				
$V_{ICR}$	Common-mode input voltage range	$V_{CC-} = -7$ V		25°C	+5		V	
$V_{ID}$	Differential input voltage range			25°C	+5		V	
$A_{VD}$	Large-signal differential voltage amplification	No load,	See Note 4	25°C	1250	1700		
				Full range	1000			
$V_{OH}$	High-level output voltage	$V_{ID} = 5$ mV,	$I_{OH} = -5$ mA	25°C	2.5	3.2	4	V
$V_{OL}$	Low-level output voltage	$V_{ID} = -5$ mV,	$I_{OL} = 0$	25°C	-1	-0.5	6‡	V
$I_{OL}$	Low-level output current	$V_{ID} = -5$ mV,	$V_O = 0$	25°C	2	2.5	mA	
				-55°C	1	2.3		
				125°C	0.5	1.7		
$r_o$	Output resistance	$V_O = 1.4$ V		25°C		200	$\Omega$	
CMRR	Common-mode rejection ratio	$R_S \leq 200 \Omega$		25°C	80	100	dB	
$I_{CC+}$	Supply current from $V_{CC+}$	$V_{ID} = -5$ V to 5 V (-10 mV for typ),		25°C	5.2	9	mA	
$I_{CC-}$	Supply current from $V_{CC-}$			25°C	-4.6	-7	mA	
$P_D$	Total power dissipation	No load		25°C	90	150	mW	

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels:  $V_O = 1.8$  V at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4$  V at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1$  V at  $T_A = 125^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

† Full range for  $\mu$ A710M is -55°C to 125°C.

‡ The algebraic convention where the more-positive (less-negative) limit is designated as maximum is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

4

Voltage Comparators

# TYPE $\mu A710M$ DIFFERENTIAL COMPARATOR

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS		TYP	UNIT
Response time	No load,	See Note 5	40	ns

NOTE 5: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

## TYPICAL CHARACTERISTICS

OUTPUT RESPONSE FOR VARIOUS  
INPUT OVERDRIVES

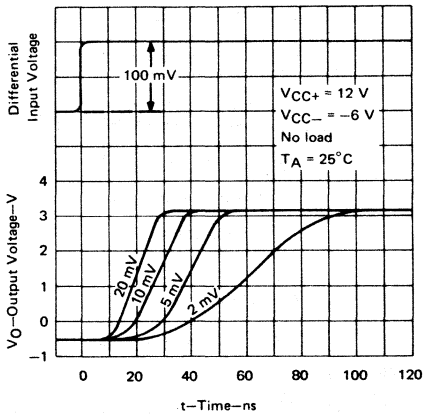


FIGURE 1

OUTPUT RESPONSE FOR VARIOUS  
INPUT OVERDRIVES

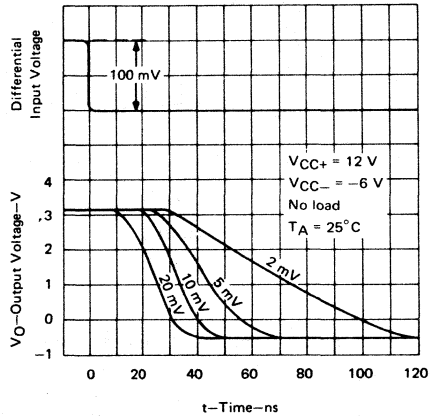


FIGURE 2

# TYPE $\mu$ A710M DIFFERENTIAL COMPARATOR

## TYPICAL CHARACTERISTICS

COMMON-MODE PULSE RESPONSE  
vs  
ELAPSED TIME

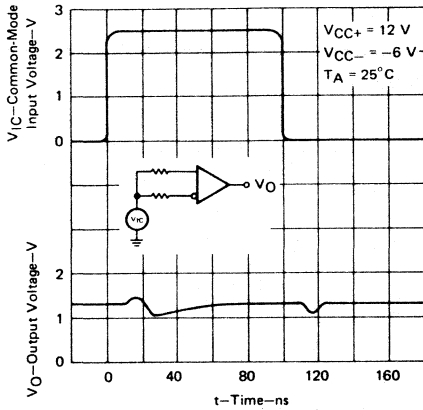


FIGURE 3

OUTPUT VOLTAGE  
vs  
FREE-AIR TEMPERATURE

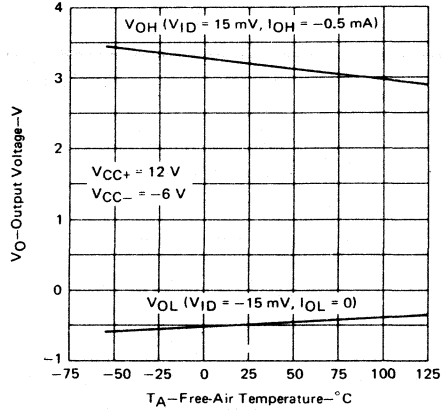


FIGURE 4

VOLTAGE TRANSFER CHARACTERISTICS

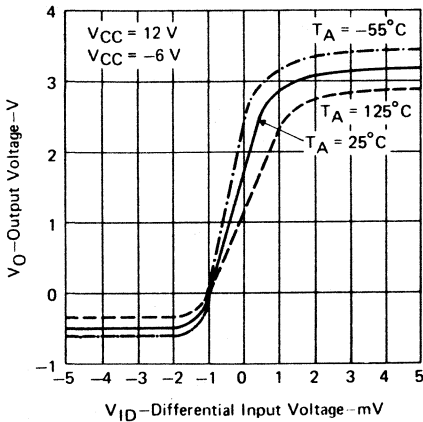


FIGURE 5

TOTAL POWER DISSIPATION  
vs  
FREE-AIR TEMPERATURE

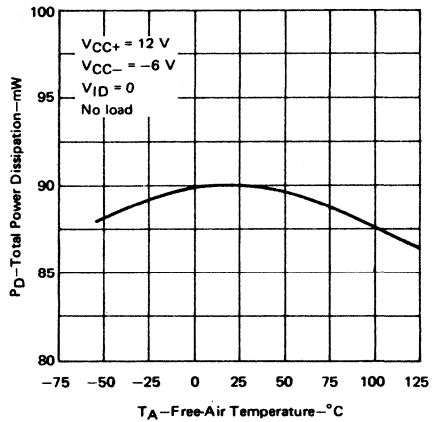


FIGURE 6

4

Voltage Comparators

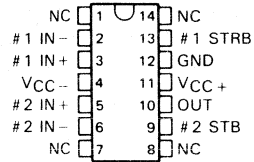
- Fast Response Times
- Low Offset Characteristics
- Output Compatible with Most TTL Circuits
- Designed to be Interchangeable with Fairchild  $\mu$ A711 and  $\mu$ A711C

**description**

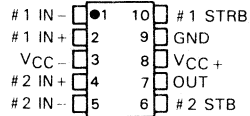
The  $\mu$ A711 is a high-speed dual-channel comparator with differential inputs and a low-impedance output. Component matching, inherent with silicon monolithic circuit fabrication techniques, produces a comparator circuit with low-drift and low-offset characteristics. An independent strobe input is provided for each of the two channels, which when taken low, inhibits the associated channel. If both strobes are simultaneously low, the output will be low regardless of the conditions applied to the differential inputs. The comparator output pulse duration can be "stretched" by varying the capacitive loading. These dual comparators are particularly useful for applications requiring an amplitude-discriminating sense amplifier with an adjustable threshold voltage.

The  $\mu$ A711M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the  $\mu$ A711C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)**

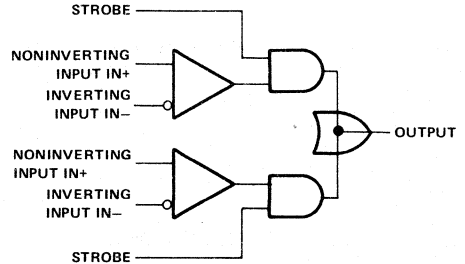


**U FLAT PACKAGE  
(TOP VIEW)**



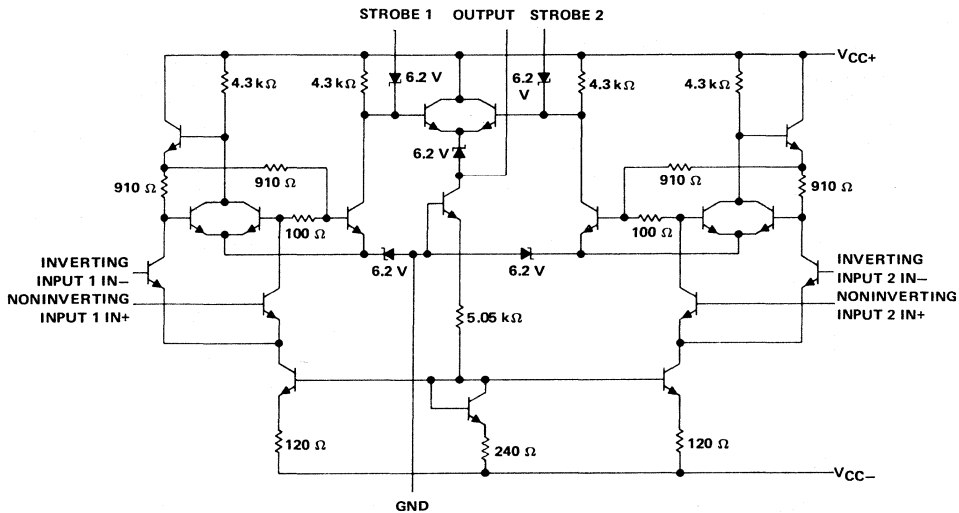
NC - No internal connection

**functional block diagram**



# TYPES $\mu A711M$ , $\mu A711C$ DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

schematic



Component values shown are nominal.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	$\mu A711M$	$\mu A711C$	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	14	14	V
Supply voltage $V_{CC-}$ (see Note 1)	-7	-7	V
Differential input voltage (see Note 2)	$\pm 5$	$\pm 5$	V
Input voltage (any input, see Note 1)	$\pm 7$	$\pm 7$	V
Strobe voltage (see Note 1)	6	6	V
Peak output current ( $t_w \leq 1$ s)	50	50	mA
Continuous total power dissipation at (or below) 70°C free-air temperature (see Note 3)	300	300	mW
Operating free-air temperature range	-55 to 125	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds   J or U package	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds   N package		260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.  
 3. For operation of  $\mu A711M$  above 70°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J package,  $\mu A711M$  chips are alloy mounted,  $\mu A711C$  chips are glass mounted.

4

Voltage Comparators



# TYPES $\mu$ A711M, $\mu$ A711C DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

electrical characteristics at specified free-air temperature,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	$\mu$ A711M			$\mu$ A711C			UNIT	
		MIN	TYP	MAX	MIN	TYP	MAX		
$V_{IO}$ Input offset voltage	$R_S \leq 200\ \Omega$ , $V_{IC} = 0$ , See Note 4	25°C	1	3.5	1	5	mV		
		Full range	4.5			6			
	$R_S \leq 200\ \Omega$ , See Note 4	25°C	1	5	1	7.5			
		Full range	6			10			
$\alpha V_{IO}$ Average temperature coefficient of input offset voltage	$R_S \leq 200\ \Omega$ , $V_{IC} = 0$ , See Note 4	Full range	5			5	$\mu\text{V}/^\circ\text{C}$		
$I_{IO}$ Input offset current	See Note 4	25°C	0.5	10	0.5	15	$\mu\text{A}$		
		Full range	20			25			
$I_{IB}$ Input bias current	See Note 4	25°C	25	75	25	100	$\mu\text{A}$		
		Full range	150			150			
$I_{IL(S)}$ Low-level strobe current	$V(\text{strobe}) = 0$ , $V_{ID} = 10\text{ mV}$	25°C	-1.2	-2.5	-1.2	-2.5	mA		
$V_{ICR}$ Common-mode input voltage range	$V_{CC-} = -7\text{ V}$	25°C	$\pm 5$		$\pm 5$		V		
$V_{ID}$ Differential input voltage range		25°C	$\pm 5$		$\pm 5$		V		
$A_{VD}$ Large-signal differential voltage amplification	No load, $V_O = 0$ to $2.5\text{ V}$	25°C	750	1500	700	1500			
		Full range	500			500			
$V_{OH}$ High-level output voltage	$V_{ID} = 10\text{ mV}$ , $I_{OH} = 0$ $V_{ID} = 10\text{ mV}$ , $I_{OH} = -5\text{ mA}$	25°C	4.5	5	4.5	5	V		
		25°C	2.5	3.5	2.5	3.5			
$V_{OL}$ Low-level output voltage	$V_{ID} = -10\text{ mV}$ , $I_{OL} = 0$ $V_{ID} = 10\text{ mV}$ , $V(\text{strobe}) = 0.3\text{ V}$ , $I_{OL} = 0$	25°C	-1	-0.5	0 $\ddagger$	-1	-0.5	0 $\ddagger$	V
		25°C	-1	0 $\ddagger$	-1	0 $\ddagger$			
$I_{OL}$ Low-level output current	$V_{ID} = -10\text{ mV}$ , $V_O = 0$	25°C	0.5	0.8	0.5	0.8	mA		
$r_o$ Output resistance	$V_O = 1.4\text{ V}$	25°C	200			200	$\Omega$		
CMRR Common-mode rejection ratio	$R_S \leq 200\ \Omega$	25°C	70	90	65	90	dB		
$I_{CC+}$ Supply current from $V_{CC+}$	$V_{ID} = -5\text{ V}$ to $5\text{ V}$ ( $-10\text{ mV}$ for typl), Strobes alternately grounded,	25°C	9			9	mA		
$I_{CC-}$ Supply current from $V_{CC-}$	Strobes alternately grounded,	25°C	-4			-4	mA		
$P_D$ Total power dissipation	No load	25°C	130	200	130	230	mW		

<sup>†</sup> Unless otherwise noted, all characteristics are measured with the strobe of the channel under test open. The strobe of the other channel is grounded. Full range for  $\mu$ A711M is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  and for the  $\mu$ A711C is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

<sup>‡</sup> The algebraic convention, where the most-positive (least-negative) limit is designated as maximum, is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for  $\mu$ A711M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ ; for  $\mu$ A711C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

switching characteristics,  $V_{CC+} = 12\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	$\mu$ A711M			$\mu$ A711C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Response time	No load, See Note 5	40	80		40		ns	
Strobe release time	No load, See Note 6	7	25		7		ns	

NOTES: 5. The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

6. For testing purposes, the input bias conditions are selected to produce an output voltage of 1.4 V. A 5-mV overdrive is then added to the input bias voltage to produce an output voltage that rises above 1.4 V. The time interval is measured from the 50% point on the strobe voltage waveform to the instant when the overdrive output voltage crosses the 1.4-V level.

# TYPES $\mu$ A711M, $\mu$ A711C DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
FREE-AIR TEMPERATURE

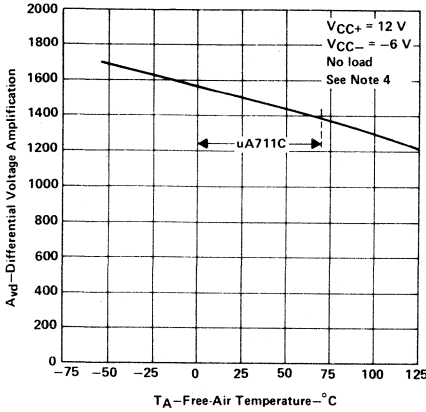


FIGURE 1

LARGE-SIGNAL DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
SUPPLY VOLTAGE

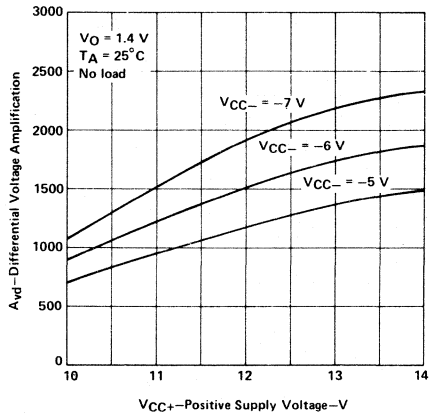


FIGURE 2

INPUT BIAS CURRENT  
vs  
FREE-AIR TEMPERATURE

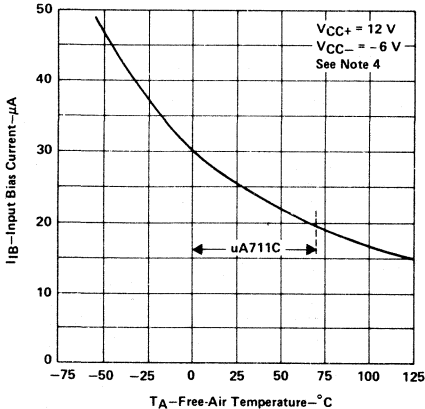


FIGURE 3

TOTAL POWER DISSIPATION  
vs  
FREE-AIR TEMPERATURE

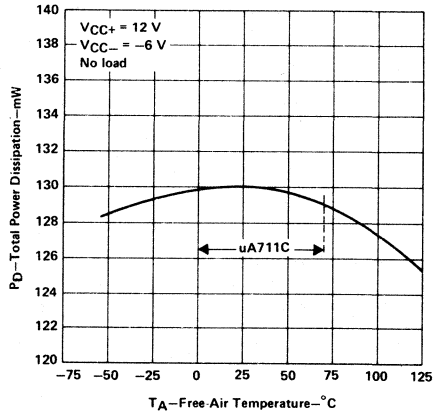
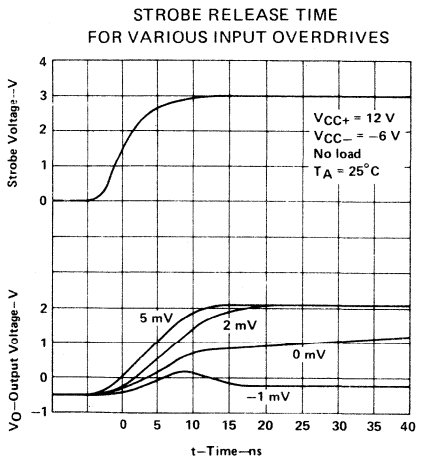
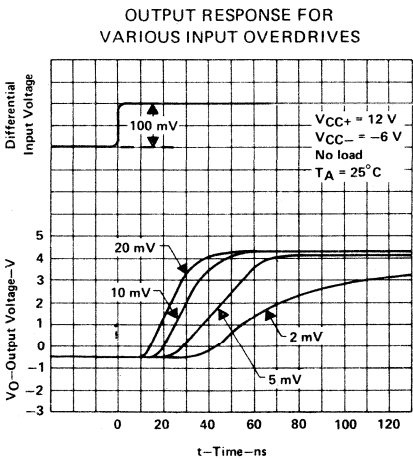
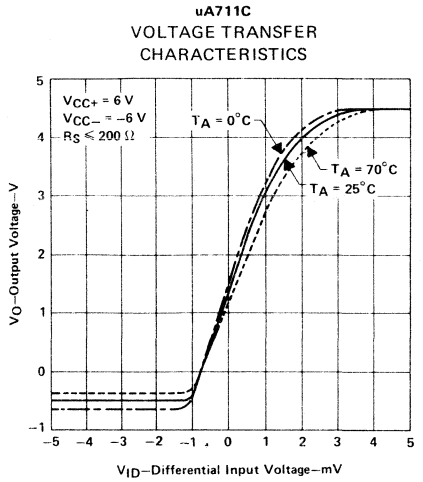
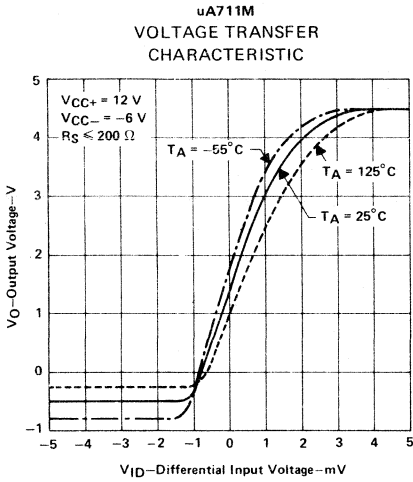


FIGURE 4

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: for  $\mu$ A711M,  $V_O = 1.8\text{ V}$  at  $T_A = -55^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1\text{ V}$  at  $T_A = 125^\circ\text{C}$ ; for  $\mu$ A711C,  $V_O = 1.5\text{ V}$  at  $T_A = 0^\circ\text{C}$ ,  $V_O = 1.4\text{ V}$  at  $T_A = 25^\circ\text{C}$ , and  $V_O = 1.2\text{ V}$  at  $70^\circ\text{C}$ . These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits these comparators are intended to drive.

# TYPES $\mu$ A711M, $\mu$ A711C DUAL-CHANNEL DIFFERENTIAL COMPARATORS WITH STROBES

## TYPICAL CHARACTERISTICS



# 4

## Voltage Comparators

**General Information**

**1**

**Thermal Information**

**2**

**Operational Amplifiers**

**3**

**Voltage Comparators**

**4**

**Special Functions**

**5**

**Voltage Regulators**

**6**

**Data Acquisition**

**7**

**Appendix**

**A**



## SPECIAL FUNCTIONS

## precision timers

## commercial temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	TIMING		OUTPUT CURRENT	PACKAGES	PAGE
		FROM	TO			
NE555	Single Timer	1 $\mu\text{s}$	1 s	$\pm 200$ mA	D,J,G,P	5-21
NE556	Dual Timer	1 $\mu\text{s}$	1 s	$\pm 200$ mA	D,J,N	5-31
TLC551C	LinCMOS, Single High-Speed Timer	1 $\mu\text{s}$	1 s	100 mA – 10 mA	D,N	5-63
TLC552C	LinCMOS, Dual High-Speed Timer	1 $\mu\text{s}$	1 s	100 mA – 10 mA	D,N	5-67
TLC555C	LinCMOS, Single High-Speed Timer	1 $\mu\text{s}$	1 s	100 mA – 10 mA	D,J,G,P	5-71
TLC556C	LinCMOS, Dual High-Speed Timer	1 $\mu\text{s}$	1 s	100 mA – 10 mA	D,N	5-67
uA2240C	Programmable Timer/Counter	10 $\mu\text{s}$	Days	4 mA	N	5-83

## automotive temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	TIMING		OUTPUT CURRENT	PACKAGES	PAGE
		FROM	TO			
SA555	Single Timer	1 $\mu\text{s}$	1 s	$\pm 200$ mA	D,J,G,P	5-21
SA556	Single Timer	1 $\mu\text{s}$	1 s	$\pm 200$ mA	D,J,N	5-31

## military temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	TIMING		OUTPUT CURRENT	PACKAGES	PAGE
		FROM	TO			
SE555	Single Timer	1 $\mu\text{s}$	1 s	$\pm 200$ mA	FK,J,G	5-21
SE555C	Single Timer	1 $\mu\text{s}$	1 s	$\pm 200$ mA	FK,J,G	5-21
SE556	Single Timer	1 $\mu\text{s}$	1 s	$\pm 200$ mA	FK,J	5-31
SE556C	Single Timer	1 $\mu\text{s}$	1 s	$\pm 200$ mA	D,J,N	5-31
TLC555M	LinCMOS, Single High-Speed Timer	1 $\mu\text{s}$	1 s	100 mA – 10 mA	JG	5-71
TLC556M	LinCMOS, Dual High-Speed Timer	1 $\mu\text{s}$	1 s	100 mA – 10 mA	J	5-71

## current mirrors

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	TYPE	TEMP RANGE	CURRENT RATIO INPUT TO OUTPUT	INPUT CURRENT RANGE	PACKAGES	PAGE
TL010C	Programmable	0°C to 70°C	3:1 to 1:15	Variable	P	5-43
TL010I	Programmable	–40°C to 85°C	3:1 to 1:15	Variable	P	5-43
TL011C	Fixed	0°C to 70°C	1:1	1 $\mu\text{A}$ to 1 mA	LP	5-47
TL011I	Fixed	–40°C to 85°C	1:1	1 $\mu\text{A}$ to 1 mA	LP	5-47
TL012C	Fixed	0°C to 70°C	1:2	1 $\mu\text{A}$ to 1 mA	LP	5-47
TL012I	Fixed	–40°C to 85°C	1:2	1 $\mu\text{A}$ to 1 mA	LP	5-47
TL014C	Fixed	0°C to 70°C	1:4	1 $\mu\text{A}$ to 1 mA	LP	5-47
TL014I	Fixed	–40°C to 85°C	1:4	1 $\mu\text{A}$ to 1 mA	LP	5-47
TL021C	Fixed	0°C to 70°C	1:2	2 $\mu\text{A}$ to 2 mA	LP	5-47
TL021I	Fixed	–40°C to 85°C	1:2	2 $\mu\text{A}$ to 2 mA	LP	5-47

## SELECTION GUIDE

### floppy-disk control circuits

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	PACKAGES	PAGE
MC3469	Write Controller	N	5-9
MC3470	Read-Amplifier System	N	5-11
MC3471	Write Controller and Head Driver	N	5-19
TL030	Four-Head Disk-Memory Read Amplifier	N	5-55
TL712	Disk-Memory Read-Chain Data	JG,P	4-60
TL721	Disk-Memory Read-Chain Data Comparator Compatible with MECL III and MECL 1000	JG,P	4-62



**differential video amplifiers**

commercial temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	BANDWIDTH	GAIN	PACKAGES	PAGE
MC1445	Amplifier with 2 multiplexed inputs, wide AGC range	60 MHz	100 Max	J,N	5-7
NE592	Amplifier with internal frequency compensation and adjustable/selectable gain options.	90 MHz	0 to 600	N	5-35
NE592A	Similar to NE592 but with tighter gain distribution.	90 MHz	0 to 600	N	5-53
TL026	Amplifier with a wide AGC range	60 MHz	100	JG,P	5-57
TL592	Similar to NE592 but in an 8-pin package.	90 MHz	0 to 600	P	5-57
TL592A	Similar to NE592A but in an 8-pin package.	90 MHz	0 to 600	P	5-61
TL592B	Low-noise version of NE592 and TL592.	90 MHz	0 to 600	N,P	5-71
uA733C	Amplifier with internal frequency compensation.	200 MHz	10, 100, 400	J,U	5-101

military temperature range

(values specified for  $T_A = 25^\circ\text{C}$ )

DEVICE NUMBER	DESCRIPTION	BANDWIDTH	GAIN	PACKAGES	PAGE
MC1545	Amplifier with 2 multiplexed inputs, wide AGC range	60 MHz	100 Max	J,N	5-7
SE592	Amplifier with internal frequency compensation and adjustable/selectable gain options.	90 MHz	0 to 600	N	5-35
uA733M	Amplifier with internal frequency compensation.	200 MHz	10, 100, 400	J,U	5-75



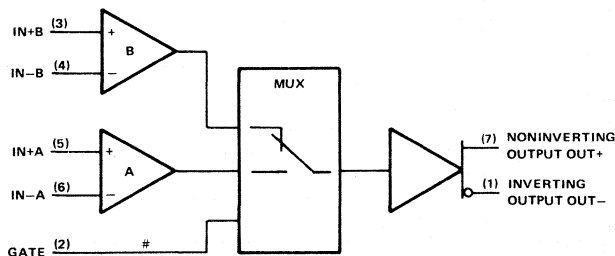
- Differential Inputs and Outputs
- Channel Select Time . . . 20 ns Typ
- Bandwidth Typically 50 MHz
- 16-dB Minimum Gain
- Common-Mode Rejection Typically 85 dB
- Broadband Noise Typically 25  $\mu$ V

**description**

The MC1545 and MC1445 are general-purpose, gated, dual-channel wideband amplifiers designed for use in video-signal mixing and switching. Channel selection is accomplished by control of the voltage level at the gate. A high logic level selects channel A; a low logic level selects channel B. The unselected channel will have a gain of one or less.

The MC1545 is characterized for operation over the full military operating temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The MC1445 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**block diagram**

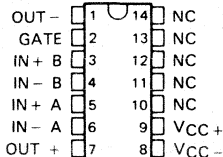


**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

	MC1545	MC1445	UNIT
Supply voltage $V_{CC+}$ (see Note 1)	+12	+12	V
Supply voltage $V_{CC-}$ (see Note 1)	-12	-12	V
Differential input voltage (see Note 2)	$\pm 5$	$\pm 5$	V
Output current	$\pm 25$	$\pm 25$	mA
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 3)	675	675	mW
Operating free-air temperature range	$-55$ to $125$	$0$ to $75$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J or W package	300	$^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	N package	260	$^{\circ}\text{C}$

- NOTES: 1. Voltage values, except differential input voltage, are with respect to the midpoint of  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential input voltages are measured at a noninverting input terminal with respect to the appropriate inverting input terminal.  
 3. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to the Dissipation Derating Curves, Section 2. In the J package, MC1545 chips are alloy mounted; MC1445 chips are glass mounted.

MC1545 . . . J DUAL-IN-LINE OR  
W FLAT PACKAGE  
MC1445 . . . J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



NC--No internal connection

**FUNCTION TABLE**

GATE INPUT	SELECT
H	Channel A
L	Channel B

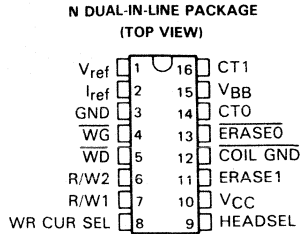
# TYPES MC1545, MC1445

## GATE-CONTROLLED 2-CHANNEL-INPUT VIDEO AMPLIFIER

electrical characteristics at  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = -5\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MC1545			MC1445			UNIT		
		MIN	TYP	MAX	MIN	TYP	MAX			
$A_{VS}$	Large-signal single-ended voltage amplification	$f = 125\text{ kHz}$ , $V_i = 20\text{ mV}$		16	19	21	16	19.5	23	dB
BW	Bandwidth	$V_i = 20\text{ mV}$		40	50		50			MHz
$V_{IO}$	Input offset voltage			1		5	7.5			mV
$I_{IO}$	Input offset current			2			2			$\mu\text{A}$
$I_{IB}$	Input bias current			15	25		15	30		$\mu\text{A}$
$V_{ICR}$	Common-mode voltage range			$\pm 2.5$			$\pm 2.5$			V
$V_{OQ}$	Quiescent output voltage			0.1			0.1			V
$\Delta V_{OQ}$	Change in quiescent output voltage	Gate input change from 5 V to 0 V		$\pm 15$			$\pm 15$			mV
$V_{OPP}$	Maximum peak-to-peak output voltage swing	$f = 50\text{ kHz}$ , $R_L = 1\text{ k}\Omega$		1.5	2.5		1.5	2.5		V
$z_i$	Input impedance	$f = 50\text{ kHz}$		4	10		3	10		$\text{k}\Omega$
$z_o$	Output impedance	$f = 50\text{ kHz}$		25			25			$\Omega$
CMRR	Common-mode rejection ratio	$f = 50\text{ kHz}$		85			85			dB
$V_n$	Broadband equivalent input noise voltage	BW = 5 Hz to 10 MHz, $R_S = 50\ \Omega$		25			25			$\mu\text{V}$
$V_{TH}$	High-level gate threshold voltage	$A_{VS(A)} \geq 16\text{ dB}$ , $A_{VS(B)} \leq 0\text{ dB}$		1.5	2.2		1.3	3		V
$V_{TL}$	Low-level gate threshold voltage	$A_{VS(B)} \geq 16\text{ dB}$ , $A_{VS(A)} \leq 0\text{ dB}$		0.4	0.7		0.2	0.4		V
$I_{IH}$	High-level gate current	$V_i = 5\text{ V}$		2			4			$\mu\text{A}$
$I_{IL}$	Low-level gate current	$V_i = 0$		2.5			4			mA
$t_{PLH}$	Propagation delay time, low-to-high-level output	$\Delta V_i = 20\text{ mV}$ , 50% to 50%		6.5	10		6.5			ns
$t_{PHL}$	Propagation delay time, high-to-low-level output	$\Delta V_i = 20\text{ mV}$ , 50% to 50%		6.3	10		6.3			ns
$t_{TLH}$	Transition time, low-to-high-level output	$\Delta V_i = 20\text{ mV}$ , 10% to 90%		6.5	15		6.5			ns
$t_{THL}$	Transition time, high-to-low-level output	$\Delta V_i = 20\text{ mV}$ , 10% to 90%		7	15		7			ns
$I_{CC+}$	Supply current from $V_{CC+}$	No load,	No signal	7	11		7	15		mA
$I_{CC-}$	Supply current from $V_{CC-}$	No load,	No signal	-7	-11		-7	-15		mA
$P_D$	Power dissipation	No load,	No signal	70	110		70	150		mW

- Designed for Straddle-Erase Heads
- Head Selection with Current Steering Through Write Head and Erase Coil in Write Mode
- Provides High-Impedance (Read Data Enable) During Read Mode
- Write Current (with Trimmed Internal Resistor and  $R_{ext} = 10\text{ k}\Omega$ ) . . . 3 A
- Write-Current Select Input Provides for Inner/Outer Track Compensation
- Degauss Period Externally Adjustable
- Specified with  $\pm 10\%$  Logic Supply and Head Supply ( $V_{BB}$ ) from 10.8 V to 26.4 V
- Minimizes External Component Requirements
- Designed to be Interchangeable with Motorola MC3469P

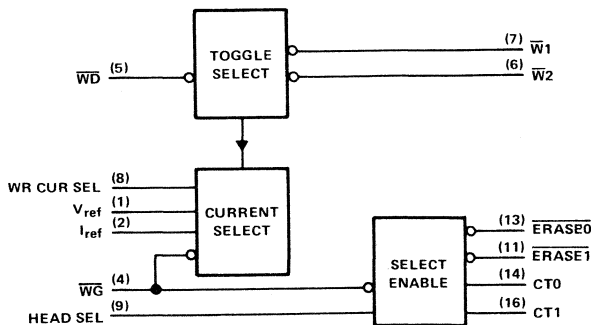


**description**

The MC3469 is a write-current controller designed to provide the entire interface for straddle-erase floppy-disk heads. The write current can be varied over a wide range by varying the value of an external resistor in series with a laser-trimmed internal resistor, and inner-track compensation is provided through the WR CUR SEL pin. A constant write current of 3 mA is provided by a 10-k $\Omega$  resistor between  $V_{ref}$  and  $I_{ref}$  when WR CUR SEL is low and 4 mA (an increase of 33%) when WR CUR SEL is high. Provisions are also made for adjusting the duration of the degaussing cycle that occurs at the end of each write operation.

The MC3469 will be characterized for operation from 0°C to 70°C.

**functional block diagram**



# TYPE MC3469 FLOPPY-DISK WRITE CONTROLLER

FUNCTION TABLE

FUNCTION	INPUTS		OUTPUTS			
	WG	HEADSEL	ERASE0	ERASE1	CT0	CT1
Write Head 0	L	H	L	H	H	L
Write Head 1	L	L	H	L	L	L
Write disable	H	X	H	H	NC	NC

L ≡ Low logic level, H ≡ High logic level  
 X ≡ Irrelevant, NC ≡ Maintains previous state

TABLE OF PIN FUNCTIONS

SIGNATURE	PIN NUMBER	DESCRIPTION
HEAD SEL	9	Selects Head 0 or Head 1
$\overline{\text{WG}}$	4	Active-low write enable
$\overline{\text{WD}}$	5	Serial data input
WR CUR SEL	8	Selects inner/outer track write current value
$V_{\text{ref}}$	1	Write-current external program resistor terminals
$I_{\text{ref}}$	2	
CT0	14	Totem-pole output to Head 0 center tap
ERASE0	13	Open-collector erase output to Head 0
CT1	16	Totem-pole output to Head 1 center tap
ERASE1	11	Open-collector erase output to Head 1
$\overline{\text{W2}}$	6	Constant-current push-pull write outputs
$\overline{\text{W1}}$	7	
VCC	10	Positive power supply
GND	12, 3	Power supply return

Special Functions

5

- Combines All Read-Amplifier Active Circuitry into One Monolithic Circuit
- Guaranteed Maximum Peak Shift of 5%
- Designed to be Interchangeable with Motorola MC3470

**description**

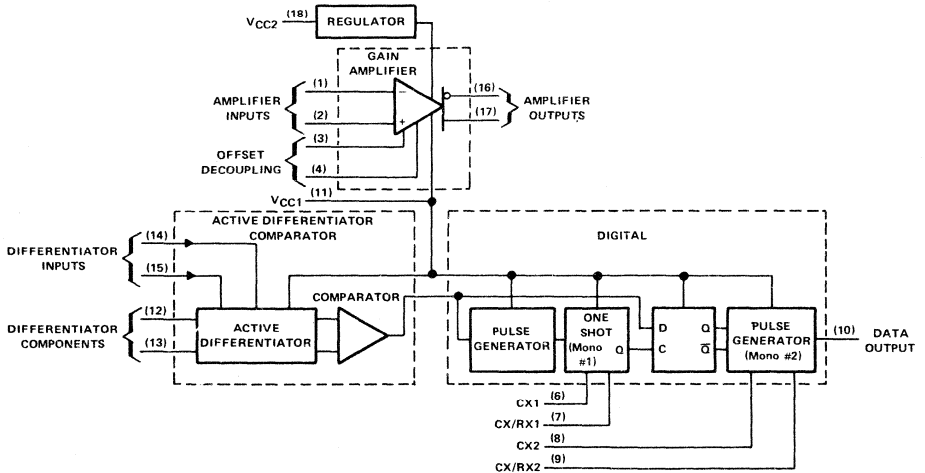
The MC3470 is a monolithic read-amplifier system containing all the active circuitry necessary for obtaining digital information from floppy disk storage. It is designed to accept the ac differential signal from the magnetic head and produce a digital output pulse corresponding to each peak of the input signal. The gain stage amplifies the input waveform and applies it to an external filter network, enabling the active differentiator and time domain filter to produce the desired output.

The MC3470 is characterized for operation from 0°C to 70°C.

**N DUAL-IN-LINE PACKAGE  
(TOP VIEW)**

AMPLIFIER INPUTS	1	2	18	VCC2
OFFSET	3	17	AMPLIFIER OUTPUTS	
DECOUPLING	4	16	DIFFERENTIATOR INPUTS	
GND	5	15	DIFFERENTIATOR COMPONENTS	
CX1	6	14	VCC1	
CX/RX1	7	13	DATA OUTPUT	
CX2	8	12		
CX/RX2	9	11		

**functional block diagram**



# TYPE MC3470

## FLOPPY DISK READ-AMPLIFIER SYSTEM

### absolute maximum ratings over operating temperature range (unless otherwise noted)

Supply voltage, V <sub>CC1</sub> (see Note 1)	7 V
Supply voltage, V <sub>CC2</sub>	16 V
Input voltage range (amplifier inputs)	-0.2 V to 7 V
Output voltage, V <sub>O</sub> (data output)	-0.2 V to 7 V
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C

NOTE 1: All voltage values are with respect to network ground terminal.

### recommended operating conditions

		MIN	NOM	MAX	UNIT
Supply voltage V <sub>CC1</sub>		4.75	5	5.25	V
Supply voltage V <sub>CC2</sub>		10	12	14	V
Timing capacitor CX1 (see Note 2)		150		680	pF
Timing capacitor CX2		100		800	pF
Timing resistors RX1 and RX2		1.5		10	kΩ
Timing of digital section	Monostable no. 1	500		4000	ns
	Monostable no. 2	150		1000	
Operating free-air temperature, T <sub>A</sub>		0		70	°C

NOTE 2: To minimize current transients, CX1 should be kept as small as convenient.

Special Functions





# TYPE MC3470 FLOPPY DISK READ-AMPLIFIER SYSTEM

electrical characteristics over recommended ranges of supply voltages and operating free-air temperature (unless otherwise noted)

### gain amplifier section

PARAMETER		TEST CONDITIONS		MIN	TYP <sup>†</sup>	MAX	UNIT
A <sub>VD</sub>	Differential voltage amplification	V <sub>id</sub> = 5 mV rms, f = 200 kHz		80	100	120	V/V
I <sub>IB</sub>	Input bias current				-10	-25	μA
V <sub>ICR</sub>	Common-mode input voltage range	THD ≤ 5%		-0.1	to	1.5	V
V <sub>IDR</sub>	Differential input voltage range	THD ≤ 5%		±25			mV
V <sub>OPP</sub>	Peak-to-peak differential output voltage			3	4		V
V <sub>OC</sub>	Common-mode output voltage	V <sub>I</sub> = 0 V, V <sub>ID</sub> = 0 V			3		V
V <sub>OD</sub>	Differential output offset voltage	V <sub>I</sub> = 0 V, T <sub>A</sub> = 25 °C	V <sub>ID</sub> = 0 V,			0.4	V
I <sub>O</sub>	Output current (each amplifier output)	To ground			-8		mA
		From V <sub>CC1</sub>		2.8	4		
r <sub>i</sub>	Input resistance	T <sub>A</sub> = 25 °C		100	250		kΩ
r <sub>o</sub>	Output resistance (single-ended)	V <sub>CC1</sub> = 5 V, T <sub>A</sub> = 25 °C	V <sub>CC2</sub> = 12 V,		15		Ω
BW	Bandwidth (3 dB)	V <sub>id</sub> = 2 mV rms, V <sub>CC2</sub> = 12 V, T <sub>A</sub> = 25 °C	V <sub>CC1</sub> = 5 V, T <sub>A</sub> = 25 °C		5		MHz
CMRR	Common-mode rejection ratio	V <sub>CC1</sub> = 5 V, f = 100 kHz, T <sub>A</sub> = 25 °C	V <sub>I</sub> PP = 200 mV, A <sub>VD</sub> = 40 dB,		50		dB
k <sub>SVR</sub>	Supply voltage rejection ratio	A <sub>VD</sub> = 40 dB, T <sub>A</sub> = 25 °C	V <sub>CC1</sub> = 5 ± 0.25 V, V <sub>CC2</sub> = 12 V		50		dB
			V <sub>CC1</sub> = 5 V, V <sub>CC2</sub> = 12 ± 2 V		60		
V <sub>n</sub>	Equivalent input noise voltage	BW = 10 Hz to 1 MHz, T <sub>A</sub> = 25 °C			15		μV

### active-differentiator section

PARAMETER		TEST CONDITIONS		MIN	TYP <sup>†</sup>	MAX	UNIT
I <sub>sink</sub>	Sink current at pins 12 and 13	V <sub>OD</sub> = V <sub>CC1</sub>		1	1.4		mA
	Peak shift	V <sub>CC1</sub> = 5 V, V <sub>ID</sub> PP = 1 V, I <sub>cap</sub> = 500 μA,	V <sub>CC2</sub> = 12 V, f = 250 kHz, See Figure 1			5%	
r <sub>id</sub>	Differential input resistance				30		kΩ
r <sub>od</sub>	Differential output resistance				40		Ω

<sup>†</sup>All typical values are at V<sub>CC1</sub> = 5 V, V<sub>CC2</sub> = 12 V, T<sub>A</sub> = 25 °C.

# TYPE MC3470

## FLOPPY DISK READ-AMPLIFIER SYSTEM

### digital section

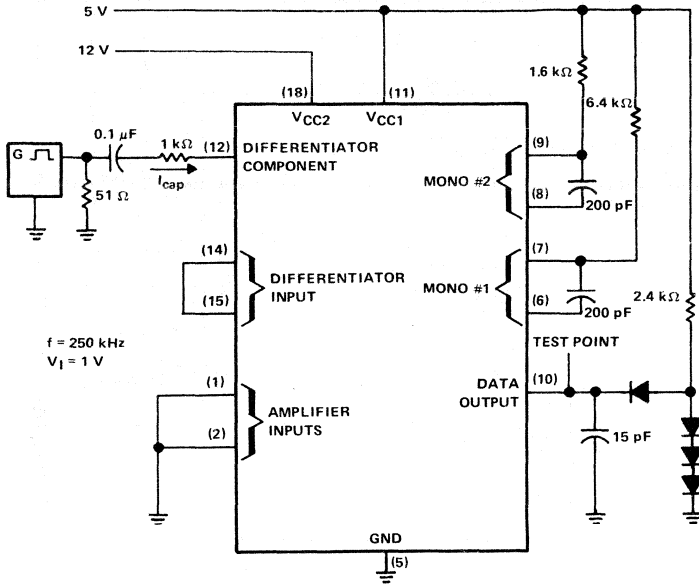
PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
V <sub>OH</sub>	High-level output voltage (pin 10)	V <sub>CC1</sub> = 4.75 V, V <sub>CC2</sub> = 12 V, I <sub>OH</sub> = -0.4 mA	2.7			V
V <sub>OL</sub>	Low-level output voltage (pin 10)	V <sub>CC1</sub> = 4.75 V, V <sub>CC2</sub> = 12 V, I <sub>OL</sub> = 8 mA			0.5	V
I <sub>CC1</sub>	Supply current from V <sub>CC1</sub>	V <sub>CC1</sub> = 5.25 V		35	50	mA
I <sub>CC2</sub>	Supply current from V <sub>CC2</sub>	V <sub>CC2</sub> = 14 V		4.5	10	mA

### timing characteristics over recommended ranges of supply voltages and operating free-air temperature (unless otherwise noted) (see Figure 2)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
t <sub>r</sub>	Rise time (pin 10)				20	ns
t <sub>f</sub>	Fall time (pin 10)				25	ns
	Timing accuracy of monostable no. 1 compared to 0.625 RX1 • CX1 + 200 ns	RX1 = 1.5 kΩ to 10 kΩ, CX1 = 150 pF to 680 pF	85%		115%	
	Timing accuracy of monostable no. 2 compared to 0.625 RX2 • CX2	RX2 = 1.5 kΩ to 10 kΩ, CX2 = 100 pF to 800 pF	85%		115%	

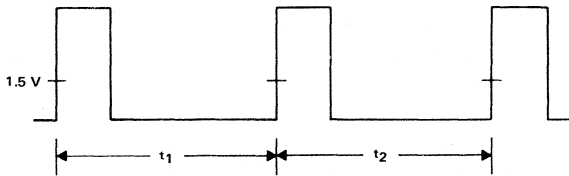
<sup>†</sup>All typical values are at V<sub>CC1</sub> = 5 V, V<sub>CC2</sub> = 12 V, T<sub>A</sub> = 25°C.

PARAMETER MEASUREMENT INFORMATION



$f = 250 \text{ kHz}$   
 $V_1 = 1 \text{ V}$

TEST CIRCUIT



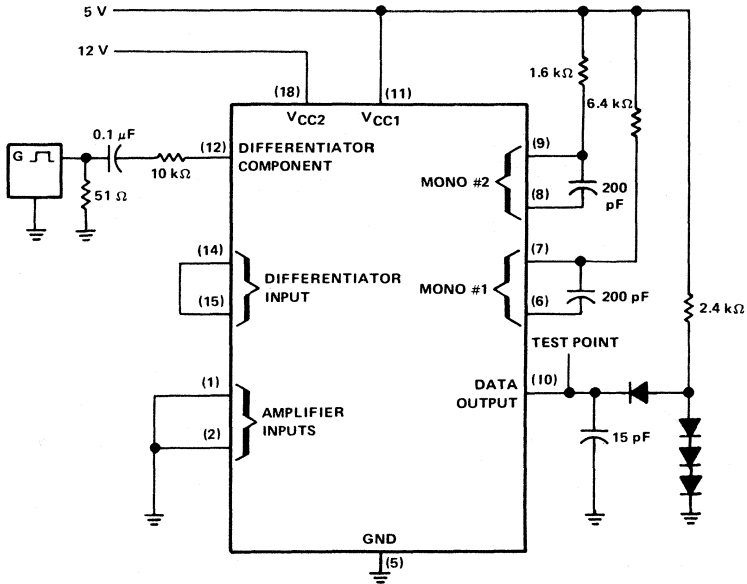
$$\text{Peak shift} = \frac{(t_1 - t_2)}{2(t_1 + t_2)} \cdot 100\%$$

VOLTAGE WAVEFORMS

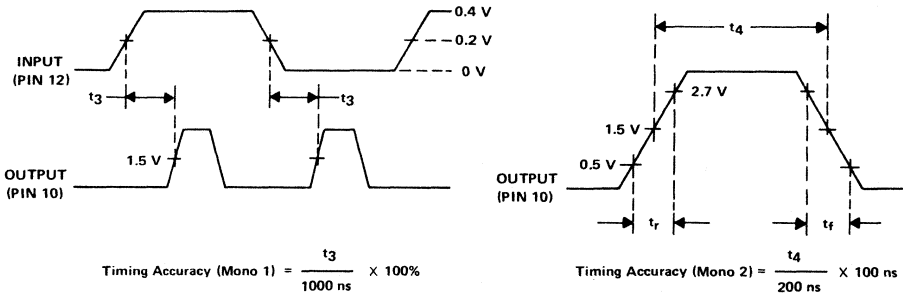
FIGURE 1—PEAK SHIFT

**TYPE MC3470  
FLOPPY DISK READ-AMPLIFIER SYSTEM**

**PARAMETER MEASUREMENT INFORMATION**



**TEST CIRCUIT**



**VOLTAGE WAVEFORMS**

**FIGURE 2—TIMING ACCURACY**

Special Functions



TYPICAL CHARACTERISTICS

NORMALIZED POWER SUPPLY CURRENT  
vs  
FREE-AIR TEMPERATURE

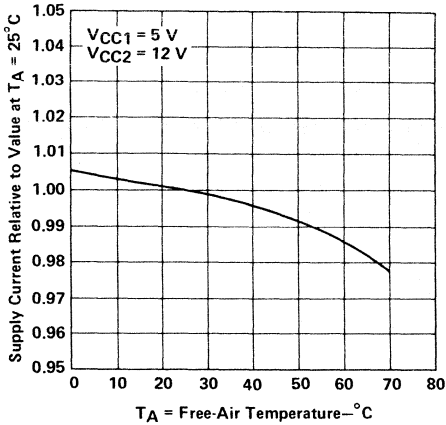


FIGURE 3

NORMALIZED VOLTAGE AMPLIFICATION  
vs  
FREE-AIR TEMPERATURE

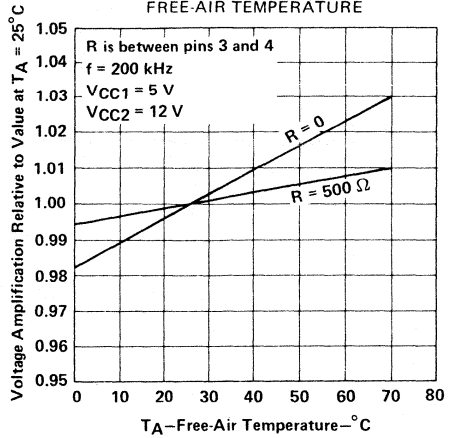


FIGURE 4

NORMALIZED TIME DELAY (PIN 12 TO PIN 10)  
vs  
FREE-AIR TEMPERATURE

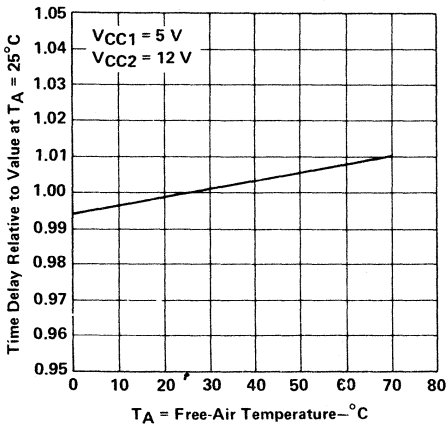


FIGURE 5

VOLTAGE AMPLIFICATION (NORMALIZED)  
and PHASE SHIFT

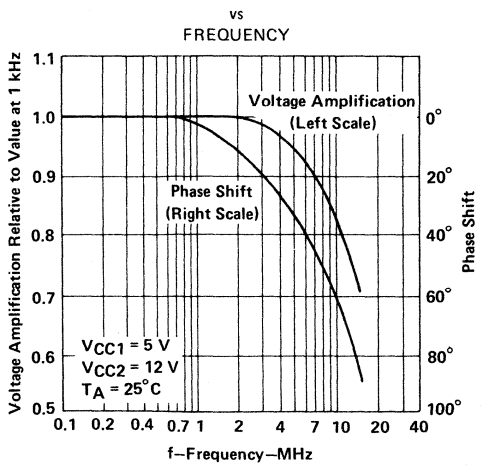


FIGURE 6

**TYPE MC3470  
FLOPPY DISK READ-AMPLIFIER SYSTEM**

**TYPICAL APPLICATION INFORMATION**

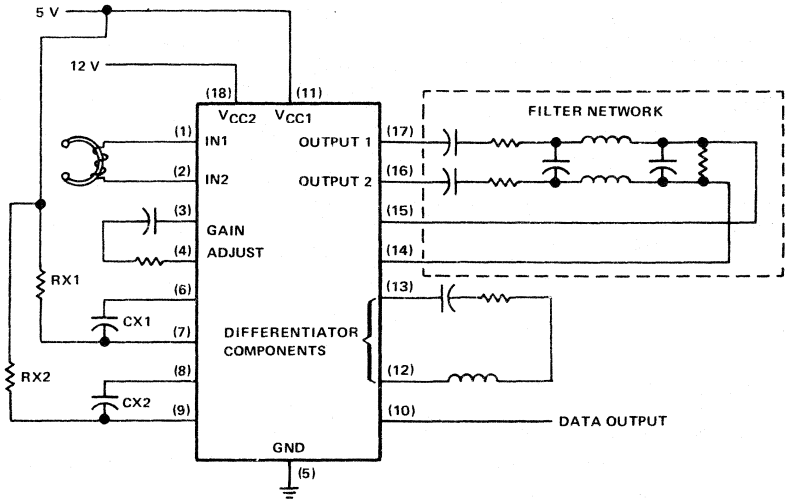
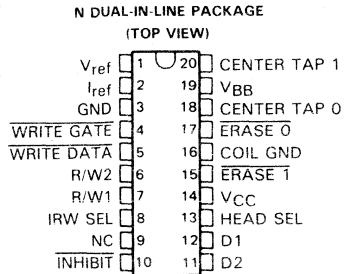


FIGURE 7

Special Functions



- Provides Entire Interface Between Inputs and the Write and Erase Heads in Floppy Disk Systems
- Can be Used with Either Straddle-Erase or Tunnel-Erase Heads
- Head Selection, with Current Steering Through Write Head and Erase Coil in Write Mode
- Adjustable On-Chip Delay of Erase Timing
- Read-Write Current Select Input Provides Inner/Outer Track Compensation
- Minimizes Requirement for External Components
- Direct Replacement for Motorola MC3471



NC - No internal connection

**description**

The MC3471 is a monolithic integrated write controller/head driver designed to provide the entire interface between the write data and head-control inputs and the heads (write and erase) for either tunnel-erase or straddle-erase floppy disk systems.

Provisions are made for selecting a range of accurately controlled write currents by varying the value of an external resistor connected between pins 1 and 2. Provisions for head selection during both read and write operations are also made. Degaussing the read/write head can be accomplished at the end of each write operation by a capacitor attached from pin 1 to ground; the degaussing period is controlled by the value of this capacitor. There are additional provisions for adjusting inner/outer track compensation, and the delay from write gate to erase turn-on and turn-off.

Erase delays are controlled by driving the delay inputs D1 and D2 with standard TTL open-collector logic (microprocessor compatible), or by using the external RC mode in which the delay is one time constant.

In addition, the INHIBIT output is provided to indicate when the heads are active during write, degauss, or erase.

The MC3471 will be characterized for operation from 0°C to 70°C.

**Special Functions**

**5**





- Timing from Microseconds to Hours
- Astable or Monostable Operation
- Adjustable Duty Cycle
- TTL-Compatible Output Can Sink or Source up to 200 mA
- Functionally Interchangeable with the Signetics SE555, SE555C, SA555, NE555; Have Same Pinout

**description**

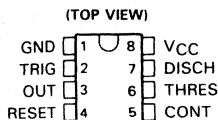
These devices are monolithic timing circuits capable of producing accurate time delays or oscillation. In the time-delay or monostable mode of operation, the timed interval is controlled by a single external resistor and capacitor network. In the astable mode of operation, the frequency and duty cycle may be independently controlled with two external resistors and a single external capacitor.

The threshold and trigger levels are normally two-thirds and one-third, respectively, of VCC. These levels can be altered by use of the control voltage terminal. When the trigger input falls below the trigger level, the flip-flop is set and the output goes high. If the trigger input is above the trigger level and the threshold input is above the threshold level, the flip-flop is reset and the output is low. The reset input can override all other inputs and can be used to initiate a new timing cycle. When the reset input goes low, the flip-flop is reset and the output goes low. Whenever the output is low, a low-impedance path is provided between the discharge terminal and ground.

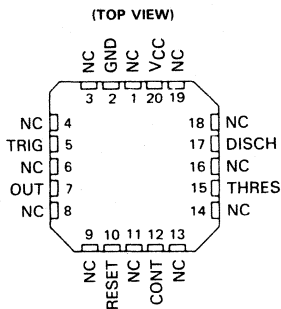
The output circuit is capable of sinking or sourcing current up to 200 milliamperes. Operation is specified for supplies of 5 to 15 volts. With a 5-volt supply, output levels are compatible with TTL inputs.

The SE555 and SE555C are characterized for operation over the full military range of -55°C to 125°C. The SA555 is characterized for operation from -40°C to 85°C, and the NE555 is characterized for operation from 0°C to 70°C.

NE555, SE555, SE555C . . . JG DUAL-IN-LINE PACKAGE  
SA555, NE555 . . . D, JG, OR P DUAL-IN-LINE PACKAGE

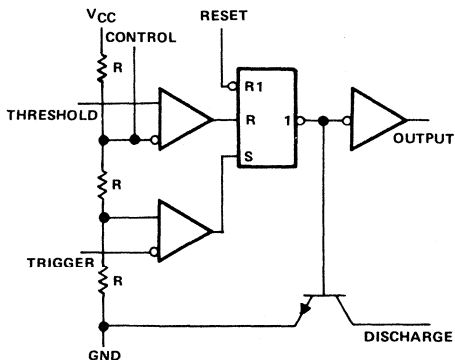


SE555, SE555C . . . FH OR FK CHIP CARRIER PACKAGE



NC—No internal connection

**functional block diagram**



Reset can override Trigger, which can override Threshold.



# TYPES SE555, SE555C, SA555, NE555 PRECISION TIMERS

FUNCTION TABLE

RESET	TRIGGER VOLTAGE†	THRESHOLD VOLTAGE†	OUTPUT	DISCHARGE SWITCH
Low	Irrelevant	Irrelevant	Low	On
High	< 1/3 V <sub>DD</sub>	Irrelevant	High	Off
High	> 1/3 V <sub>DD</sub>	> 2/3 V <sub>DD</sub>	Low	On
High	> 1/3 V <sub>DD</sub>	< 2/3 V <sub>DD</sub>	As previously established	

†Voltage levels shown are nominal.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V <sub>CC</sub> (see Note 1)	18 V
Input voltage (control voltage, reset, threshold, trigger)	V <sub>CC</sub>
Output current	±225 mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	600 mW
Operating free-air temperature range: SE555, SE555C	-55°C to 125°C
SA555	-40°C to 85°C
NE555	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: FH, FK, or JG package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package	260°C

- NOTES: 1. All voltage values are with respect to network ground terminal.  
 2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the JG package, SE555 and SE555C chips are alloy mounted, SA555 and NE555 chips are glass mounted.

## recommended operating conditions

	SE555		SE555C		SA555		NE555		UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
Supply voltage, V <sub>CC</sub>	4.5	18	4.5	16	4.5	16	4.5	16	V
Input voltage (control voltage, reset, threshold, trigger)	V <sub>CC</sub>		V <sub>CC</sub>		V <sub>CC</sub>		V <sub>CC</sub>		V
Output current	±200		±200		±200		±200		mA
Operating free-air temperature, T <sub>A</sub>	-55	125	-55	125	-40	85	0	70	°C

# TYPES SE555, SE555C, SA555, NE555 PRECISION TIMERS

electrical characteristics at 25°C free-air temperature, V<sub>CC</sub> = 5 V to 15 V (unless otherwise noted)

PARAMETER	TEST CONDITIONS		SE555			SE555C, SA555 NE555			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Threshold voltage level	V <sub>CC</sub> = 15 V		9.4	10	10.6	8.8	10	11.2	V
	V <sub>CC</sub> = 5 V		2.7	3.3	4	2.4	3.3	4.2	
Threshold current (see Note 3)			30			250			nA
Trigger voltage level	V <sub>CC</sub> = 15 V		4.8	5	5.2	4.5	5	5.6	V
	V <sub>CC</sub> = 5 V		1.45	1.67	1.9	1.1	1.67	2.2	
Trigger current	Trigger at 0 V		0.5			0.9			μA
Reset voltage level			0.4	0.7	1	0.4	0.7	1	V
Reset current	Reset at V <sub>CC</sub>		0.1			0.4			mA
	Reset at 0 V		-0.4			-1			
Discharge switch off-state current			20			100			nA
Control voltage (open circuit)	V <sub>CC</sub> = 15 V		9.6	10	10.4	9	10	11	V
	V <sub>CC</sub> = 5 V		2.9	3.3	3.8	2.6	3.3	4	
Low-level output voltage	V <sub>CC</sub> = 15 V	I <sub>OL</sub> = 10 mA	0.1		0.15	0.1		0.25	V
		I <sub>OL</sub> = 50 mA	0.4		0.5	0.4		0.75	
		I <sub>OL</sub> = 100 mA	2		2.25	2		3.2	
		I <sub>OL</sub> = 200 mA	2.5			2.5			
	V <sub>CC</sub> = 5 V	I <sub>OL</sub> = 5 mA	0.05		0.15	0.05		0.25	
		I <sub>OL</sub> = 8 mA	0.1		0.2	0.25		0.3	
High-level output voltage	V <sub>CC</sub> = 15 V	I <sub>OH</sub> = -100 mA	13		13.3	12.75		13.3	V
		I <sub>OH</sub> = -200 mA			12.5	12.5			
	V <sub>CC</sub> = 5 V	I <sub>OH</sub> = -100 mA	3		3.3	2.75		3.3	
Supply current	Output low, No load	V <sub>CC</sub> = 15 V	10		12	10		15	mA
		V <sub>CC</sub> = 5 V	3		5	3		6	
	Output high, No load	V <sub>CC</sub> = 15 V	9		10	9		13	
		V <sub>CC</sub> = 5 V	2		4	2		5	

NOTE 3: This parameter influences the maximum value of the timing resistors R<sub>A</sub> and R<sub>B</sub> in the circuit of Figure 13. For example, when V<sub>CC</sub> = 5 V the maximum value is R = R<sub>A</sub> + R<sub>B</sub> = 3.4 MΩ and for V<sub>CC</sub> = 15 V the maximum value is 10 MΩ.

## operating characteristics, V<sub>CC</sub> = 5 V and 15 V

PARAMETER		TEST CONDITIONS <sup>†</sup>	SE555			SE555C, SA555 NE555			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Initial error of timing interval <sup>‡</sup>	Each timer, monostable <sup>§</sup>	T <sub>A</sub> = 25°C	0.5		1.5	1		3	%
	Each timer, astable <sup>¶</sup>		1.5		2.25				
Temperature coefficient of timing interval	Each timer, monostable <sup>§</sup>	T <sub>A</sub> = MIN to MAX	30		100	50		ppm/°C	
	Each timer, astable <sup>¶</sup>		90		150				
Supply voltage sensitivity of timing interval	Each timer, monostable <sup>§</sup>	T <sub>A</sub> = 25°C	0.05		0.2	0.1		0.5	%/V
	Each timer, astable <sup>¶</sup>		0.15		0.3				
Output pulse rise time		C <sub>L</sub> = 15 pF,	100		200	100		300	ns
Output pulse fall time		T <sub>A</sub> = 25°C	100		200	100		300	

<sup>†</sup>For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

<sup>‡</sup>Timing interval error is defined as the difference between the measured value and the nominal value computed by the formula: t<sub>w</sub> = 1.1 R<sub>A</sub>C.

<sup>§</sup>Values specified are for a device in a monostable circuit similar to Figure 10, with component values as follow: R<sub>A</sub> = 2 kΩ to 100 kΩ, C = 0.1 μF.

<sup>¶</sup>Values specified are for a device in an astable circuit similar to Figure 1, with component values as follow: R<sub>A</sub> = 1 kΩ to 100 kΩ, C = 0.1 μF.

5 Special Functions

# TYPES SE555, SE555C, SA555, NE555 PRECISION TIMERS

## TYPICAL CHARACTERISTICS†

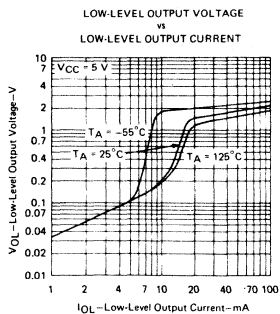


FIGURE 1

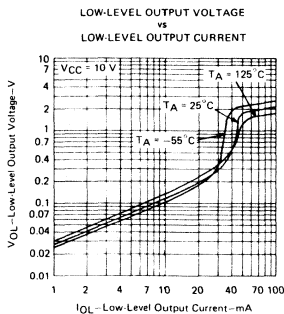


FIGURE 2

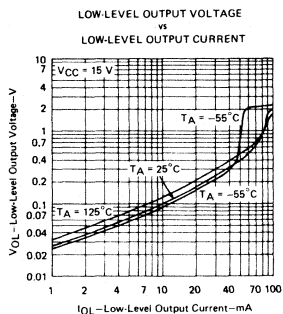


FIGURE 3

DROP BETWEEN SUPPLY VOLTAGE AND OUTPUT  
vs.  
HIGH-LEVEL OUTPUT CURRENT

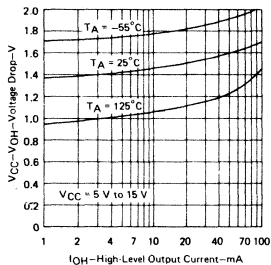


FIGURE 4

SUPPLY CURRENT  
vs.  
SUPPLY VOLTAGE

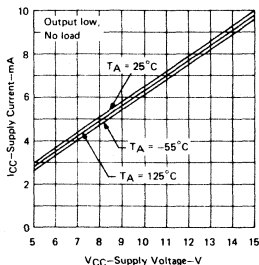


FIGURE 5

MINIMUM PULSE WIDTH REQUIRED  
FOR TRIGGERING  
vs.  
LOWEST VOLTAGE LEVEL OF  
TRIGGER PULSE

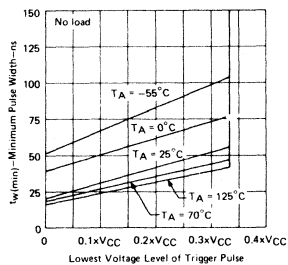


FIGURE 6

NORMALIZED OUTPUT PULSE WIDTH  
(MONOSTABLE OPERATION)  
vs.  
SUPPLY VOLTAGE

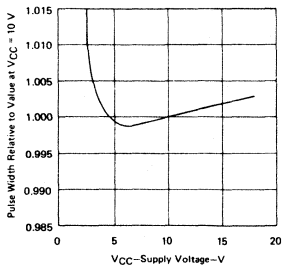


FIGURE 7

NORMALIZED OUTPUT PULSE WIDTH  
(MONOSTABLE OPERATION)  
vs.  
FREE-AIR TEMPERATURE

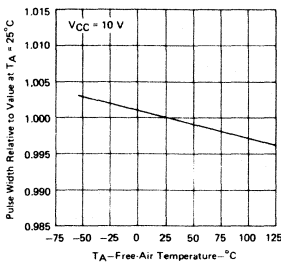


FIGURE 8

PROPAGATION DELAY TIME  
vs.  
LOWEST VOLTAGE LEVEL  
OF TRIGGER PULSE

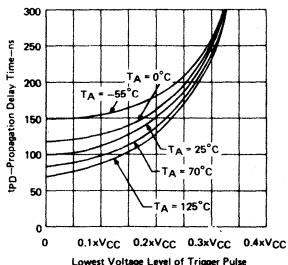


FIGURE 9

†Data for temperatures below 0°C and above 70°C are applicable for SE555 circuits only.



TYPICAL APPLICATION DATA

monostable operation

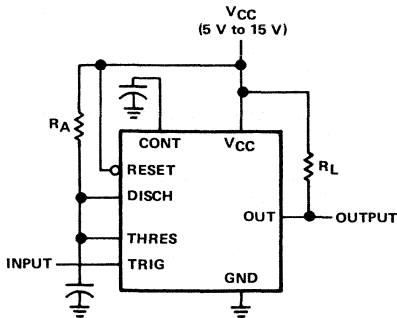


FIGURE 10—CIRCUIT FOR MONOSTABLE OPERATION

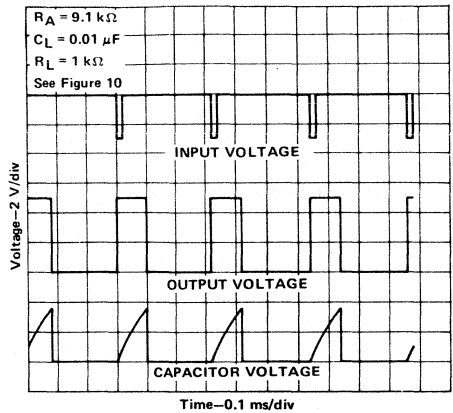


FIGURE 11—TYPICAL MONOSTABLE WAVEFORMS

For monostable operation, any of these timers may be connected as shown in Figure 10. If the output is low, application of a negative-going pulse to the trigger input sets the flip-flop ( $\bar{Q}$  goes low), drives the output high, and turns off Q1. Capacitor C is then charged through  $R_A$  until the voltage across the capacitor reaches the threshold voltage of the threshold input. If the trigger input has returned to a high level, the output of the threshold comparator will reset the flip-flop ( $\bar{Q}$  goes high), drive the output low, and discharge C through Q1.

Monostable operation is initiated when the trigger input voltage falls below the trigger threshold. Once initiated, the sequence will complete only if the trigger input is high at the end of the timing interval. Because of the threshold level and saturation voltage of Q1, the output pulse duration is approximately  $t_W = 1.1 R_A C$ . Figure 12 is a plot of the time constant for various values of  $R_A$  and C. The threshold levels and charge rates are both directly proportional to the supply voltage,  $V_{CC}$ . The timing interval is therefore independent of the supply voltage, so long as the supply voltage is constant during the time interval.

Applying a negative-going trigger pulse simultaneously to the reset and trigger terminals during the timing interval will discharge C and re-initiate the cycle, commencing on the positive edge of the reset pulse. The output is held low as long as the reset pulse is low. When the reset input is not used, it should be connected to  $V_{CC}$  to prevent false triggering.

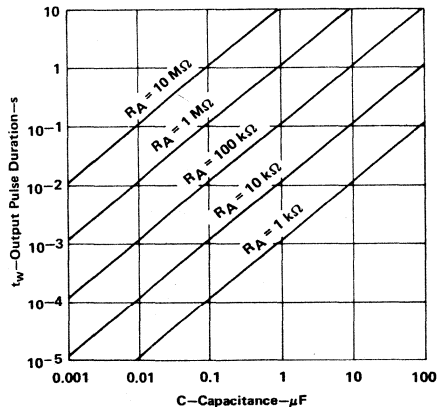
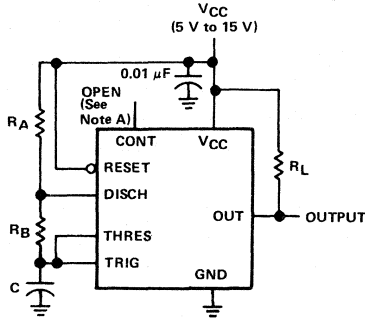


FIGURE 12—OUTPUT PULSE DURATION vs CAPACITANCE

**TYPICAL APPLICATION DATA**

**astable operation**



NOTE A: Decoupling the control voltage input to ground with a capacitor may improve operation. This should be evaluated for individual applications.

FIGURE 13—CIRCUIT FOR ASTABLE OPERATION

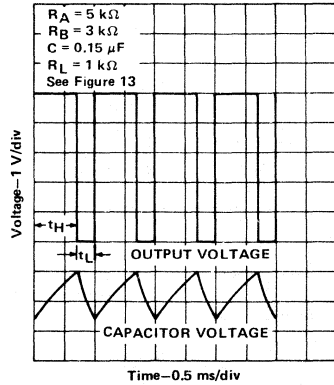


FIGURE 14—TYPICAL ASTABLE WAVEFORMS

Addition of a second resistor,  $R_B$ , to the circuit of Figure 10, as shown in Figure 13, and connection of the trigger input to the threshold input will cause the timer to self-trigger and run as a multivibrator. The capacitor  $C$  will charge through  $R_A$  and  $R_B$  then discharge through  $R_B$  only. The duty cycle may be controlled, therefore, by the values of  $R_A$  and  $R_B$ .

This astable connection results in capacitor  $C$  charging and discharging between the threshold-voltage level ( $\approx 0.67 \cdot V_{CC}$ ) and the trigger-voltage level ( $\approx 0.33 \cdot V_{CC}$ ). As in the monostable circuit, charge and discharge times (and therefore the frequency and duty cycle) are independent of the supply voltage.

Figure 14 shows typical waveforms generated during astable operation. The output high-level duration  $t_H$  and low-level duration  $t_L$  may be found by:

$$t_H = 0.693 (R_A + R_B) C$$

$$t_L = 0.693 (R_B) C$$

Other useful relationships are shown below.

$$\text{period} = t_H + t_L = 0.693 (R_A + 2R_B) C$$

$$\text{frequency} = \frac{1.44}{(R_A + 2R_B) C}$$

$$\text{Output driver duty cycle} = \frac{t_L}{t_H + t_L} = \frac{R_B}{R_A + 2R_B}$$

$$\text{Output waveform duty cycle} = \frac{t_H}{t_H + t_L} = 1 - \frac{R_B}{R_A + 2R_B}$$

$$\text{Low-to-high ratio} = \frac{t_L}{t_H} = \frac{R_B}{R_A + R_B}$$

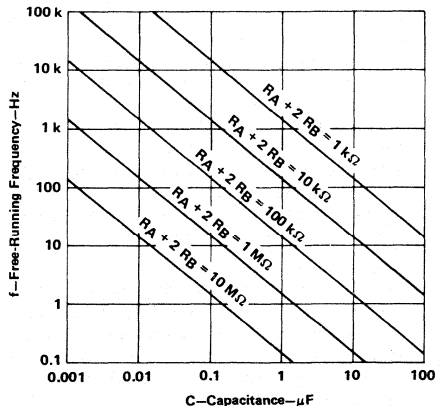


FIGURE 15—FREE-RUNNING FREQUENCY

TYPICAL APPLICATION DATA

missing-pulse detector

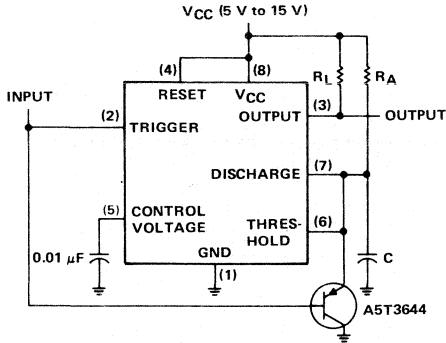


FIGURE 16—CIRCUIT FOR MISSING-PULSE DETECTOR

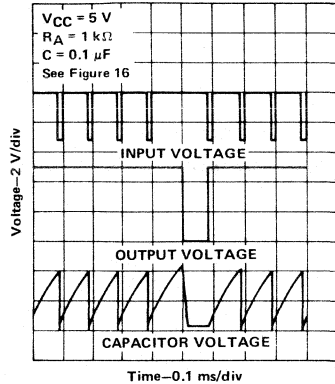


FIGURE 17—MISSING-PULSE DETECTOR WAVEFORMS

The circuit shown in Figure 16 may be utilized to detect a missing pulse or abnormally long spacing between consecutive pulses in a train of pulses. The timing interval of the monostable circuit is continuously retriggered by the input pulse train as long as the pulse spacing is less than the timing interval. A longer pulse spacing, missing pulse, or terminated pulse train will permit the timing interval to be completed, thereby generating an output pulse as illustrated in Figure 17.

frequency divider

By adjusting the length of the timing cycle, the basic circuit of Figure 10 can be made to operate as a frequency divider. Figure 18 illustrates a divide-by-3 circuit that makes use of the fact that retriggering cannot occur during the timing cycle.

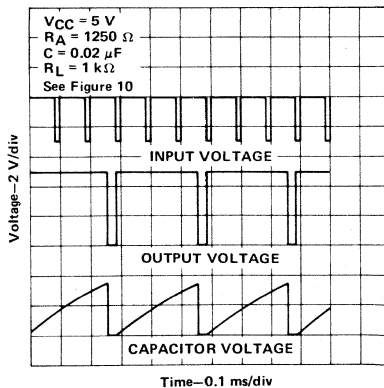
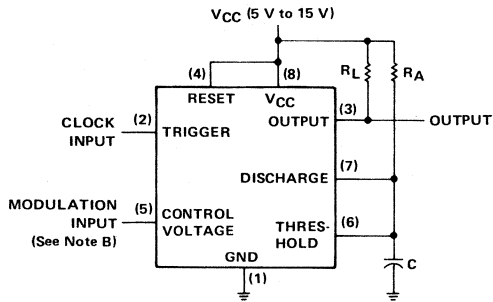


FIGURE 18—DIVIDE-BY-THREE CIRCUIT WAVEFORMS

# TYPES SE555, SE555C, SA555, NE555 PRECISION TIMERS

## TYPICAL APPLICATION DATA

### pulse-width modulation



NOTE B: The modulating signal may be direct or capacitively coupled to the control voltage terminal. For direct coupling, the effects of modulation source voltage and impedance on the bias of the timer should be considered.

FIGURE 19—CIRCUIT FOR PULSE-WIDTH MODULATION

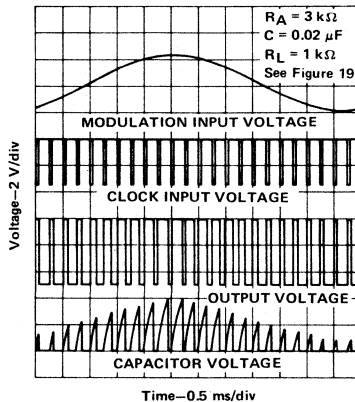


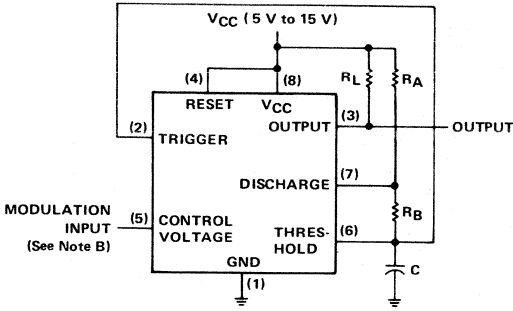
FIGURE 20—PULSE-WIDTH MODULATION WAVEFORMS

The operation of the timer may be modified by modulating the internal threshold and trigger voltages. This is accomplished by applying an external voltage (or current) to the control voltage pin. Figure 19 is a circuit for pulse-width modulation. The monostable circuit is triggered by a continuous input pulse train and the threshold voltage is modulated by a control signal. The resultant effect is a modulation of the output pulse width, as shown in Figure 20. A sine-wave modulation signal is illustrated, but any wave-shape could be used.



TYPICAL APPLICATION DATA

pulse-position modulation



NOTE B: The modulating signal may be direct or capacitively coupled to the control voltage terminal. For direct coupling, the effects of modulation source voltage and impedance on the bias of the timer should be considered.

FIGURE 21—CIRCUIT FOR PULSE-POSITION MODULATION

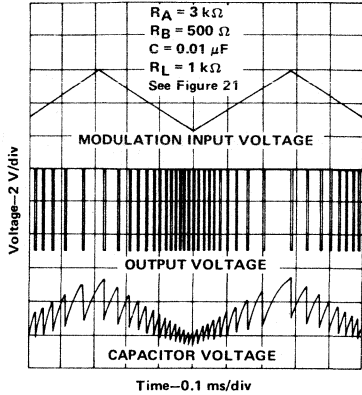


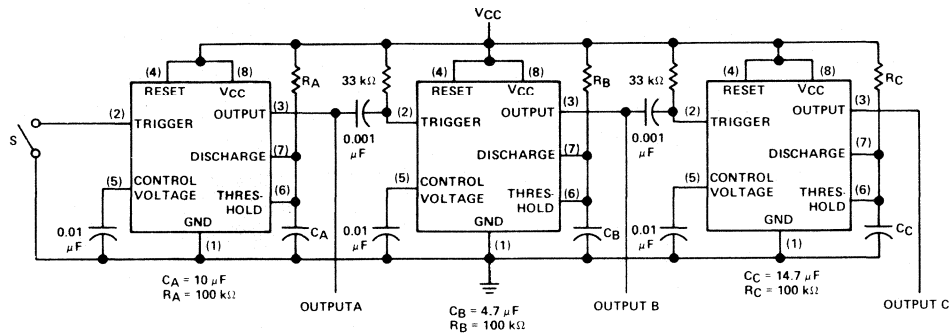
FIGURE 22—PULSE POSITION-MODULATION WAVEFORMS

Any of these timers may be used as a pulse-position modulator as shown in Figure 21. In this application, the threshold voltage, and thereby the time delay, of a free-running oscillator is modulated. Figure 22 shows such a circuit, with a triangular-wave modulation signal, however, any modulating wave-shape could be used.

**TYPES SE555, SE555C, SA555, NE555  
PRECISION TIMERS**

**TYPICAL APPLICATION DATA**

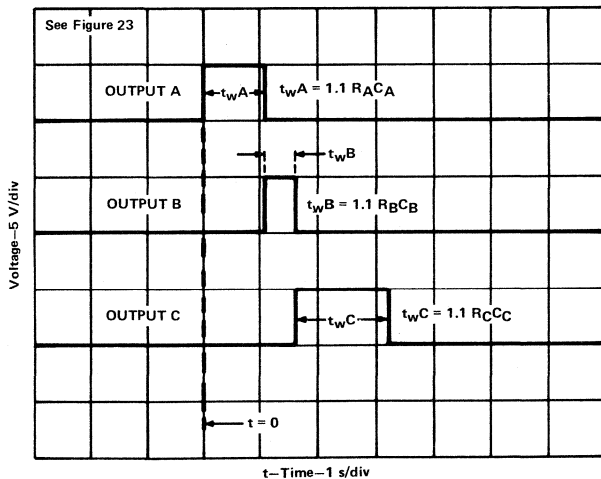
**sequential timer**



S closes momentarily at  $t = 0$ .

**FIGURE 23—SEQUENTIAL TIMER CIRCUIT**

Many applications, such as computers, require signals for initializing conditions during start-up. Other applications such as test equipment require activation of test signals in sequence. These timing circuits may be connected to provide such sequential control. The timers may be used in various combinations of astable or monostable circuit connections, with or without modulation, for extremely flexible waveform control. Figure 23 illustrates a sequencer circuit with possible applications in many systems and Figure 24 shows the output waveforms.



**FIGURE 24—SEQUENTIAL TIMER WAVEFORMS**

- Two Precision Timing Circuits per Package
- Astable or Monstable Operation
- TTL-Compatible Output can Sink or Source up to 150 mA
- Active Pull-Up or Pull-Down
- Designed to be Interchangeable with Signetics SE556, SE556C, SA556, NE556

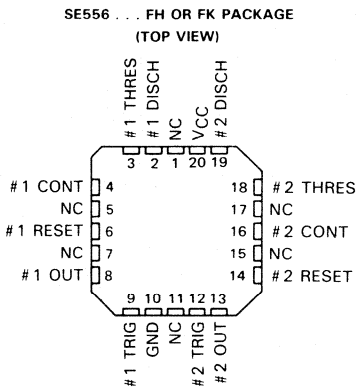
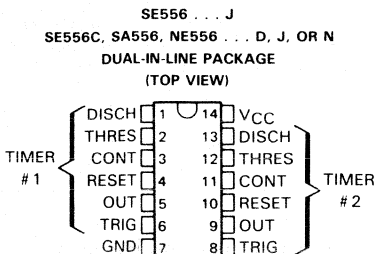
**APPLICATIONS**

- Precision Timer from Microseconds to Hours
- Sequential Timer
- Pulse-Shaping Circuit
- Pulse Generator
- Missing-Pulse Detector
- Tone-Burst Generator
- Pulse-Width Modulator
- Time-Delay Circuit
- Frequency Divider
- Pulse-Position Modulator
- Appliance Timer
- Touch-Tone Encoder
- Industrial Controls

**description**

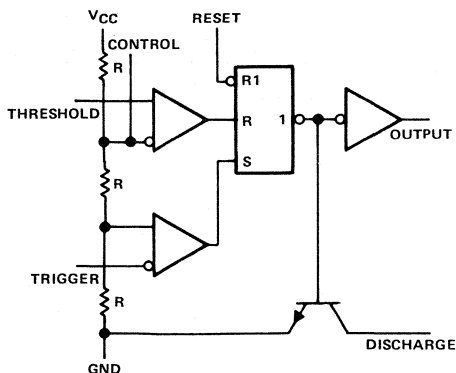
These devices provide two monolithic, independent timing circuits of the SE555, SE555C, SA555, or NE555 type in each package. These circuits can be operated in the astable or the monostable mode with external resistor-capacitor timing control. The basic timing provided by the RC time constant may be actively controlled by modulating the bias of the control voltage input.

The threshold and trigger levels are normally two-thirds and one-third respectively of  $V_{CC}$ . These levels can be altered by use of the control voltage terminal. When the trigger input falls below trigger level, the flip-flop is set and the output goes high. If the trigger input is above the trigger level and the threshold input is above the threshold level, the flip-flop is reset and the output is low. The reset input can override all other inputs and can be used to initiate a new timing cycle. When the reset input goes low, the flip-flop is reset and the output goes low. Whenever the output is low, a low-impedance path is provided between the discharge terminal and ground.



NC—No internal connection

**functional block diagram (each timer)**



Reset can override Trigger, which can override Threshold.

# TYPES SE556, SE556C, SA556, NE556

## DUAL PRECISION TIMERS

The SE556 and SE556C are characterized for operation over the full military range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The SA556 is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the NE556 is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

FUNCTION TABLE

RESET	TRIGGER VOLTAGE†	THRESHOLD VOLTAGE†	OUTPUT	DISCHARGE SWITCH
Low	Irrelevant	Irrelevant	Low	On
High	$< 1/3 V_{DD}$	Irrelevant	High	Off
High	$> 1/3 V_{DD}$	$> 2/3 V_{DD}$	Low	On
High	$> 1/3 V_{DD}$	$< 2/3 V_{DD}$	As previously established	

†Voltage levels shown are nominal.

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	18 V
Input voltage (control voltage, reset, threshold, trigger)	$V_{CC}$
Output current	$\pm 225$ mA
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 2)	600 mW
Operating free-air temperature range: SE556, SE556C	$-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$
SA556	$-40^{\circ}\text{C}$ to $85^{\circ}\text{C}$
NE556	$0^{\circ}\text{C}$ to $70^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: FH, FK, or J package	$300^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package	$260^{\circ}\text{C}$

NOTES: 1. All voltage values are with respect to network ground terminal.

2. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J package, SE556 and SE556C chips are alloy mounted, SA556 and NE556 chips are glass mounted.

### recommended operating conditions

	SE556		SE556C		SA556		NE556		UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
Supply voltage, $V_{CC}$	4.5	18	4.5	16	4.5	16	4.5	16	V
Input voltage (control voltage, reset, threshold, trigger)	$V_{CC}$		$V_{CC}$		$V_{CC}$		$V_{CC}$		V
Output current	$\pm 200$		$\pm 200$		$\pm 200$		$\pm 200$		mA
Operating free-air temperature, $T_A$	-55	125	-55	125	-40	85	0	70	$^{\circ}\text{C}$

# TYPES SE556, SE556C, SA556, NE556 DUAL PRECISION TIMERS

electrical characteristics at 25 °C free-air temperature,  $V_{CC} = 5\text{ V to }15\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	SE556			SE556C, SA556			UNIT	
		MIN	TYP	MAX	NE556				
Threshold voltage level	$V_{CC} = 15\text{ V}$	9.4	10	10.6	8.8	10	11.2	V	
	$V_{CC} = 5\text{ V}$	2.7	3.3	4	2.4	3.3	4.2		
Threshold current (see Note 1)		30			250			nA	
Trigger voltage level	$V_{CC} = 15\text{ V}$	4.8	5	5.2	4.5	5	5.6	V	
	$V_{CC} = 5\text{ V}$	1.45	1.67	1.9	1.1	1.67	2.2		
Trigger current	Trigger at 0 V	0.5			0.9			$\mu\text{A}$	
Reset voltage level		0.4	0.7	1	0.4	0.7	1	V	
Reset current <sup>†</sup>	Reset at $V_{CC}$	0.1			0.4			mA	
	Reset at 0 V	-0.4			-1				
Discharge switch off-state current		20			100			nA	
Control voltage (open-circuit)	$V_{CC} = 15\text{ V}$	9.6	10	10.4	9	10	11	V	
	$V_{CC} = 5\text{ V}$	2.9	3.3	3.8	2.6	3.3	4		
Low-level output voltage	$V_{CC} = 15\text{ V}$	$I_{OL} = 10\text{ mA}$	0.1		0.15		0.1	0.25	V
		$I_{OL} = 50\text{ mA}$	0.4		0.5		0.4	0.75	
		$I_{OL} = 100\text{ mA}$	2		2.25		2	3.2	
		$I_{OL} = 200\text{ mA}$	2.5				2.5		
	$V_{CC} = 5\text{ V}$	$I_{OL} = 5\text{ mA}$	0.05		0.15		0.05	0.25	
		$I_{OL} = 8\text{ mA}$	0.1		0.2		0.25	0.3	
High-level output voltage	$V_{CC} = 15\text{ V}$	$I_{OH} = -100\text{ mA}$	13	13.3	12.75		13.3	V	
		$I_{OH} = -200\text{ mA}$	12.5		12.5				
	$V_{CC} = 5\text{ V}$	$I_{OH} = -100\text{ mA}$	3	3.3	2.75	3.3			
Supply current	Output low,	$V_{CC} = 15\text{ V}$	20		24		30	mA	
		$V_{CC} = 5\text{ V}$	6		10		12		
	Output high,	$V_{CC} = 15\text{ V}$	18		20		26		
		$V_{CC} = 5\text{ V}$	4		8		10		

NOTE 1: This parameter influences the maximum value of the timing resistors  $R_A$  and  $R_B$  in the circuit of Figure 1. For example, when  $V_{CC} = 5\text{ V}$  the maximum value is  $R = R_A + R_B = 3.4\text{ M}\Omega$  and for  $V_{CC} = 15\text{ V}$  the maximum value for  $R_A + R_B = 10\text{ M}\Omega$ .

## operating characteristics, $V_{CC} = 5\text{ V and }15\text{ V}$

PARAMETER	TEST CONDITIONS <sup>†</sup>	SE556			SE556C, SA556			UNIT
		MIN	TYP	MAX	NE556			
Initial error of timing interval <sup>‡</sup>	Each timer, monostable <sup>§</sup>	0.5			1.5			%
	Each timer, astable <sup>¶</sup>	1.5			2.25			
	Timer 1 – Timer 2	$\pm 0.5$			$\pm 1$			
Temperature coefficient of timing interval	Each timer, monostable <sup>§</sup>	30			100			ppm/°C
	Each timer, astable <sup>¶</sup>	90			150			
	Timer 1 – Timer 2	$\pm 10$			$\pm 10$			
Supply voltage sensitivity of timing interval	Each timer, monostable <sup>§</sup>	0.05			0.2			%/V
	Each timer, astable <sup>¶</sup>	0.15			0.3			
	Timer 1 – Timer 2	$\pm 0.1$			$\pm 0.2$			
Output pulse rise time	$C_L = 15\text{ pF}$ , $T_A = 25\text{ }^\circ\text{C}$	100			200			ns
Output pulse fall time	$T_A = 25\text{ }^\circ\text{C}$	100			200			ns

<sup>†</sup>For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

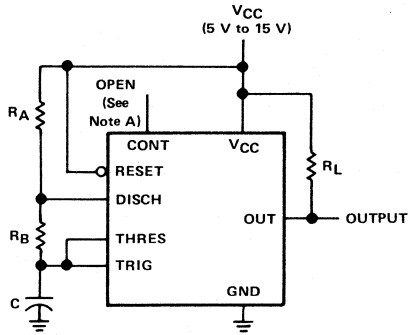
<sup>‡</sup>Timing interval error is defined as the difference between the measured value and the nominal value computed by the formula:  $t_w = 1.1 R_A C$ .

<sup>§</sup>Values specified are for a device in a monostable circuit similar to Figure 2, with component values as follow:  $R_A = 2\text{ k}\Omega$  to  $100\text{ k}\Omega$ ,  $C = 0.1\text{ }\mu\text{F}$ .

<sup>¶</sup>Values specified are for a device in an astable circuit similar to Figure 1, with component values as follow:  $R_A = 1\text{ k}\Omega$  to  $100\text{ k}\Omega$ ,  $C = 0.1\text{ }\mu\text{F}$ .

**TYPES SE556, SE556C, SA556, NE556**  
**DUAL PRECISION TIMERS**

**TYPICAL APPLICATION DATA**



NOTE A: Bypassing the control voltage input to ground with a capacitor may improve operation. This should be evaluated for individual applications.

FIGURE 1—CIRCUIT FOR ASTABLE OPERATION

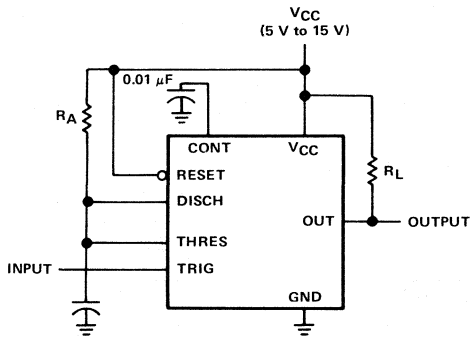
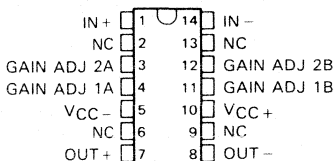


FIGURE 2—CIRCUIT FOR MONOSTABLE OPERATION

- 90-MHz Bandwidth
- Adjustable Gain to 400
- No Frequency Compensation Required
- Adjustable Passband
- Designed to be Interchangeable with Signetics SE592 and NE592

J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



NC—No internal connection

**description**

These devices are monolithic two-stage amplifiers with differential inputs and differential outputs.

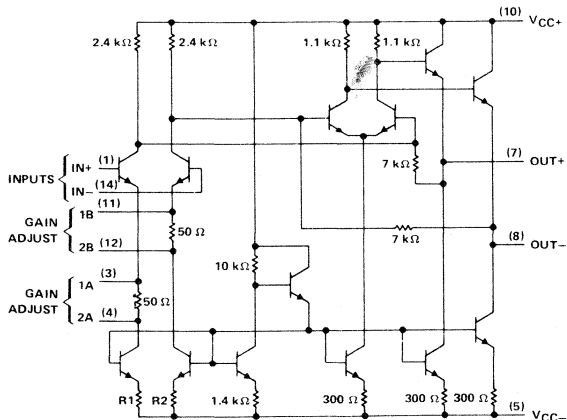
Internal series-shunt feedback provides wide bandwidth, low phase distortion, and excellent gain stability. Emitter-follower outputs enable the devices to drive capacitive loads, and all stages are current-source biased to obtain high common-mode and supply-voltage rejection ratios.

Fixed differential amplification of 100 or 400 may be selected without external components; or amplification may be adjusted from 0 to 400 by the use of a single external resistor connected between the gain-adjustment pins 1A and 1B. External frequency-compensating components are not required for any gain option.

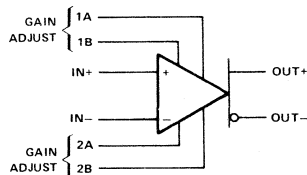
The devices are particularly useful in magnetic-tape or disc-file systems using phase or NRZ encoding and in high-speed thin-film or plated-wire memories. Other applications include general purpose video and pulse amplifiers where wide bandwidth, low phase shift, and excellent gain stability are required.

The SE592 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The NE592 and NE592A are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**schematic**



**symbol**



All resistor values shown are in ohms and nominal.  
In NE592 or SE592, R1 = 500 Ω, R2 = 500 Ω.  
In NE592A, R1 = 600 Ω, R2 = 600 Ω.

# TYPES SE592, NE592, NE592A DIFFERENTIAL VIDEO AMPLIFIERS

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage $V_{CC+}$ (see Note 1)	8 V
Supply voltage $V_{CC-}$ (see Note 1)	-8 V
Differential input voltage	$\pm 5$ V
Common-mode input voltage	$\pm 6$ V
Output current	10 mA
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 2)	500 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N package	260°C

- NOTES: 1. All voltage values except differential input voltages are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves in Section 2. In the J package, SE592 chips are alloy mounted, NE592 and NE592A chips are glass mounted.

## recommended operating conditions

	SE592			NE592 NE592A			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{CC+}$	3	6	8	3	6	8	V
Supply voltage, $V_{CC-}$	-3	-6	-8	-3	-6	-8	V
Operating free-air temperature, $T_A$	-55		125	0		70	°C





# TYPE SE592 DIFFERENTIAL VIDEO AMPLIFIER

electrical characteristics at 25 °C operating free-air temperature,  $V_{CC+} = 6\text{ V}$ ,  $V_{CC-} = -6\text{ V}$  (unless otherwise noted)

PARAMETER	TEST FIGURE	TEST CONDITIONS	GAIN OPTION †	SE592			UNIT		
				MIN	TYP	MAX			
A <sub>VD</sub>	Large-signal differential voltage amplification	1	$V_{OPP} = 3\text{ V}$ , $R_L = 2\text{ k}\Omega$	1	300	400	500	V/V	
				2	90	100	110		
BW	Bandwidth (–3 dB)	2	$V_{OPP} = 1\text{ V}$	1	40			MHz	
				2	90				
I <sub>O</sub>	Input offset current		1, 2, or 3	0.4	3		$\mu\text{A}$		
I <sub>B</sub>	Input bias current		1, 2, or 3	9	20		$\mu\text{A}$		
V <sub>ICR</sub>	Common-mode input voltage range	3	1, 2, or 3	$\pm 1$			V		
V <sub>OC</sub>	Common-mode output voltage	1	$R_L = \infty$	1, 2, or 3	2.4	2.9	3.4	V	
V <sub>OO</sub>	Output offset voltage	1	$V_{IO} = 0$ , $R_L = \infty$	1	1.5			V	
				2	1				
				3	0.35				
V <sub>OPP</sub>	Maximum peak-to-peak output voltage swing	1	$R_L = 2\text{ k}\Omega$	1, 2, or 3	3	4		V	
r <sub>i</sub>	Input resistance			1	4			k $\Omega$	
				2	20	30			
r <sub>o</sub>	Output resistance				20			$\Omega$	
C <sub>i</sub>	Input capacitance				2			pF	
CMRR	Common-mode rejection ratio	3	$V_{IC} = \pm 1\text{ V}$ , $f = 100\text{ kHz}$	2	60	86		dB	
		3	$V_{IC} = \pm 1\text{ V}$ , $f = 5\text{ MHz}$	2	60				
k <sub>SVR</sub>	Supply-voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	4	$\Delta V_{CC+} = \pm 0.5\text{ V}$ , $\Delta V_{CC-} = \pm 0.5\text{ V}$	2	50	70		dB	
V <sub>n</sub>	Broadband equivalent noise voltage	4	$BW = 1\text{ kHz to }10\text{ MHz}$	1, 2, or 3	12			$\mu\text{V}$	
t <sub>pd</sub>	Propagation delay time	2	$\Delta V_O = 1\text{ V}$	1	7.5			ns	
				2	6				
t <sub>r</sub>	Rise time	2	$\Delta V_O = 1\text{ V}$	1	10.5			ns	
				2	4.5				
I <sub>sink(max)</sub>	Maximum output sink current ‡			1, 2, or 3	3	4		mA	
I <sub>CC</sub>	Supply current		No load, No signal	1, 2, or 3	18			24	mA

† The gain option is selected as follows:

Gain Option 1 . . Gain Adjust pin 1A is connected to pin 1B, pins 2A and 2B are open.

Gain Option 2 . . Gain Adjust pin 2A is connected to pin 2B, pins 1A and 1B are open.

Gain Option 3 . . All Gain Adjust pins are open.

‡ For interchangeability considerations it should be kept in mind that this parameter is not guaranteed by all major manufacturers of SE592 as of the publication of this data sheet.

# TYPE SE592

## DIFFERENTIAL VIDEO AMPLIFIER

electrical characteristics over recommended operating free-air temperature range,  $V_{CC+} = 6\text{ V}$ ,  $V_{CC-} = -6\text{ V}$  (unless otherwise noted)

PARAMETER	TEST FIGURE	TEST CONDITIONS	GAIN OPTION †	SE592			UNIT
				MIN	TYP	MAX	
$A_{VD}$	Large-signal differential voltage amplification	$V_{OPP} = 3\text{ V}$	1	200		600	V/V
			2	80		120	
$I_{IO}$	Input offset current		1 or 2			5	$\mu\text{A}$
$I_{IB}$	Input bias current		1 or 2			40	$\mu\text{A}$
$V_{ICR}$	Common-mode input voltage range	3	1 or 2	$\pm 1$			V
$V_{OO}$	Output offset voltage	$V_{ID} = 0$ , $R_L = \infty$	1			1.5	V
			2			1.2	
			3			1	
$V_{OPP}$	Maximum output voltage peak-to-peak swing	1	$R_L = 2\text{ k}\Omega$	1 or 2	2.5		V
$r_i$	Input resistance			2	8		$\text{k}\Omega$
CMRR	Common-mode rejection ratio	3	$V_{IC} = \pm 1\text{ V}$ , $f = 100\text{ kHz}$	2	50		dB
kSVR	Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	4	$\Delta V_{CC+} = \pm 0.5\text{ V}$ , $\Delta V_{CC-} = \pm 0.5\text{ V}$	2	50		dB
$I_{sink(max)}$	Maximum output sink current			1, 2, or 3	2.5		mA
$I_{CC}$	Supply current	1	No load, No signal	1, 2, or 3		27	mA

† The gain option is selected as follows:

Gain Option 1 . . . Gain Adjust pin 1A is connected to pin 1B; pins 2A and 2B are open.

Gain Option 2 . . . Gain Adjust pin 2A is connected to pin 2B; pins 1A and 1B are open.

Gain Option 3 . . . All Gain Adjust pins are open.

electrical characteristics at 25 °C operating free-air temperature,  $V_{CC+} = 6\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
(unless otherwise noted)

PARAMETER	TEST FIGURE	TEST CONDITIONS	GAIN OPTION†	NE592			NE592A			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
AVD Large signal differential voltage amplification	1	$V_{Opp} = 3\text{ V}$ , $R_L = 2\text{ k}\Omega$	1	250	400	600	400	440	600	V/V
			2	80	100	120	80	100	120	
BW Bandwidth (-3 dB)	2	$V_{Opp} = 1\text{ V}$	1	40			40			MHz
			2	90			90			
$I_{io}$ Input offset current			1, 2, or 3	0.4	5		0.4	5	$\mu\text{A}$	
$I_{ib}$ Input bias current			1, 2, or 3	9	30		10	30	$\mu\text{A}$	
$V_{iCR}$ Common-mode input voltage range	3		1, 2, or 3	$\pm 1$			$\pm 1$		V	
			Common-mode output voltage							V
$V_{OC}$ Common-mode output voltage	1	$R_L = \infty$	1, 2, or 3	2.4	2.9	3.4	2.4	2.9	3.4	V
$V_{OO}$ Output offset voltage	1	$V_{ID} = 0$ , $R_L = \infty$	1 or 2			1.5			1.5	V
			3	0.35	0.75		0.35	0.75		
$V_{Opp}$ Maximum peak-to-peak output voltage swing	1	$R_L = 2\text{ k}\Omega$	1, 2, or 3	3	4		3	4	V	
$r_i$ Input resistance			1		4			4	k $\Omega$	
$r_o$ Output resistance			2	10	30		10	30	$\Omega$	
				20						
$C_i$ Input capacitance					2			2	pF	
CMRR Common-mode rejection ratio	3	$V_{IC} = \pm 1\text{ V}$ , $f = 100\text{ kHz}$	2	60	86		60	86	dB	
	3	$V_{IC} = \pm 1\text{ V}$ , $f = 5\text{ MHz}$	2	60	60		60	60		
kSVR Supply-voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	4	$\Delta V_{CC+} = \pm 0.5\text{ V}$ , $\Delta V_{CC-} = \pm 0.5\text{ V}$	2	50	70		50	70	dB	
$V_n$ Broadband equivalent noise voltage	4	$BW = 1\text{ kHz to }10\text{ MHz}$	1, 2, or 3		12			12	$\mu\text{V}$	
$t_{pd}$ Propagation delay time	2	$\Delta V_O = 1\text{ V}$	1	7.5		7.5			ns	
			2	6	10		6	10		
$t_r$ Rise time	2	$\Delta V_O = 1\text{ V}$	1	10.5		10.5			ns	
			2	4.5	12		4.5	12		
$I_{sink(max)}$ Maximum output sink current‡			1, 2, or 3	3	4		3	4	mA	
$I_{CC}$ Supply current		No load,	1, 2, or 3	18	24		19	24	mA	

† The gain option is selected as follows:

Gain Option 1 . . . Gain Adjust pin 1A is connected to pin 1B, pins 2A and 2B are open.

Gain Option 2 . . . Gain Adjust pin 2A is connected to pin 2B, pins 1A and 1B are open.

Gain Option 3 . . . All Gain Adjust pins are open.

‡ For interchangeability considerations it should be kept in mind that this parameter is not guaranteed by all major manufacturers of NE592 as of the publication of this data sheet.

# TYPES NE592, NE592

## DIFFERENTIAL VIDEO AMPLIFIERS

electrical characteristics over recommended operating free-air temperature range,  $V_{CC+} = 6\text{ V}$ ,  $V_{CC-} = -6\text{ V}$  (unless otherwise noted)

PARAMETER	TEST FIGURE	TEST CONDITIONS	GAIN OPTION†	NE592			NE592A			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
A/D Large-signal differential voltage amplification	1	$V_{Opp} = 3\text{ V}$	1	250	600	600	400	600	600	V/V
I/O Input offset current			2	80	120	80	80	120	120	V/V
I/O Input bias current			1 or 2			6		6	6	$\mu\text{A}$
I/O Common-mode input voltage range			1 or 2			40		40	40	$\mu\text{A}$
V <sub>ICR</sub> Common-mode input voltage range	3		1 or 2	$\pm 1$			$\pm 1$			V
V <sub>OO</sub> Output offset voltage	1	$V_{ID} = 0$ , $R_L = \infty$	1 or 2		1.5			1.5		V
V <sub>OPP</sub> Maximum output voltage peak-to-peak swing	1	$R_L = 2\text{ k}\Omega$	3		1			1		V
r <sub>i</sub> Input resistance			1 or 2	2.8			2.8			V
CMRR Common-mode rejection ratio	3	$V_{IC} = \pm 1\text{ V}$ , $f = 100\text{ kHz}$	2	8			8			k $\Omega$
CMRR Common-mode rejection ratio	3	$V_{IC} = \pm 1\text{ V}$ , $f = 100\text{ kHz}$	2	50			50			dB
kSVR Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	4	$\Delta V_{CC+} = \pm 0.5\text{ V}$ , $\Delta V_{CC-} = \pm 0.5\text{ V}$	2	50			50			dB
I <sub>sink(max)</sub> Maximum output sink current			1, 2, or 3				2.8	4		mA
ICC Supply current	1	No load, No signal	1, 2, or 3				27		27	mA

† The gain option is selected as follows:

Gain Option 1 . . . Gain Adjust pin 1A is connected to pin 1B; pins 2A and 2B are open.

Gain Option 2 . . . Gain Adjust pin 2A is connected to pin 2B; pins 1A and 1B are open.

Gain Option 3 . . . All Gain Adjust pins are open.

PARAMETER MEASUREMENT INFORMATION

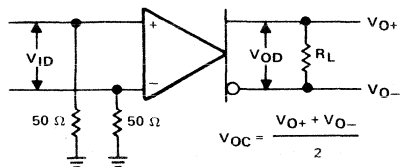


FIGURE 1

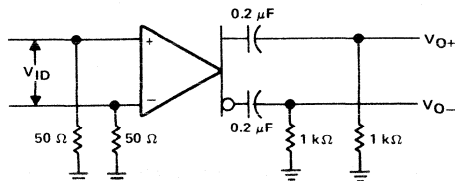


FIGURE 2

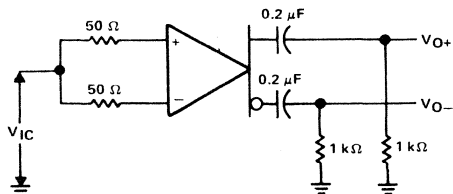


FIGURE 3

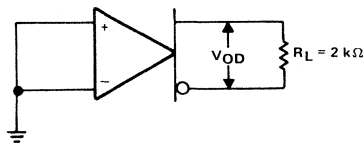
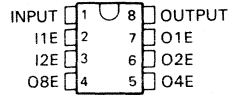


FIGURE 4



- 33 Distinct Input-to-Output Emitter Ratios from 3:1 to 1:15
- Wide Input Current Range: 1  $\mu$ A to 3 mA
- 35-Volt Output Capability
- High Output Impedance

P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**description**

The TL010 is a Wilson current mirror that provides output current in a selectable fixed ratio to the input current. The ratio is substantially independent of changes in load, voltages, and temperature. Selecting the ratio consists of connecting appropriate input emitter pins and output emitter pins to ground as shown in Figure 1.

The TL010 is designed to operate with up to 3 milliamperes input current if all three input emitter pins are used. It will also operate at voltages up to 35 volts.

The TL010I is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The TL010C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

typical values of current ratio at  $T_A = 25^{\circ}\text{C}$

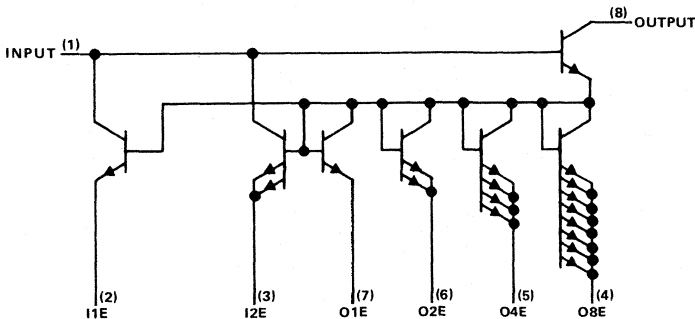
EMITTER RATIO $m:n^{\dagger}$	CURRENT RATIO $h_F = I_O/I_I$
1:15	14.1
1:14	13.2
1:13	12.3
1:12	11.4
1:11	10.5
1:10	9.55
1:9	8.62
1:8	7.72
2:15	7.23
1:7	6.71
2:13	6.29

EMITTER RATIO $m:n^{\dagger}$	CURRENT RATIO $h_F = I_O/I_I$
1:6	5.78
2:11	5.34
1:5	4.82
3:14	4.53
2:9	4.38
3:13	4.21
1:4	3.89
3:11	3.57
2:7	3.40
3:10	3.25
1:3	2.90

EMITTER RATIO $m:n^{\dagger}$	CURRENT RATIO $h_F = I_O/I_I$
3:8	2.61
2:5	2.43
3:7	2.26
1:2	1.98
3:5	1.64
2:3	1.45
3:4	1.32
1:1	0.99
3:2	0.663
2:1	0.50
3:1	0.332

$^{\dagger}m$  is the number of input emitters used,  $n$  is the number of output emitters used.

**schematic**



# TYPES TL010I, TL010C ADJUSTABLE-RATIO CURRENT MIRRORS

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Output voltage (see Note 1) . . . . .	45 V
Input current . . . . .	5 mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2) . . . . .	725 mW
Operating free-air temperature range: TL010I . . . . .	-40°C to 85°C
TL010C . . . . .	0°C to 70°C
Storage temperature range . . . . .	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . .	260°C

- NOTES: 1. Input and output voltages are with respect to the common terminal. Neither voltage should be more negative than -0.3 V.  
2. For operation above 25°C free-air temperature, derate linearly at the rate of 5.8 mW/°C.

## recommended operating conditions

	TL010I		TL010C		UNIT
	MIN	MAX	MIN	MAX	
Output voltage, $V_O$	5	35	5	35	V
Input voltage, $V_I$	0.6	1.7	0.65	1.6	V
Input current per input emitter, $I_I$	0.001	1	0.001	1	mA
Operating free-air temperature, $T_A$	-40	85	0	70	°C

## electrical characteristics over recommended ranges of operating free-air temperature and output voltage (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>1</sup>	TL010I			TL010C			UNIT	
		MIN	TYP <sup>2</sup>	MAX	MIN	TYP <sup>2</sup>	MAX		
$V_I$ Input voltage	$I_I = m \times 1 \mu\text{A}$	1			1			V	
		1.1			1.1				
		1.25			1.25				
		1.4			1.4				
$h_F$ Current ratio ( $I_O/I_I$ )	$I_I = \text{MIN to MAX}$	$m:n = 1:8$	6.97	7.72	8.13	7.05	7.72	8.13	
		$m:n = 1:4$	3.61	3.89	4.05	3.64	3.89	4.05	
		$m:n = 1:2$	1.84	1.98	2.07	1.88	1.98	2.07	
		$m:n = 1:1$	0.89	0.99	1.08	0.94	0.99	1.04	
		$m:n = 2:1$	0.46	0.50	0.56	0.475	0.50	0.525	
$\alpha_{HF}$ Temperature coefficient of current ratio	$I_I = \text{MIN to MAX}$	300			300			ppm/°C	
Output-to-input isolation	$I_I = \text{MIN to MAX}$ , $f = 1 \text{ kHz}$	60			60			dB	
$V_{O(th)}$ Output threshold voltage <sup>§</sup>	$I_I = \text{MIN to MAX}$	$T_A = \text{MIN}$	1.1			1.05			V
		$T_A = 25^\circ\text{C}$	1			1			
$r_O$ Output resistance <sup>¶</sup>	$F = 1 \text{ kHz}$	$I_I = m \times 10 \mu\text{A}$	200 m/n			200 m/n			MΩ
		$I_I = m \times 100 \mu\text{A}$	20 m/n			20 m/n			
		$I_I = m \times 1 \text{ mA}$	2 m/n			2 m/n			
$f_{max}$ Maximum operating frequency <sup>#</sup>	$I_I = m \times 1 \text{ mA}$ , $R_L = 500 \Omega$	10			10			MHz	

<sup>1</sup> m is the number of input emitters, n is the number of output emitters. For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

<sup>2</sup> All typical values are at  $T_A = 25^\circ\text{C}$ .

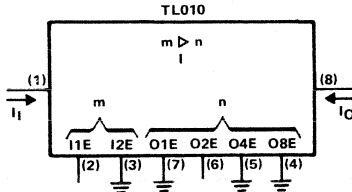
<sup>§</sup> Output threshold voltage is the voltage at which the current ratio is equal to 90% of its value at  $V_O = 15 \text{ V}$ .

<sup>¶</sup> The output resistance is directly proportional to the number of input emitters divided by the number of output emitters (m/n).

<sup>#</sup> Maximum operating frequency is the frequency at which the output current is down 3 dB from its low-frequency value.



TYPICAL APPLICATION INFORMATION



See notes 3 and 4

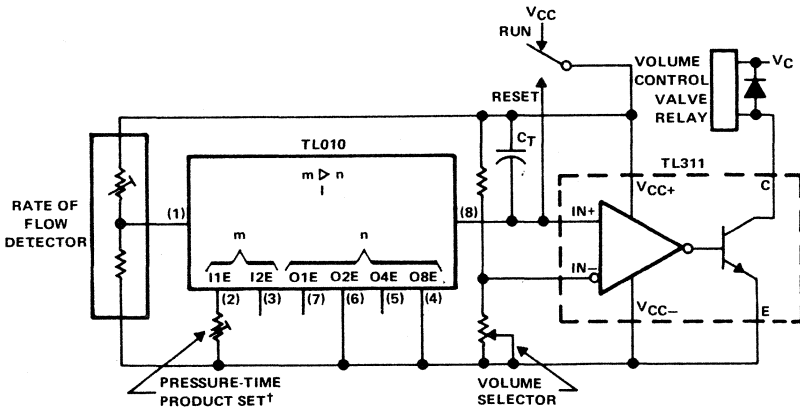
FIGURE 1—CURRENT MIRROR SET FOR A CURRENT RATIO OF 2:13

NOTES: 3. Selected emitters must be grounded as close as possible to the package to avoid unstable device behavior.  
Using the fixed-Beta model, the current ratio for a current mirror of  $m$  input emitters and  $n$  output emitters may be calculated as

$$\frac{I_O}{I_I} = \frac{\beta^2 n + \beta(n+m)}{\beta^2 m + (\beta+1)(m+n)}$$

Second-order effects, such as on-chip self-heating, may slightly perturb the observed ratio from the calculated value.

4. At high current levels a small capacitor (270 pF) may be required between the input and output terminals to improve stability.



†Adjust for a mirror of 11.9

In this application of the TL010, the problem is to measure a precise volume of liquid flowing through a line and shut off the flow with a relay when the limit is reached. For the particular volume to be measured and the pressure detector used, a current gain of 11.9 is required. By setting the TL010 for a gain of 10 with the emitter selection, the exact gain of 11.9 may be obtained by adjusting the pressure-time product control.





- Wide Input Current Range:  
1  $\mu$ A to 1 mA
- 35-Volt Output Capability
- High Output Impedance
- Guaranteed Current-Ratio Tolerances over Full Temperature Range:  
±8% for I Suffix  
±7% for C Suffix
- Typically Less Than ±1% Error at 25°C

LP PACKAGE  
(TOP VIEW)



TEMPERATURE RANGE	INPUT-TO-OUTPUT CURRENT RATIO			
	1:1	1:2	1:4	2:1
-40°C to 85°C	TL011I	TL012I	TL014I	TL021I
0°C to 70°C	TL011C	TL012C	TL014C	TL021C

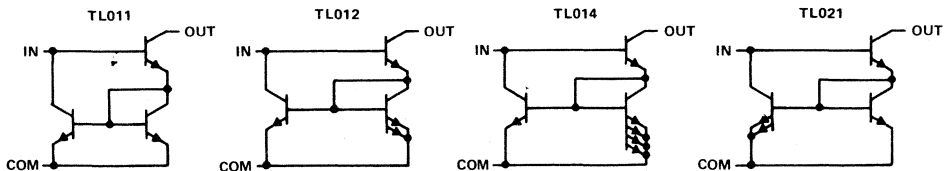
**description**

The TL011, TL012, TL014, and TL021 are Wilson current mirrors with output currents in fixed proportion to the input currents and substantially independent of changes in voltage, load, and temperature. These devices make use of the tight matching properties of identical bipolar transistors on a monolithic integrated circuit chip to achieve current-ratio accuracy typically better than 98%.

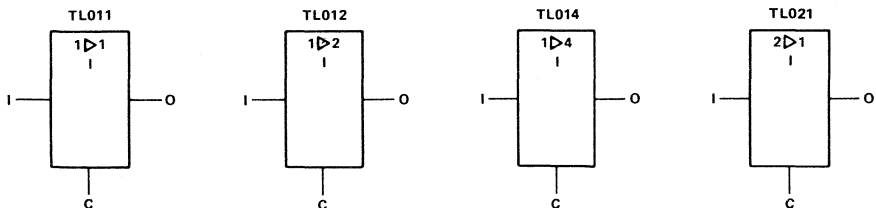
Current mirrors are used extensively in linear integrated circuit designs as active loads for operational-amplifier stages and as current sources for other stages. The TL011 family gives the designer this same capability with no sacrifice in accuracy or stability.

The TL011, TL012, and TL014 are designed to operate with input currents up to 1 milliamperes and output voltage up to 35 volts. The TL021 is designed for 2 milliamperes and 35 volts.

**schematics**



**symbols**



**Special Functions**

# SERIES TL011, TL012, TL014, TL021 FIXED-RATIO N-P-N CURRENT MIRRORS

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Output voltage (see Note 1) .....	45 V
Input current .....	5 mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2) .....	775 mW
Operating free-air temperature range: TL011I, TL012I, TL014I, TL021I .....	-40°C to 85°C
TL011C, TL012C, TL014C, TL021C .....	0°C to 70°C
Storage temperature range .....	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	260°C

- NOTES: 1. Input and output voltages are with respect to the common terminal. Neither voltage should be more negative than -0.3 V.  
 2. For operation above 25°C free-air temperature, derate linearly at the rate of 6.2 mW/°C.

## recommended operating conditions

		TLO__I		TLO__C		UNIT
		MIN	MAX	MIN	MAX	
Output voltage, $V_O$		5	35	5	35	V
Input current, $I_O$	TL021	0.002	2	0.002	2	mA
	All others	0.001	1	0.001	1	
Operating free-air temperature, $T_A$		-40	85	0	70	°C



**SERIES TL011, TL012, TL014, TL021  
FIXED-RATIO N-P-N CURRENT MIRRORS**

electrical characteristics over recommended ranges of operating free-air temperature and output voltage (unless otherwise noted)

PARAMETER	TEST CONDITIONS	TL011			TL012			TL014			TL021			UNIT
		MIN	TYPT	MAX	MIN	TYPT	MAX	MIN	TYPT	MAX	MIN	TYPT	MAX	
V <sub>I</sub> Input voltage	I <sub>I</sub> = 1 μA			1										
	I <sub>I</sub> = 2 μA													
	I <sub>I</sub> = 10 μA			1.1										
	I <sub>I</sub> = 20 μA													
	I <sub>I</sub> = 100 μA			1.25										
V <sub>I</sub> Input voltage	I <sub>I</sub> = 200 μA													
	I <sub>I</sub> = 1 mA			1.4										
	I <sub>I</sub> = 2 mA													
h <sub>FE</sub> Current ratio (I <sub>O</sub> /I <sub>I</sub> )	I <sub>I</sub> = MIN to MAX†	0.92	1	1.08	1.84	2	2.16	3.68	4	4.32	0.46	0.5	0.54	
		0.93	1	1.07	1.86	2	2.14	3.72	4	4.28	0.465	0.5	0.535	
α <sub>HF</sub> Temperature coefficient of current ratio	I <sub>I</sub> = MIN to MAX			50			100			200			200	ppm/°C
	I <sub>I</sub> = MIN to MAX, f = 1 kHz			80			80			80			80	dB
V <sub>O</sub> (lth) Output-to-input isolation threshold voltage‡	TA = -40°C			1.35			1.35			1.35			1.35	
	TA = 0°C			1.25			1.25			1.25			1.25	V
	TA = 25°C			1.2			1.2			1.2			1.2	
	TA = 25°C			200			100			50			200	
f <sub>O</sub> Output resistance	I <sub>I</sub> = 20 μA													
	I <sub>I</sub> = 100 μA			20			10			5				MΩ
	I <sub>I</sub> = 200 μA												20	
	I <sub>I</sub> = 1 mA			2			1			0.5				
f <sub>max</sub> Maximum operating frequency††	I <sub>I</sub> = 2 mA												2	
	I <sub>I</sub> = MAX, R <sub>L</sub> = 500 Ω			10			10			10			10	MHz

† All typical values are at T<sub>A</sub> = 25°C.

‡ For test conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

§ Output threshold voltage is the voltage at which the current ratio is equal to 90% of its value at V<sub>O</sub> = 15 V.

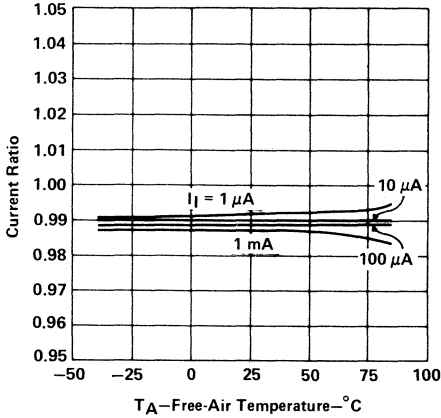
¶ Maximum operating frequency is the frequency at which the output current is down 3 dB from its low frequency value.

**SERIES TL011, TL012, TL014, TL021  
FIXED-RATIO N-P-N CURRENT MIRRORS**

**TYPICAL CHARACTERISTICS**

**TL011  
CURRENT RATIO  
vs**

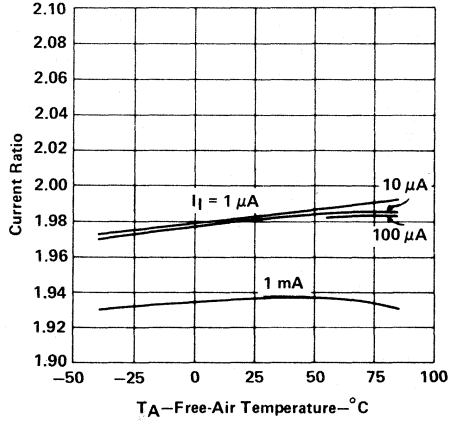
**FREE-AIR TEMPERATURE**



**FIGURE 1**

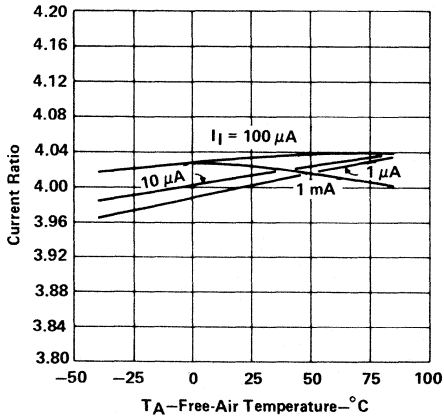
**TL012  
CURRENT RATIO  
vs**

**FREE-AIR TEMPERATURE**



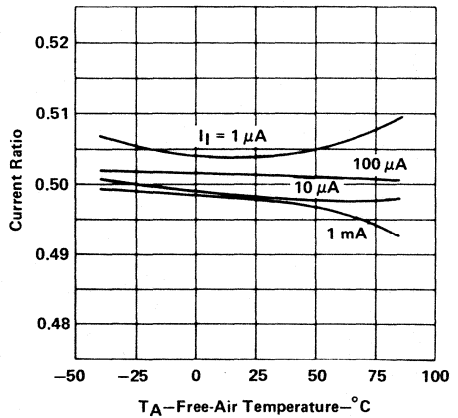
**FIGURE 2**

**TL014  
CURRENT RATIO  
vs  
FREE-AIR TEMPERATURE**



**FIGURE 3**

**TL021  
CURRENT RATIO  
vs  
FREE-AIR TEMPERATURE**



**FIGURE 4**

**SERIES TL011, TL012, TL014, TL021  
FIXED-RATIO N-P-N CURRENT MIRRORS**

**TYPICAL APPLICATIONS INFORMATION**

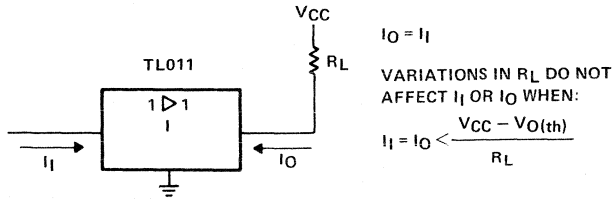
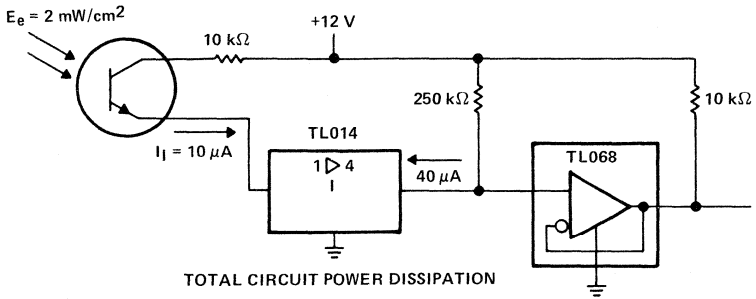


FIGURE 5—BASIC CURRENT BUFFER



Idle condition:  $P_D = 1.5 \text{ mW}$  typical  
 On condition:  $P_D = 12.5 \text{ mW}$  typical  
 $10 \mu\text{A}$  from phototransistor provides a  $V_O$  swing of  $10 \text{ V}$  at  $1 \text{ mA}$ .

FIGURE 6—PHOTOTRANSISTOR PREAMPLIFIER

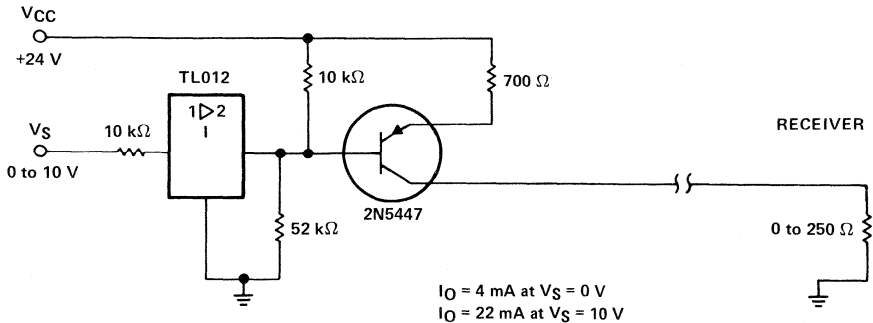
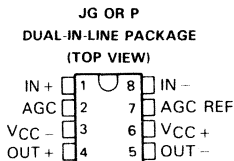


FIGURE 7—TWO-WIRE LINEAR CURRENT-MODE TRANSMITTER





- Low Output Common-Mode Sensitivity to AGC Voltages
- Input and Output Impedances Independent of AGC Voltage
- Maximum Gain of 100 Typ
- Wide AGC Range
- 3-dB Bandwidth at 60 MHz
- Other Characteristics Similar to NE592 and uA733



**description**

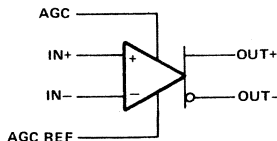
This device is a monolithic two-stage video amplifier with differential inputs and outputs.

Internal feedback provides wide bandwidth, low phase distortion, and excellent gain stability. Variable gain based on signal summation provides large AGC control over a wide bandwidth with low harmonic distortion.

Emitter-follower outputs enable the device to drive capacitive loads. All stages are current-source biased to obtain high common-mode and supply-voltage rejection ratios. The gain of 100 may be electronically attenuated as much as 50 dB at 60 MHz by applying a control voltage to the AGC pins. No external frequency compensation components are required.

This device is particularly useful in TV and Radio IF and RF AGC circuits, as well as magnetic-tape and disc-file systems where AGC is needed. Other applications include video and pulse amplifiers where a large AGC range, wide bandwidth, low phase shift, and excellent gain stability are required.

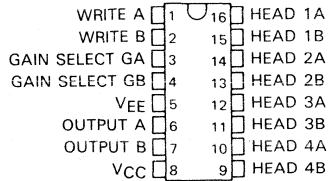
**symbol**





- Operates from  $\pm 6\text{-V}$  Supplies or 12-V Supply
- Head Read-Select-Diode Array
- Dual Write Current Inputs
- Read Amplifier Gain Adjustable with Single External Resistor and Capacitor
- Wide Bandwidth, Low Phase Distortion, and Excellent Gain Stability
- High Common-Mode Rejection

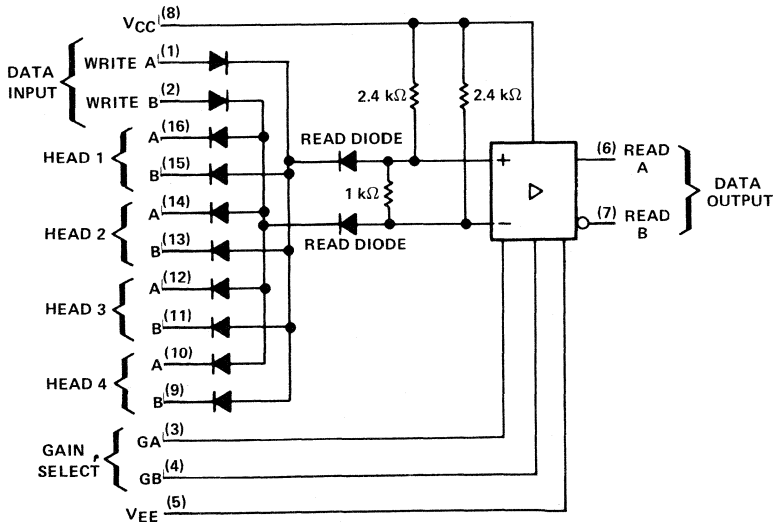
N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**description**

The TL030 is a monolithic high-speed disk-memory read amplifier fabricated with bipolar Schottky process technology. The device consists of a diode selection matrix comprised of write, read, and head diodes preceding a video amplifier. The head read diode array may be externally biased to select one of four-disk memory heads. The resultant analog signal is then amplified by the read amplifier and presented as differential emitter-follower output voltages. The TL030 is characterized for operation from 0°C to 70°C.

**functional block diagram**

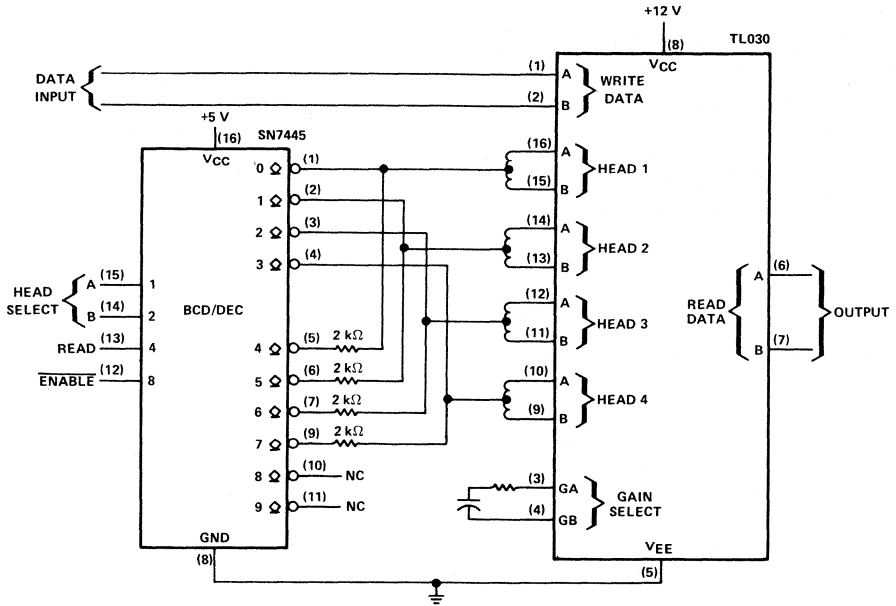


**PRODUCT PREVIEW**

This document contains information on a product under development. Texas Instruments reserves the right to change or discontinue this product without notice.

**TYPE TL030  
FOUR-HEAD DISK-MEMORY READ AMPLIFIER**

**TYPICAL APPLICATION DATA**

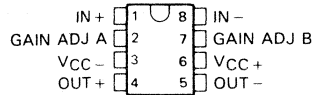


Special Functions



- 8-Pin Version of NE592 . . . Saves Printed Circuit Board Space
- Adjustable Gain to 400
- No Frequency Compensation Required
- Adjustable Passband

P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**description**

This device is a monolithic two-stage video amplifier with differential inputs and differential outputs.

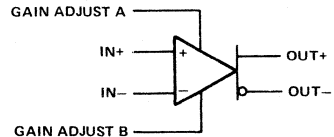
Internal series-shunt feedback provides wide bandwidth, low phase distortion, and excellent gain stability. Emitter-follower outputs enable the device to drive capacitive loads. All stages are current-source biased to obtain high common-mode and supply-voltage rejection ratios.

Fixed differential amplification of nominally 400 may be selected without external components, or amplification may be adjusted from 0 to approximately 400 by the use of a single external resistor connected between the gain-adjustment pins A and B. No external frequency-compensating components are required for any gain option.

The device is particularly useful in magnetic-tape or disc-file systems using phase or NRZ encoding and in high-speed thin-film or plated-wire memories. Other applications include general-purpose video and pulse amplifiers where wide bandwidth, low phase shift, and excellent gain stability are required.

The TL592 and TL592A are characterized for operation from 0°C to 70°C.

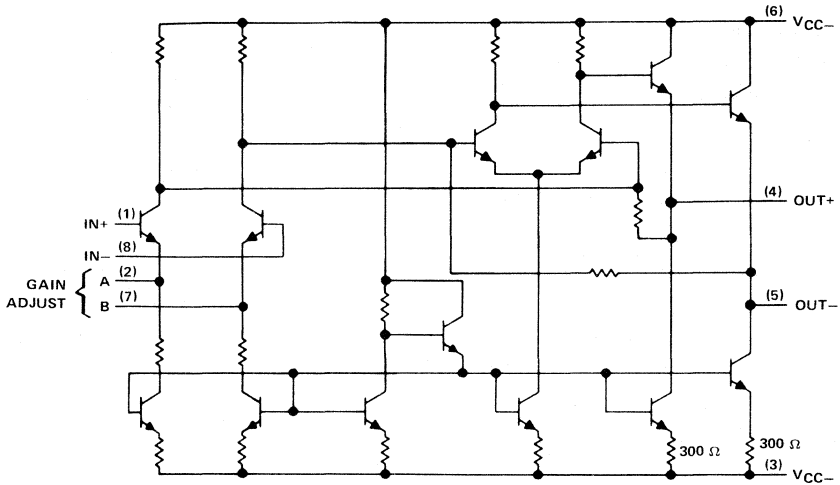
**symbol**



# TYPES TL592, TL592A

## DIFFERENTIAL VIDEO AMPLIFIERS

schematic



### absolute maximum ratings over operating free-air temperature (unless otherwise noted)

Supply voltage, $V_{CC+}$ (see Note 1) .....	8 V
Supply voltage, $V_{CC-}$ (see Note 1) .....	-8 V
Differential input voltage .....	$\pm 5$ V
Voltage range, any input .....	$V_{CC+}$ to $V_{CC-}$
Output current .....	10 mA
Continuous total power dissipation .....	500 mW
Operating free-air temperature range .....	0°C to 70°C
Storage temperature range .....	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	260°C

NOTE 1: All voltage values except differential input voltages are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC+}$	3	6	8	V
Supply voltage, $V_{CC-}$	-3	-6	-8	V
Operating free-air temperature, $T_A$	0		70	°C

electrical characteristics at specified free-air temperature,  $V_{CC+} = 6\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $R_L = 2\text{ k}\Omega$  (unless otherwise noted)

PARAMETER	TEST FIGURE	TEST CONDITIONS	GAIN OPTION <sup>1</sup>		TL592		TL592A		UNIT	
			MIN	MAX	MIN	MAX	MIN	MAX		
A <sub>V</sub> D	1	$V_{OPP} = 3\text{ V}$ , $R_L = 2\text{ k}\Omega$	250	400	600	400	440	600	V/V	
BW	2	$V_{OPP} = 1\text{ V}$	250	50	600	400	600	600	MHz	
I <sub>IO</sub>			25°C	0.4	5	50	0.4	5	μA	
I <sub>IB</sub>			0°C to 70°C	9	6	30	10	30	μA	
V <sub>ICR</sub>	3		25°C	±1		±1			V	
V <sub>OC</sub>	1	$R_L = \infty$	0°C to 70°C	±1		±1			V	
V <sub>OO</sub>	1	$V_{ID} = 0$ , $R_L = \infty$	25°C	0.35	0.75	0.35	0.75	0.75	V	
V <sub>OPP</sub>	1	$R_L = 2\text{ k}\Omega$	0°C to 70°C	3	4	3	4	4	V	
z <sub>i</sub>		$V_{OD} = 1\text{ V}$ , $f = 1\text{ kHz to } 10\text{ MHz}$	25°C	2.8	4	2.8	3.6	3.6	kΩ	
CMRR	3	$V_{IC} = \pm 1\text{ V}$	25°C	60	86	60	86	86	dB	
k <sub>SVR</sub>	4	$\Delta V_{CC+} = \pm 0.5\text{ V}$ , $\Delta V_{CC-} = \pm 0.5\text{ V}$	0°C to 70°C	50	60	50	60	60	dB	
V <sub>n</sub>	4	BW = 1 kHz to 10 MHz	25°C	50	70	50	70	70	dB	
t <sub>pd</sub>	2	$\Delta V_{O} = 1\text{ V}$	25°C	7.5	10.5	7.5	10.5	10.5	ns	
t <sub>r</sub>	2	$\Delta V_{O} = 1\text{ V}$	25°C	7.5	10.5	7.5	10.5	10.5	ns	
I <sub>sink(max)</sub>		Maximum output sink current	1, 2, or 3	3	4	3	4	4	ma	
I <sub>CC</sub>		Supply current	25°C	18	24	18	24	19	24	mA
		No signal	0°C to 70°C	27	27	27	27	27	mA	

<sup>1</sup>The gain option is selected as follows:  
Gain Option 1 . . . . . Gain adjust pin A is connected to pin B.  
Gain Option 2 . . . . . Gain adjust pins A and B are open.

**TYPES TL592, TL592A**  
**DIFFERENTIAL VIDEO AMPLIFIERS**

**PARAMETER MEASUREMENT INFORMATION**

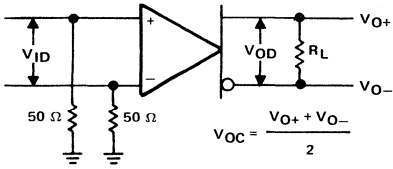


FIGURE 1

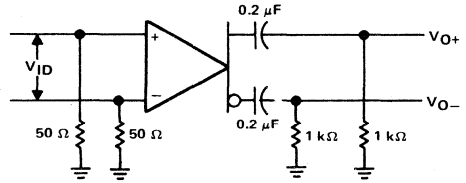


FIGURE 2

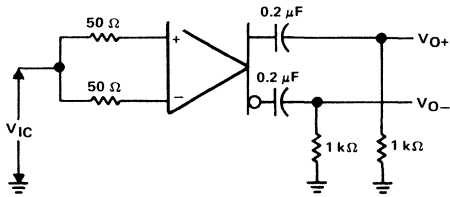


FIGURE 3

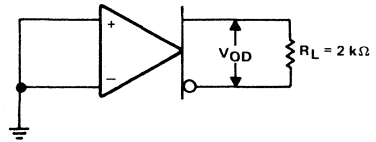


FIGURE 4

Special Functions





- Adjustable Gain to 400
- No Frequency Compensation Required
- Adjustable Passband
- Lower Noise . . . Less than 3  $\mu$ V

**description**

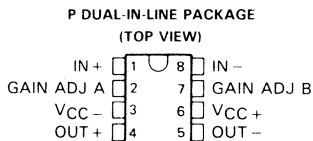
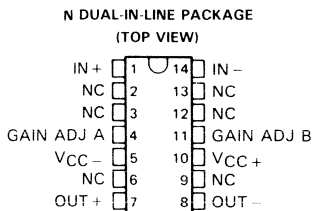
This device is a monolithic two-stage video amplifier with differential inputs and differential outputs. It features internal series-shunt feedback that provides wide bandwidth, low phase distortion, and excellent gain stability. Emitter-follower outputs enable the device to drive capacitive loads. All stages are current-source biased to obtain high common-mode and supply-voltage rejection ratios.

Fixed differential amplification of 400 may be selected without external components, or amplification may be adjusted from 0 to 400 by the use of a single external resistor connected between the gain-adjustment pins A and B. No external frequency-compensating components are required for any gain option.

The device is particularly useful in magnetic-tape or disc-file systems that use phase or NRZ encoding and in high-speed thin-film or plated-wire memories. Other applications include general-purpose video and pulse amplifiers.

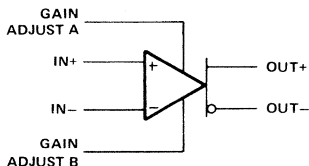
The device achieves lower equivalent noise through special processing and a new circuit layout incorporating input transistors with low base resistance.

The TL592B will be characterized for operation from 0°C to 70°C.



NC - No internal connection

**symbol**





- Very Low Power Consumption . . . 1 mW  
Typ at  $V_{DD} = 5\text{ V}$
- Capable of Very-High-Speed Operation  
Typically 2 MHz in Astable Mode
- Complementary MOS Output Capable of  
Swinging Rail-to-Rail
- High Output-Current Capability  
Sink 100 mA Typ  
Source 10 mA Typ
- Output Fully CMOS-, TTL-, and  
MOS-Compatible
- Low Supply Current Reduces Spikes During  
Output Transitions
- High Impedance Inputs . . .  $10^{12}\ \Omega$  Typ
- Single-Supply Operation from 1 to 18 Volts
- Functionally Interchangeable with the  
Signetics NE555; has Same Pinout

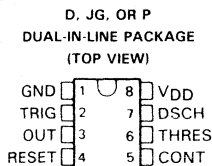
**description**

The TLC551 is a monolithic timing circuit fabricated using TI's LinCMOS™ process. Due to its high-impedance inputs (typically  $10^{12}\ \Omega$ ), it is capable of producing accurate time delays and oscillations while using less-expensive, smaller timing capacitors than the NE555. Like the NE555, the TLC551 achieves both monostable (using one resistor and one capacitor) and astable (using two resistors and one capacitor) operation. In addition, 50% duty cycle astable operation is possible using only a single resistor and one capacitor. The LinCMOS™ process allows the TLC551 to operate at frequencies up to 2 MHz and be fully compatible with CMOS, TTL, and MOS logic. It also provides very low power consumption (typically 1 mW at  $V_{DD} = 5\text{ V}$ ) over a wide range of supply voltages ranging from 1 volt to 18 volts.

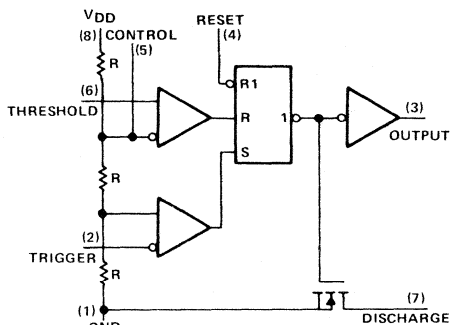
The threshold and trigger levels are normally two-thirds and one-third respectively of  $V_{DD}$ . These levels can be altered by use of the control voltage terminal. When the trigger input falls below the trigger level, the flip-flop is set and the output goes high. If the trigger input is above the trigger level and the threshold input is above the threshold level, the flip-flop is reset and the output is low. The reset input can override all other inputs and can be used to initiate a new timing cycle. When the reset input goes low, the flip-flop is reset and the output goes low. Whenever the output is low, a low-impedance path is provided between the discharge terminal and ground.

While the CMOS output is capable of sinking over 100 mA and sourcing over 10 mA, the TLC551 exhibits greatly reduced supply current spikes during output transitions. This minimizes the need for the large decoupling capacitors required by the NE555.

The TLC551C is characterized for operation from 0°C to 70°C.



**functional block diagram**



Reset can override Trigger, which can override Threshold.

**ADVANCE INFORMATION**

This document contains information on a new product. Specifications are subject to change without notice.

# TYPE TLC551C LinCMOS™ TIMER

FUNCTION TABLE

RESET	TRIGGER VOLTAGE†	THRESHOLD VOLTAGE†	OUTPUT	DISCHARGE SWITCH
Low	Irrelevant	Irrelevant	Low	On
High	< 1/3 V <sub>DD</sub>	Irrelevant	High	Off
High	> 1/3 V <sub>DD</sub>	> 2/3 V <sub>DD</sub>	Low	On
High	> 1/3 V <sub>DD</sub>	< 2/3 V <sub>DD</sub>	As previously established	

† Voltages levels shown are nominal.

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V <sub>DD</sub> (see Note 1)	18 V
Input voltage range (any input)	-0.3 V to 18 V
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	600 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package	260°C

- NOTES: 1. All voltage values are with respect to network ground terminal.  
2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2.

### electrical characteristics at 25°C free-air temperature, V<sub>DD</sub> = 1 V to 15 V (unless otherwise noted)

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Threshold voltage level as a percentage of supply voltage			66.7%			
Threshold current	V <sub>DD</sub> = 5 V		10			pA
Trigger voltage level as a percentage of supply voltage			33.3%			
Trigger current	V <sub>DD</sub> = 5 V		10			pA
Reset voltage level			0.7			V
Reset current	V <sub>DD</sub> = 5 V		±10			pA
Control voltage (open-circuit) as a percentage of supply voltage			66.7%			
Low-level output voltage	V <sub>DD</sub> = 15 V	I <sub>OL</sub> = 10 mA	0.1		V	
		I <sub>OL</sub> = 50 mA	0.5			
		I <sub>OL</sub> = 100 mA	1			
	V <sub>DD</sub> = 5 V	I <sub>OL</sub> = 5 mA	0.1			
		I <sub>OL</sub> = 8 mA	0.16			
		I <sub>OL</sub> = 10 mA	14.8			
High-level output voltage	V <sub>DD</sub> = 15 V	I <sub>OH</sub> = -1 mA	14		V	
		I <sub>OH</sub> = -5 mA	12.7			
		I <sub>OH</sub> = -10 mA	4			
	V <sub>DD</sub> = 5 V	I <sub>OH</sub> = -2 mA	4.5			
		I <sub>OH</sub> = -1 mA	360			
		I <sub>OH</sub> = -1 mA	170			
Supply current	V <sub>DD</sub> = 15 V		360		μA	
	V <sub>DD</sub> = 5 V		170			

operating characteristics,  $V_{DD} = 1.2\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Initial error of timing interval	$V_{DD} = 1\text{ V to }15\text{ V}$ , $R_A = R_B = 1\text{ k}\Omega\text{ to }100\text{ k}\Omega$ , $C_T = 0.1\ \mu\text{F}$ , See Note 1		1%		
Supply voltage sensitivity of timing interval			0.1		%/V
Output pulse rise time	$R_L = 10\text{ M}\Omega$ , $C_L = 10\text{ pF}$		20		ns
Output pulse fall time			20		
Maximum frequency in astable mode	$R_A = 470\ \Omega$ , $R_B = 200\ \Omega$ , $C_T = 200\text{ pF}$ , See Note 1		2.1		MHz

NOTE 1:  $R_A$ ,  $R_B$ , and  $C_T$  are as defined in Figure 1.

**TYPICAL APPLICATION DATA**

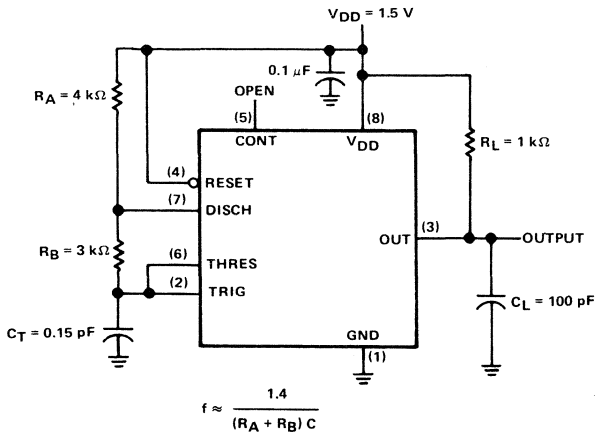


FIGURE 1—CIRCUIT FOR ASTABLE OPERATION



- Very Low Power Consumption  
... 2 mW Typ at  $V_{DD} = 5\text{ V}$
- Capable of Very High-Speed Operation  
... Typically 2 MHz in Astable Mode
- Complementary MOS output Capable of Swinging Rail-to-Rail
- High Output-Current Capability  
... Sink 100 mA Typ  
... Source 10 mA Typ
- Output Fully CMOS-, TTL-, and MOS-Compatible
- Low Supply Current Reduces Spikes During Output Transitions
- High Impedance Inputs ...  $10^{12}\ \Omega$  Typ
- Single-Supply Operation  
TLC552 ... from 1 to 18 Volts  
TLC556 ... from 2 to 18 Volts
- Functionally Interchangeable with the Signetics NE556 and SE556; Has Same Pinout

**description**

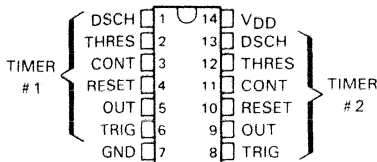
The TLC552 and TLC556 are dual monolithic timing circuits fabricated using TI's LinCMOST™ process. Due to their high-impedance inputs (typically  $10^{12}\ \Omega$ ), they are capable of producing accurate time delays and oscillations while using less expensive, smaller timing capacitors than the NE556. Like the NE556, the TLC552 and TLC556 achieve both monostable (using one resistor and one capacitor) and astable (using two resistors and one capacitor) operation. In addition, 50% duty cycle astable operation is possible using only a single resistor and one capacitor. The LinCMOST™ process allows the TLC552 and TLC556 to operate at frequencies up to 2 MHz and be fully compatible with CMOS, TTL, and MOS logic. It also provides very low power consumption (typically 2 mW at  $V_{DD} = 5\text{ V}$ ) over a wide range of supply voltages ranging from 1 volt to 18 volts for the TLC552 and 2 volts to 18 volts for the TLC556.

The threshold and trigger levels are normally two-thirds and one-third respectively of  $V_{DD}$ . These levels can be altered by use of the control voltage terminal. When the trigger input falls below trigger level, the flip-flop is set and the output goes high. If the trigger input is above the trigger level and the threshold input is above the threshold level, the flip-flop is reset and the output is low. The reset input can override all other inputs and can be used to initiate a new timing cycle. When the reset input goes low, the flip-flop is reset and the output goes low. Whenever the output is low, a low impedance path is provided between the discharge terminal and ground.

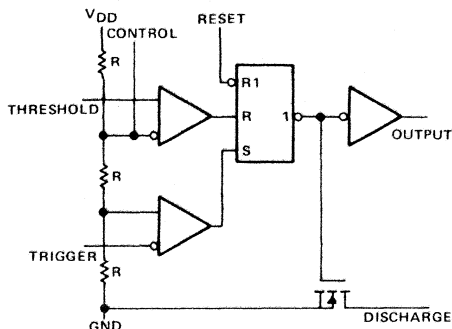
While the CMOS output is capable of sinking over 100 mA and sourcing over 10 mA, the TLC552 and TLC556 exhibit greatly reduced supply current spikes during output transitions. This minimizes the need for the large decoupling capacitors required by the NE556.

The TLC556M will be characterized for operation over the full military temperature range of  $-55\text{ }^\circ\text{C}$  to  $125\text{ }^\circ\text{C}$ . The TLC552CM and TLC556C are characterized for operation from  $0\text{ }^\circ\text{C}$  to  $70\text{ }^\circ\text{C}$ .

TLC556M ... J DUAL-IN-LINE PACKAGE  
TLC552C, TLC556C ... D OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



functional block diagram (each timer)



Reset can override Trigger and Threshold.  
Trigger can override Threshold.

**Special Functions**

**5**

**PRODUCT PREVIEW**

This document contains information on a product under development. Texas Instruments reserves the right to change or discontinue this product without notice.

# TYPES TLC552C, TLC556M, TLC556C

## DUAL LinCMOS™ TIMERS

FUNCTION TABLE

RESET	TRIGGER VOLTAGE†	THRESHOLD VOLTAGE†	OUTPUT	DISCHARGE SWITCH
Low	Irrelevant	Irrelevant	Low	On
High	< 1/3 V <sub>DD</sub>	Irrelevant	High	Off
High	> 1/3 V <sub>DD</sub>	> 2/3 V <sub>DD</sub>	Low	On
High	> 1/3 V <sub>DD</sub>	< 2/3 V <sub>DD</sub>	As previously established	

† Voltages levels shown are nominal.

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V <sub>DD</sub> (see Note 1)	18 V
Input voltage range (any input)	-0.3 V to 18 V
Continuous total dissipation at (or below 25°C free-air temperature (see Note 2))	950 mW
Operating free-air temperature range: TLC556M	-55°C to 125°C
TLC552C, TLC556C	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300°
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package	260°C

NOTES: 1. All voltage values are with respect to network ground terminal.

2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2.

### electrical characteristics at 25°C free-air temperature, V<sub>DD</sub> = 1 V to 15 V for TLC552 or 2 V to 15 V for TLC556 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Threshold voltage level as a percentage of supply voltage			66.7%		
Threshold current	V <sub>DD</sub> = 5 V		10		pA
Trigger voltage level as a percentage of supply voltage			33.3%		
Trigger current	V <sub>DD</sub> = 5 V		10		pA
Reset voltage level			0.7		V
Reset current	V <sub>DD</sub> = 5 V		± 10		pA
Control voltage (open-circuit) as a percentage of supply voltage			66.7%		
Low-level output voltage	V <sub>DD</sub> = 15 V	I <sub>OL</sub> = 10 mA	0.1		V
		I <sub>OL</sub> = 50 mA	0.5		
		I <sub>OL</sub> = 100 mA	1		
	V <sub>DD</sub> = 5 V	I <sub>OL</sub> = 5 mA	0.1		
		I <sub>OL</sub> = 8 mA	0.16		
High-level output voltage	V <sub>DD</sub> = 15 V	I <sub>OH</sub> = -1 mA	14.8		V
		I <sub>OH</sub> = -5 mA	14		
		I <sub>OH</sub> = -10 mA	12.7		
	V <sub>DD</sub> = 5 V	I <sub>OH</sub> = -2 mA	4		
		I <sub>OH</sub> = -1 mA	4.5		
Supply current	V <sub>DD</sub> = 15 V		360		μA
	V <sub>DD</sub> = 5 V		170		



# TYPES TLC552C, TLC556M, TLC556C DUAL LinCMOST™ TIMERS

operating characteristics,  $V_{DD} = 1.2 \text{ V}$  for TLC552 or  $2 \text{ V}$  for TLC556,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Initial error of timing interval	$V_{DD} = 1 \text{ V}$ to $15 \text{ V}$ for TLC552, or $2 \text{ V}$ to $15 \text{ V}$ for TLC556 $R_A = R_B = 1 \text{ k}\Omega$ to $100 \text{ k}\Omega$ ,		1%		
Supply voltage sensitivity of timing interval	$C_T = 0.1 \mu\text{F}$ , See Figure 1		0.1		%/V
Output pulse rise time	$V_{DD} = 5 \text{ V}$ , $R_L = 10 \text{ M}\Omega$ ,		20		ns
Output pulse fall time	$C_L = 10 \text{ pF}$		20		
Maximum frequency in astable mode	$R_A = 470 \Omega$ , $R_B = 200 \Omega$ , $C_T = 200 \text{ pF}$		2.1		MHz

## TYPICAL APPLICATION DATA

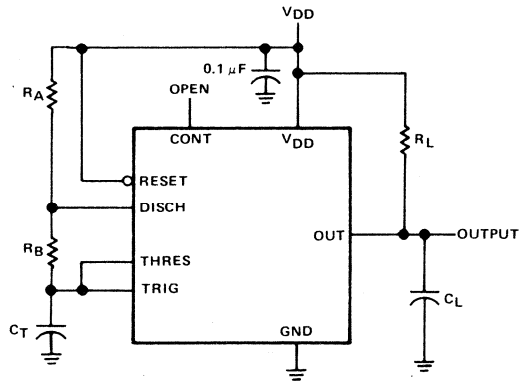


FIGURE 1—CIRCUIT FOR ASTABLE OPERATION



- Very Low Power Consumption . . . 1 mW  
Typ at  $V_{DD} = 5\text{ V}$
- Capable of Very-High-Speed Operation  
. . . Typically 2 MHz in Astable Mode
- Complementary CMOS output Capable of  
Swinging Rail-to-Rail
- High Output-Current Capability  
. . . Sink 100 mA Typ  
. . . Source 10 mA Typ
- Output Fully CMOS-, TTL-, and  
MOS-Compatible
- Low Supply Current Reduces Spikes During  
Output Transitions
- High Impedance Inputs . . .  $10^{12}\ \Omega$  Typ
- Single-Supply Operation from 2 to 18 V
- Functionally Interchangeable with the  
Signetics NE555; has Same Pinout

**description**

The TLC555 is a monolithic timing circuit fabricated using TI's LinCMOSTM process. Due to its high-impedance inputs (typically  $10^{12}\ \Omega$ ), it is capable of producing accurate time delays and oscillations while using less expensive, smaller timing capacitors than the NE555. Like the NE555, the TLC555 achieves both monostable (using one resistor and one capacitor) and astable (using two resistors and one capacitor) operation. In addition, 50% duty cycle astable operation is possible using only a single resistor and one capacitor. The LinCMOSTM process allows the TLC555 to operate at frequencies up to 2 MHz and be fully compatible with CMOS, TTL, and MOS logic. It also provides very low power consumption (typically 1 mW at  $V_{DD} = 5\text{ V}$ ) over a wide range of supply voltages ranging from 2 volts to 18 volts.

Like the NE555, the threshold and trigger levels are normally two-thirds and one-third respectively of  $V_{DD}$ . These levels can be altered by use of the control voltage terminal. When the trigger input falls below trigger level, the flip-flop is set and the output goes high. If the trigger input is above the trigger level and the threshold input is above the threshold level, the flip-flop is reset and the output is low. The reset input can override all other inputs and can be used to initiate a new timing cycle. When the reset input goes low, the flip-flop is reset and the output goes low. Whenever the output is low, a low-impedance path is provided between the discharge terminal and ground.

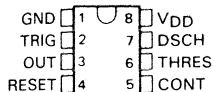
While the complementary CMOS output is capable of sinking over 100 mA and sourcing over 10 mA, the TLC555 exhibits greatly reduced supply current spikes during output transitions. This minimizes the need for the large decoupling capacitors required by the NE555.

These devices have internal electrostatic discharge (ESD) protection circuits that will prevent catastrophic failures at voltage up to 2000 volts as tested under MIL-STD-883B, Method 3015.1. However, care should be exercised in handling these devices as exposure to ESD may result in a degradation of the device parametric performance.

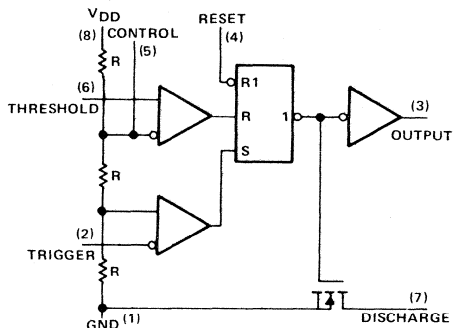
All unused inputs should be tied to an appropriate logic level to prevent false triggering.

The TLC555M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the TLC555C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

TLC555M . . . JG PACKAGE  
TLC555C . . . D, JG, or P PACKAGE  
(TOP VIEW)



**functional block diagram**



Reset can override Trigger, which can override Threshold.

**ADVANCE INFORMATION**

This document contains information on a new product. Specifications are subject to change without notice.

# TYPES TLC555M, TLC555C

## LinCMOST™ TIMERS

FUNCTION TABLE

RESET	TRIGGER VOLTAGE†	THRESHOLD VOLTAGE†	OUTPUT	DISCHARGE SWITCH
Low	Irrelevant	Irrelevant	Low	On
High	< 1/3 V <sub>DD</sub>	Irrelevant	High	Off
High	> 1/3 V <sub>DD</sub>	> 2/3 V <sub>DD</sub>	Low	On
High	> 1/3 V <sub>DD</sub>	< 2/3 V <sub>DD</sub>	As previously established	

† Voltages levels shown are nominal.

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V <sub>DD</sub> (see Note 1)	18 V
Input voltage range (any input)	-0.3 V to 18 V
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	600 mW
Operating free-air temperature range: TLC555M	-55°C to 125°C
TLC555C	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package	260°C

NOTES: 1. All voltage values are with respect to network ground terminal.

2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the JG package, TLC555M chips are alloy-mounted.

### electrical characteristics at 25°C free-air temperature, V<sub>DD</sub> = 5 V to 15 V (unless otherwise noted)

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Threshold voltage level as a percentage of supply voltage			66.7%			
Threshold current	V <sub>DD</sub> = 5 V		10			µA
Trigger voltage level as a percentage of supply voltage			33.3%			
Trigger current	V <sub>DD</sub> = 5 V		10			µA
Reset voltage level			0.7			V
Reset current	V <sub>DD</sub> = 5 V		±10			µA
Control voltage (open-circuit) as a percentage of supply voltage			66.7%			
Low-level output voltage	V <sub>DD</sub> = 15 V	I <sub>OL</sub> = 10 mA	0.1		V	
		I <sub>OL</sub> = 50 mA	0.5			
		I <sub>OL</sub> = 100 mA	1			
	V <sub>DD</sub> = 5 V	I <sub>OL</sub> = 5 mA	0.1			
		I <sub>OL</sub> = 8 mA	0.16			
		I <sub>OL</sub> = 10 mA	0.16			
High-level output voltage	V <sub>DD</sub> = 15 V	I <sub>OH</sub> = -1 mA	14.8		V	
		I <sub>OH</sub> = -5 mA	14			
		I <sub>OH</sub> = -10 mA	12.7			
	V <sub>DD</sub> = 5 V	I <sub>OH</sub> = -2 mA	4			
		I <sub>OH</sub> = -1 mA	4.5			
		I <sub>OH</sub> = -1 mA	4.5			
Supply current	V <sub>DD</sub> = 15 V		360		µA	
	V <sub>DD</sub> = 5 V		170			

operating characteristics,  $V_{DD} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Initial error of timing interval	$V_{DD} = 5\text{ V to }15\text{ V}$ , $R_A = R_B = 1\text{ k}\Omega\text{ to }100\text{ k}\Omega$ , $C_T = 0.1\ \mu\text{F}$ , See Figure 1	1%			
Supply voltage sensitivity of timing interval		0.1	%/V		
Output pulse rise time	$V_{DD} = 5\text{ V}$ , $R_L = 10\text{ M}\Omega$ , $C_L = 10\text{ pF}$	20			ns
Output pulse fall time		20			
Maximum frequency in astable mode	$R_A = 470\ \Omega$ , $R_B = 200\ \Omega$ , $C_T = 200\text{ pF}$	2.1			MHz

**TYPICAL APPLICATION DATA**

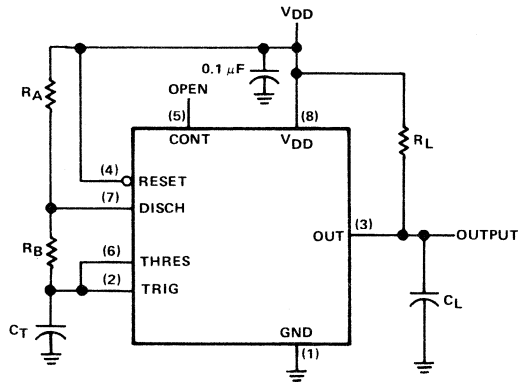


FIGURE 1—CIRCUIT FOR ASTABLE OPERATION



- 200 MHz Bandwidth
- 250 k $\Omega$  Input Resistance
- Selectable Nominal Amplification of 10, 100, or 400
- No Frequency Compensation Required
- Designed to be Interchangeable with Fairchild  $\mu$ A733M and  $\mu$ A733C

**description**

The  $\mu$ A733 is a monolithic two-stage video amplifier with differential inputs and differential outputs.

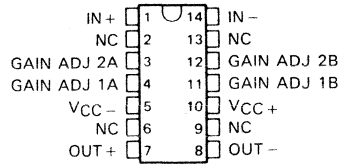
Internal series-shunt feedback provides wide bandwidth, low phase distortion, and excellent gain stability. Emitter-follower outputs enable the device to drive capacitive loads and all stages are current-source biased to obtain high common-mode and supply-voltage rejection ratios.

Fixed differential amplification of 10, 100, or 400 may be selected without external components, or amplification may be adjusted from 10 to 400 by the use of a single external resistor connected between 1A and 1B. No external frequency-compensating components are required for any gain option.

The device is particularly useful in magnetic-tape or disc-file systems using phase or NRZ encoding and in high-speed thin-film or plated-wire memories. Other applications include general purpose video and pulse amplifiers where wide bandwidth, low phase shift, and excellent gain stability are required.

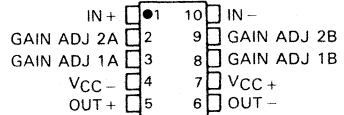
The  $\mu$ A733M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ; the  $\mu$ A733C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)**

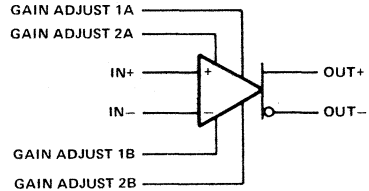


NC: No internal connection

**$\mu$ A733M . . . U FLAT PACKAGE  
(TOP VIEW)**



**symbol**



**Special Functions**



**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

	$\mu$ A733M	$\mu$ A733C	UNIT
Supply voltage $V_{CC+}$ (See Note 1)	8	8	V
Supply voltage $V_{CC-}$ (See Note 1)	-8	-8	V
Differential input voltage	$\pm 5$	$\pm 5$	V
Common-mode input voltage	$\pm 6$	$\pm 6$	V
Output current	10	10	mA
Continuous total power dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 2)	500	500	mW
Operating free-air temperature range	$-55$ to $125$	$0$ to $70$	$^{\circ}\text{C}$
Storage temperature range	$-65$ to $150$	$-65$ to $150$	$^{\circ}\text{C}$
Lead temperature 1.6 mm (1/16 inch) from case for 60 seconds	300	300	$^{\circ}\text{C}$
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds	J or U package	N package	
	300	260	$^{\circ}\text{C}$

NOTES: 1. All voltage values, except differential input voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
2. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J package,  $\mu$ A733M chips are alloy mounted;  $\mu$ A733C chips are glass mounted.

# TYPES $\mu$ A733M, $\mu$ A733C

## DIFFERENTIAL VIDEO AMPLIFIERS

electrical characteristics,  $V_{CC+} = 6\text{ V}$ ,  $V_{CC-} = -6\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST FIGURE	TEST CONDITIONS	GAIN OPTION <sup>†</sup>	$\mu$ A733M			$\mu$ A733C			UNIT	
				MIN	TYP	MAX	MIN	TYP	MAX		
$A_{VD}$	Large-signal differential voltage amplification	$V_{OD} = 1\text{ V}$	1	300	400	500	250	400	600		
			2	90	100	110	80	100	120		
			3	9	10	11	8	10	12		
BW	Bandwidth	$R_S = 50\ \Omega$	1	50			50			MHz	
			2	90			90				
			3	200			200				
$I_{IO}$	Input offset current		Any	0.4	3	0.4	5	$\mu\text{A}$			
$I_{IB}$	Input bias current		Any	9	20	9	30	$\mu\text{A}$			
$V_{ICR}$	Common-mode input voltage range	1	Any	$\pm 1$		$\pm 1$		V			
$V_{OC}$	Common-mode output voltage	1	Any	2.4	2.9	3.4	2.4	2.9	3.4	V	
$V_{OO}$	Output offset voltage	1	1	0.6	1.5	0.6	1.5	V			
			2 & 3	0.35	1	0.35	1.5				
$V_{OPP}$	Maximum peak-to-peak output voltage swing	1	Any	3	4.7	3	4.7	V			
$r_i$	Input resistance	$V_{OD} \leq 1\text{ V}$	1	4			4			k $\Omega$	
			2	20	24	10	24				
			3	250			250				
$r_o$	Output resistance			20			20			$\Omega$	
$C_i$	Input capacitance	3	$V_{OD} \leq 1\text{ V}$	2			2			pF	
CMRR	Common-mode rejection ratio	4	$V_{IC} = \pm 1\text{ V}$ , $f \leq 100\text{ kHz}$	2	60	86	60	86	dB		
			$V_{IC} = \pm 1\text{ V}$ , $f = 5\text{ MHz}$	2	70			70			
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	1	$\Delta V_{CC+} = \pm 0.5\text{ V}$ , $\Delta V_{CC-} = \pm 0.5\text{ V}$	2	50	70	50	70	dB		
$V_n$	Broadband equivalent input noise voltage	5	BW = 1 kHz to 10 MHz	Any	12			12			$\mu\text{V}$
$t_{pd}$	Propagation delay time	2	$R_S = 50\ \Omega$ , Output voltage step = 1 V	1	7.5			7.5			ns
				2	6.0	10	6.0	10			
				3	3.6			3.6			
$t_r$	Rise time	2	$R_S = 50\ \Omega$ , Output voltage step = 1 V	1	10.5			10.5			ns
				2	4.5	10	4.5	12			
				3	2.5			2.5			
$I_{\text{sink(max)}}$	Maximum output sink current		Any	2.5	3.6	2.5	3.6	mA			
$I_{CC}$	Supply current		No load, no signal	Any	16	24	16	24	mA		

<sup>†</sup>The gain option is selected as follows:

Gain Option 1 . . . Gain-adjust pin 1A is connected to pin 1B, and pins 2A and 2B are open.

Gain Option 2 . . . Gain-adjust pin 1A and pin 1B are open, pin 2A is connected to pin 2B.

Gain Option 3 . . . All four gain-adjust pins are open.



# TYPES $\mu$ A733M, $\mu$ A733C DIFFERENTIAL VIDEO AMPLIFIERS

electrical characteristics (continued),  $V_{CC+} = 6\text{ V}$ ,  $V_{CC-} = -6\text{ V}$   
 $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$  for  $\mu$ A733M,  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for  $\mu$ A733C

PARAMETER	TEST FIGURE	TEST CONDITIONS	GAIN OPTION <sup>†</sup>	$\mu$ A733M		$\mu$ A733C		UNIT
				MIN	MAX	MIN	MAX	
AVD Large-signal differential voltage amplification	1	$V_{OD} = 1\text{ V}$	1	200	600	250	600	
			2	80	120	80	120	
			3	8	12	8	12	
$I_{IO}$ Input offset current			Any		5		6	$\mu\text{A}$
$I_{IB}$ Input bias current			Any		40		40	$\mu\text{A}$
$V_{ICR}$ Common-mode input voltage range	1		Any	$\pm 1$		$\pm 1$		V
$V_{OO}$ Output offset voltage	1		1		1.5		1.5	V
			2 & 3		1.2		1.5	
$V_{OPP}$ Maximum peak-to-peak output voltage swing	1		Any	2.5		2.8		V
$r_i$ Input resistance	3	$V_{OD} \leq 1\text{ V}$	2	8		8		$\text{k}\Omega$
CMRR Common-mode rejection ratio	4	$V_{IC} = \pm 1\text{ V}$ , $f \leq 100\text{ kHz}$ $V_{IC} = \pm 1\text{ V}$ , $f = 5\text{ MHz}$	2	50		50		dB
			2					
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	1	$\Delta V_{CC+} = \pm 0.5\text{ V}$ , $\Delta V_{CC-} = \pm 0.5\text{ V}$	2	50		50		dB
$I_{\text{sink(max)}}$ Maximum output sink current			Any	2.2		2.5		mA
$I_{CC}$ Supply current		No load, No signal	Any		27		27	mA

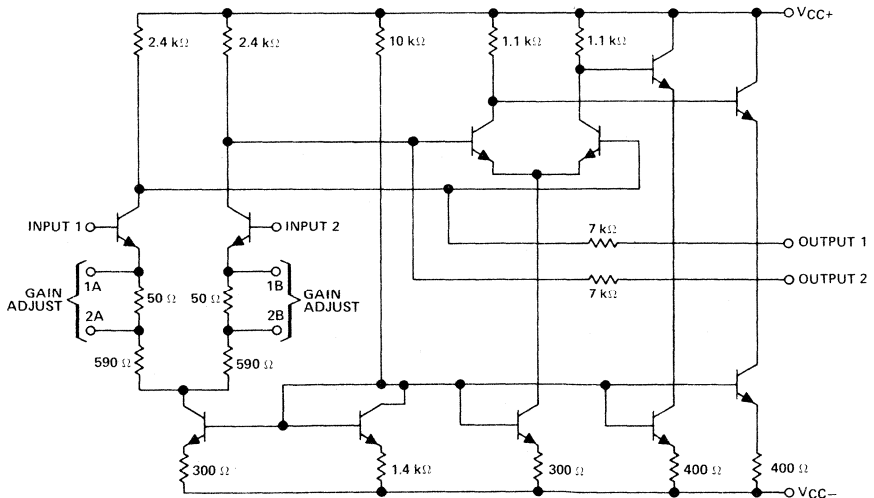
<sup>†</sup>The gain option is selected as follows:

Gain Option 1 . . . Gain-adjust pin 1A is connected to pin 1B, and pins 2A and 2B are open.

Gain Option 2 . . . Gain-adjust pin 1A and pin 1B are open, pin 2A is connected to pin 2B.

Gain Option 3 . . . All four gain-adjust pins are open.

schematic



Component values shown are nominal.

Special Functions



# TYPES $\mu$ A733M, $\mu$ A733C

## DIFFERENTIAL VIDEO AMPLIFIERS

---

### DEFINITION OF TERMS

**Large-Signal Differential Voltage Amplification ( $A_{VD}$ )** The ratio of the change in voltage between the output terminals to the change in voltage between the input terminals producing it.

**Bandwidth (BW)** The range of frequencies within which the differential gain of the amplifier is not more than 3 dB below its low-frequency value.

**Input Offset Current ( $I_{IO}$ )** The difference between the currents into the two input terminals with the inputs grounded.

**Input Bias Current ( $I_{IB}$ )** The average of the currents into the two input terminals with the inputs grounded.

**Input Voltage Range ( $V_I$ )** The range of voltage that if exceeded at either input terminal will cause the amplifier to cease functioning properly.

**Common-Mode Output Voltage ( $V_{OC}$ )** The average of the d-c voltages at the two output terminals.

**Output Offset Voltage ( $V_{OO}$ )** The difference between the d-c voltages at the two output terminals when the input terminals are grounded.

**Maximum Peak-to-Peak Output Voltage Swing ( $V_{OPP}$ )** The maximum peak-to-peak output voltage swing that can be obtained without clipping. This includes the unbalance caused by output offset voltage.

**Input Resistance ( $r_i$ )** The resistance between the input terminals with either input grounded.

**Output Resistance ( $r_o$ )** The resistance between either output terminal and ground.

**Input Capacitance ( $C_i$ )** The capacitance between the input terminals with either input grounded.

**Common-Mode Rejection Ratio (CMRR)** The ratio of differential voltage amplification to common-mode voltage amplification. This is measured by determining the ratio of a change in input common-mode voltage to the resulting change in input offset voltage.

**Supply Voltage Rejection Ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )** The absolute value of the ratio of the change in power supply voltages to the change in input offset voltage. For these devices, both supply voltages are varied symmetrically.

**Equivalent Input Noise Voltage ( $V_n$ )** The voltage of an ideal voltage source (having an internal impedance equal to zero) in series with the input terminals of the device that represents the part of the internally generated noise that can properly be represented by a voltage source.

**Propagation Delay Time ( $t_{pd}$ )** The interval between the application of an input voltage step and its arrival at either output, measured at 50% of the final value.

**Rise Time ( $t_r$ )** The time required for an output voltage step to change from 10% to 90% of its final value.

**Maximum Output Sink Current ( $I_{sink(max)}$ )** The maximum available current into either output terminal when that output is at its most negative potential.

**Supply Current ( $I_{CC}$ )** The average of the magnitudes of the two supply currents  $I_{CC1}$  and  $I_{CC2}$ .

# TYPES $\mu$ A733M, $\mu$ A733C DIFFERENTIAL VIDEO AMPLIFIERS

## PARAMETER MEASUREMENT INFORMATION

test circuits

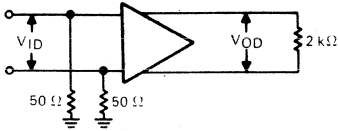


FIGURE 1

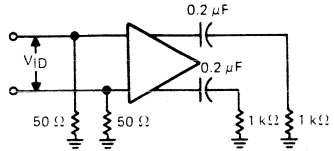


FIGURE 2

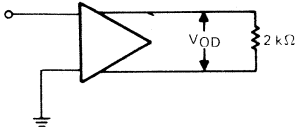


FIGURE 3

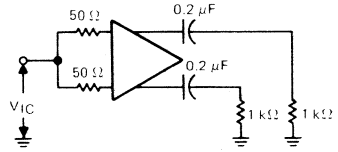


FIGURE 4

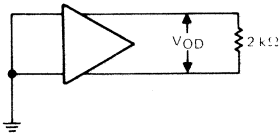
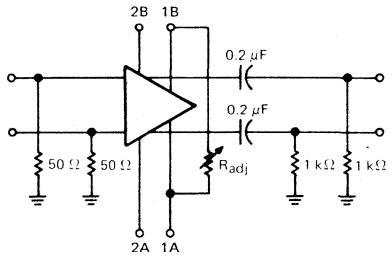


FIGURE 5



VOLTAGE AMPLIFICATION ADJUSTMENT

FIGURE 6

**TYPES  $\mu$ A733M,  $\mu$ A733C**  
**DIFFERENTIAL VIDEO AMPLIFIERS**

**TYPICAL CHARACTERISTICS**

PHASE SHIFT  
vs  
FREQUENCY

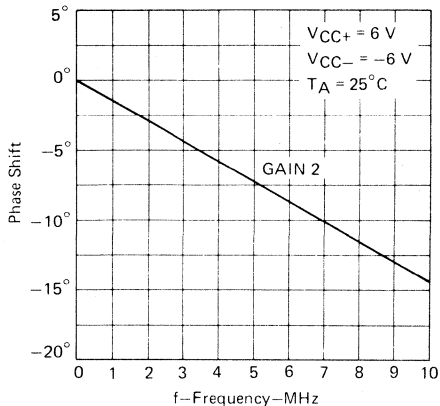


FIGURE 7

PHASE SHIFT  
vs  
FREQUENCY

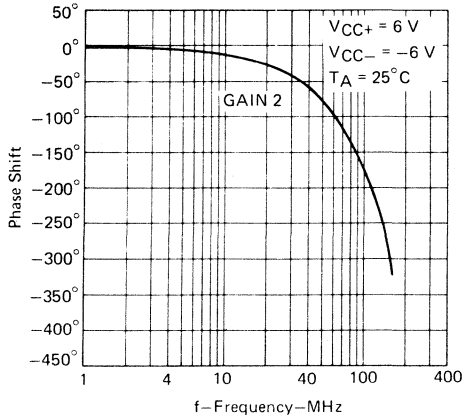


FIGURE 8

VOLTAGE AMPLIFICATION  
(SINGLE-ENDED OR DIFFERENTIAL)  
vs  
TEMPERATURE

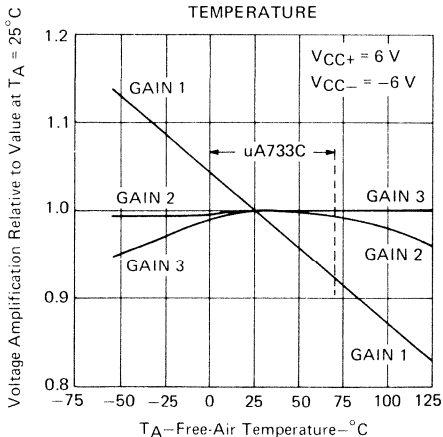


FIGURE 9

VOLTAGE AMPLIFICATION  
(SINGLE-ENDED OR DIFFERENTIAL)  
vs  
SUPPLY VOLTAGE

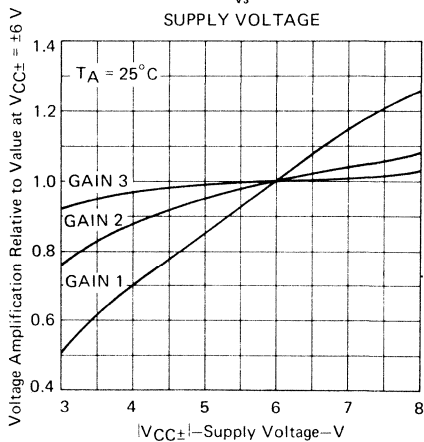


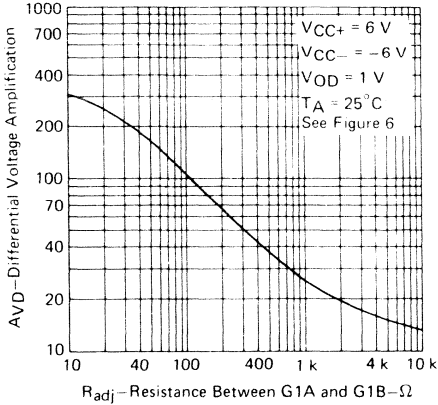
FIGURE 10

Special Functions



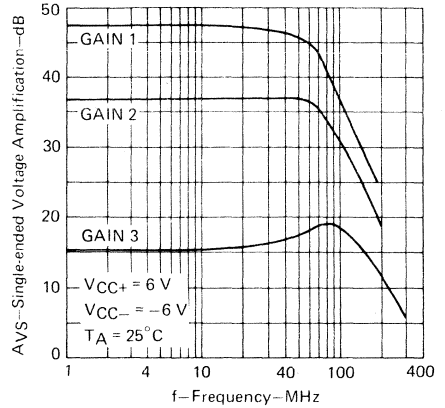
**TYPICAL CHARACTERISTICS**

**DIFFERENTIAL VOLTAGE AMPLIFICATION**  
 vs  
**RESISTANCE BETWEEN G1A AND G1B**



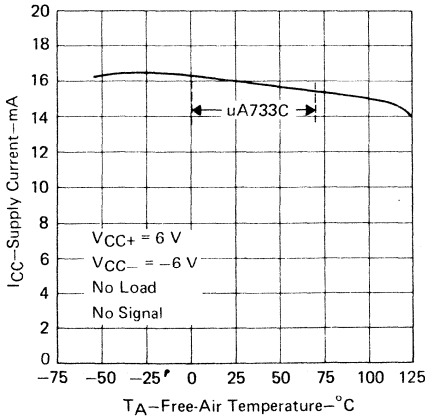
**FIGURE 11**

**SINGLE-ENDED VOLTAGE AMPLIFICATION**  
 vs  
**FREQUENCY**



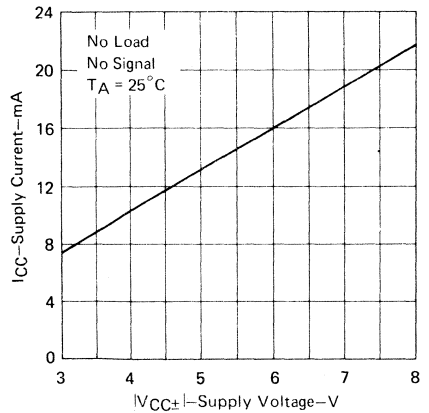
**FIGURE 12**

**SUPPLY CURRENT**  
 vs  
**FREE-AIR TEMPERATURE**



**FIGURE 13**

**SUPPLY CURRENT**  
 vs  
**SUPPLY VOLTAGE**



**FIGURE 14**



**TYPES  $\mu$ A733M,  $\mu$ A733C**  
**DIFFERENTIAL VIDEO AMPLIFIERS**

**TYPICAL CHARACTERISTICS**

Special Functions

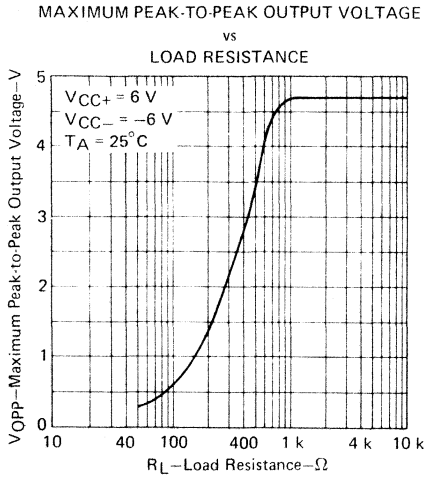


FIGURE 15

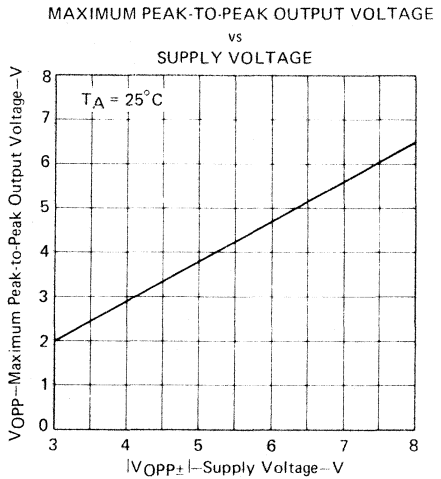


FIGURE 16

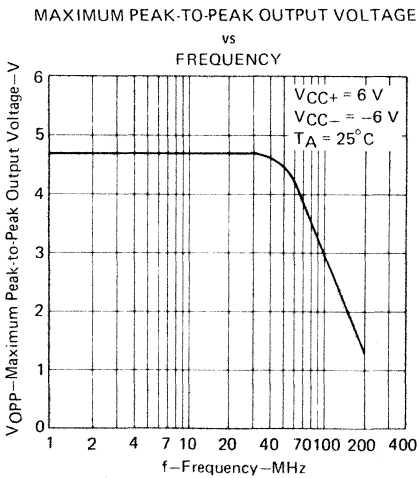


FIGURE 17

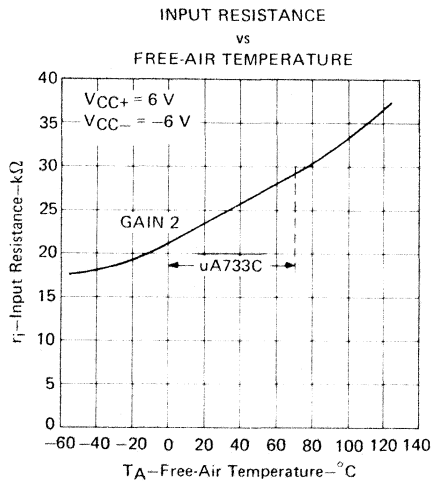
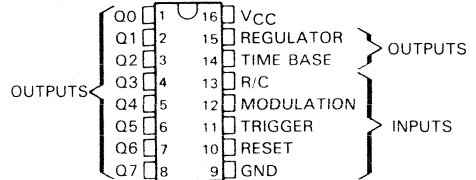


FIGURE 18

- Accurate Timing from Microseconds to Days
- Programmable Delays from 1 Time Constant to 255 Time Constants
- Outputs Compatible with TTL and CMOS
- Wide Supply-Voltage Range
- External Sync and Modulation Capability

**N DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



**description**

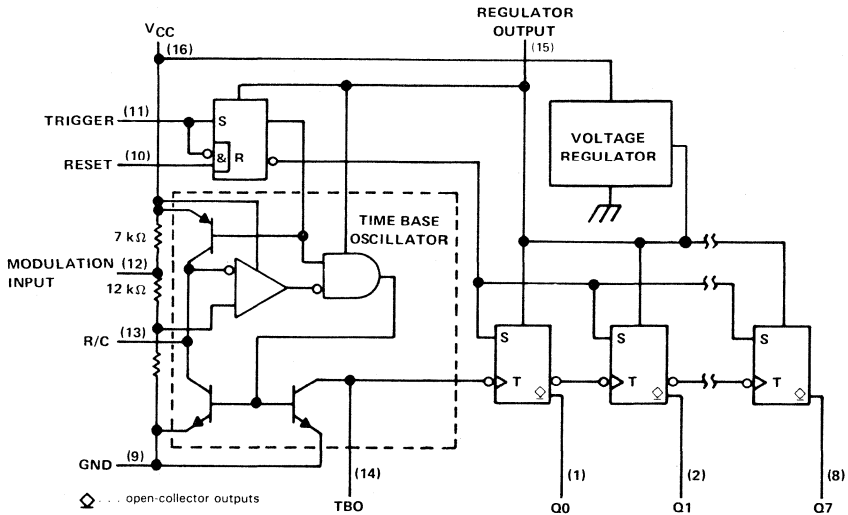
These circuits consist of a time-base oscillator, an eight-bit counter, a control flip-flop, and a voltage regulator. The frequency of the time-base oscillator is set by the time constant of an external resistor and capacitor at pin 13 and can be synchronized or modulated by signals applied to the modulation input. The output of the time-base section is applied directly to the input of the counter section and also appears at pin 14 (time base). The time-base pin may be used to monitor the frequency of the oscillator, to provide an output pulse to other circuitry, or (with the time-base section disabled) to drive the counter input from an external source. The counter input is activated on a negative-going transition. The reset input stops the time-base oscillator and sets each binary output, Q0 through Q7, and the time-base output to a TTL high level. After resetting, the trigger input starts the oscillator and all Q outputs go low. Once triggered, the  $\mu$ A2240C will ignore any signals at the trigger input until it is reset.

The  $\mu$ A2240C timer/counter may be operated in the free-running mode or with output-signal feedback to the reset input for automatic reset. Two or more binary outputs may be connected together to generate complex pulse patterns, or each output may be used separately to provide eight output frequencies. Using two circuits in cascade can provide precise time delays of up to three years.

The  $\mu$ A2240C is characterized for operation from 0°C to 70°C.

# TYPE $\mu$ A2240C PROGRAMMABLE TIMER/COUNTER

functional block diagram



## absolute maximum ratings

Supply voltage, $V_{CC}$ (see Note 1)	18 V
Output voltage: Q0 thru Q7	18 V
Output current: Q0 thru Q7	10 mA
Regulator output current	-5 mA
Continuous dissipation at (or below) 25°C free-air temperature (see Note 2):	650 mW
Operating free-air temperature range	0°C to 70°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

- NOTES: 1. Voltage values are with respect to the network ground terminal.  
2. For operation above 25°C, see the Dissipation Derating Curves, Section 2.

## recommended operating conditions

	$\mu$ A2240C			UNIT
	MIN	NOM	MAX	
Supply voltage, $V_{CC}$ (see Note 3)	4	14		V
Timing resistor	0.001	10		M $\Omega$
Timing capacitor	0.01	1000		$\mu$ F
Counter input frequency (Pin 14)		1.5		MHz
Pull-up resistor, time-base output		20		k $\Omega$
Trigger and reset input pulse voltage	2	3		V
Trigger and reset input pulse duration	2			$\mu$ s
External clock input pulse voltage	3			V
External clock input pulse duration	1			$\mu$ s

NOTE 3: For operation with  $V_{CC} \leq 4.5$  V, short regulator output to  $V_{CC}$ .



**electrical characteristics at 25°C free-air temperature**

PARAMETER	TEST CIRCUIT	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Regulator output voltage	1	$V_{CC} = 5\text{ V}$ , Trigger and reset open or grounded	3.9	4.4		V
	2	$V_{CC} = 15\text{ V}$ , Trigger and reset open or grounded	5.8	6.3	6.8	
Modulation input open circuit voltage	1	$V_{CC} = 5\text{ V}$ , Trigger and reset open or grounded	2.8	3.5	4.2	V
		$V_{CC} = 15\text{ V}$ , Trigger and reset open or grounded		10.5		
Trigger threshold voltage	1	$V_{CC} = 5\text{ V}$ , Reset at 0 V		1.4	2	V
High-level trigger current	1	$V_{CC} = 5\text{ V}$ , Trigger at 2 V, Reset at 0 V		10		$\mu\text{A}$
Reset threshold voltage	1	$V_{CC} = 5\text{ V}$ , Trigger at 0 V		1.4	2	V
High-level reset current	1	$V_{CC} = 5\text{ V}$ , Trigger at 0 V		10		$\mu\text{A}$
Counter input (time base) threshold voltage	2	$V_{CC} = 5\text{ V}$ , Trigger and reset open or grounded	1	1.4		V
Low-level output current, Q0 thru Q7	2	$V_{CC} = 5\text{ V}$ , Trigger at 2 V, Reset at 0 V, $V_{OL} < 0.4\text{ V}$	2	4		mA
High-level output current, Q0 thru Q7	2	$V_{OH} = 15\text{ V}$ , Reset at 2 V, Trigger at 0 V		0.01	15	$\mu\text{A}$
Supply current	1	$V_{CC} = 5\text{ V}$ , Trigger at 0 V, Reset at 5 V		4	7	mA
	1	$V_{CC} = 15\text{ V}$ , Trigger at 0 V, Reset at 5 V		13	18	
	3	$V_{+} = 4\text{ V}$		1.5		

**operating characteristics at 25°C free-air temperature (unless otherwise noted)**

PARAMETER	TEST CIRCUIT	TEST CONDITIONS <sup>†</sup>	MIN	TYP	MAX	UNIT
Initial error of time base <sup>‡</sup>	1	$V_{CC} = 5\text{ V}$ , Trigger at 5 V, Reset at 0 V		$\pm 0.5$	$\pm 5$	%
Temperature coefficient of time-base period	1	$T_A = 0^{\circ}\text{C}$ to $70^{\circ}\text{C}$	$V_{CC} = 5\text{ V}$		-200	ppm/ $^{\circ}\text{C}$
			$V_{CC} = 15\text{ V}$		-80	
Supply voltage sensitivity of time-base period	1	$V_{CC} \geq 8\text{ V}$		-0.08	-0.3	%/V
Time-base output frequency	1	$V_{CC} = 5\text{ V}$ , R = MIN, C = MIN		130		kHz
Propagation delay time		see Note 4	From trigger input		1	$\mu\text{s}$
			From reset input		0.8	
Output rise time	2	$R_L = 3\text{ k}\Omega$ , $C_L = 10\text{ pF}$	Q0 thru Q7		180	ns
Output fall time					180	

<sup>†</sup>For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

<sup>‡</sup>This is the time-base period error due only to the uA2240C and expressed as a percentage of nominal (1.00 RC).

NOTE 4: Propagation delay time is measured from the 50% point on the leading edge of an input pulse to the 50% point on the leading edge of the resulting change of state at Q0.

# TYPE $\mu$ A2240C PROGRAMMABLE TIMER/COUNTER

## PARAMETER MEASUREMENT INFORMATION

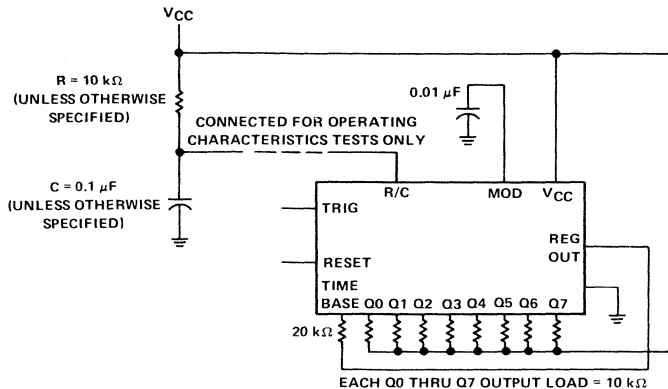


FIGURE 1—GENERAL TEST CIRCUIT

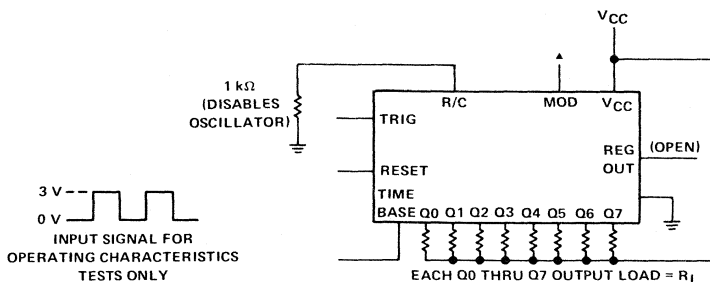


FIGURE 2—COUNTER TEST CIRCUIT

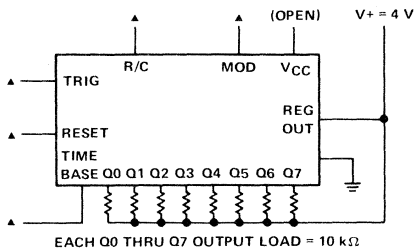


FIGURE 3—REDUCED-POWER TEST CIRCUIT  
(TIME BASE DISABLED)

<sup>^</sup> These connections may be open or grounded for this test.

TYPICAL CHARACTERISTICS

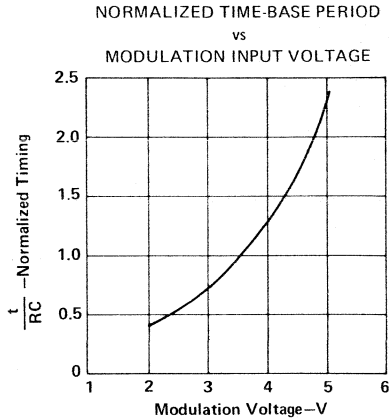


FIGURE 4

TYPICAL APPLICATION INFORMATION

Figure 5 shows voltage waveforms for typical operation of the  $\mu$ A2240C. If both reset and trigger inputs are low during power-up, the timer/counter will be in a reset state with all binary (Q) outputs high and the oscillator stopped. In this state, a high level on the trigger input starts the time-base oscillator. The initial negative-going pulse from the oscillator sets the Q outputs to low logic levels at the beginning of the first time-base period. The  $\mu$ A2240C will ignore any further signals at the trigger input until after a reset signal is applied to the reset input. With the trigger input low, a high level at the reset input will set Q outputs high and stop the time-base oscillator. If the reset signal occurs while the trigger input is high, the reset is ignored. If the reset input remains high when the trigger input goes low, the  $\mu$ A2240C will reset.

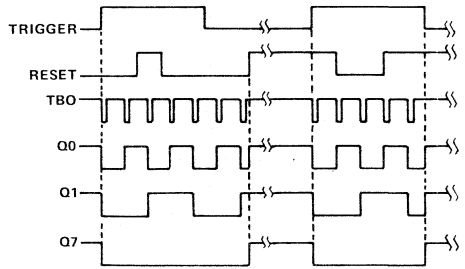


FIGURE 5—TIMING DIAGRAM OF OUTPUT WAVEFORMS

# TYPE $\mu$ A2240C PROGRAMMABLE TIMER/COUNTER

## TYPICAL APPLICATION INFORMATION

In monostable applications of the  $\mu$ A2240C one or more of the binary outputs will be connected to the reset terminal as shown in Figure 6. The binary outputs are open-collector stages that can be connected together to a common pull-up resistor to provide a "wired-OR" function. The combined output will be low as long as any one of the outputs is low. This type of arrangement can be used for time delays that are integer multiples of the time-base period. For example, if Q5 ( $2^5 = 32$ ) only is connected to the reset input, every trigger pulse will generate a 32-period active-low output. Similarly, if Q0, Q4, and Q5 are connected to reset, each trigger pulse creates a 49-period delay.

In astable operation, the  $\mu$ A2240C will free-run from the time it is triggered until it receives an external reset signal.

The period of the time-base oscillator is equal to the RC time constant of an external resistor and capacitor connected as shown in Figure 6 when the modulation input is open (approximately 3.5 volts internal, see Figure 4). Under conditions of high supply voltage ( $V_{CC} > 7$  V) and low value of timing capacitor ( $C < 0.1 \mu\text{F}$ ), the pulse duration of the time-base oscillator may be too short to properly trigger the counters. This situation can be corrected by adding a 300-picofarad capacitor between the time-base output and ground. The time-base output (TBO) is an open-collector output that requires a 20-k $\Omega$  pull-up resistor to Pin 15 for proper operation. The time-base pin may also be used as an input to the counters for an external time-base or as an active-low inhibit input to interrupt counting without resetting.

The modulation input varies the ratio of the time-base period to the RC time constant as a function of the dc bias voltage (see Figure 4). It can also be used to synchronize the timer/counter to an external clock or sync signal.

The regulator output is used internally to drive the binary counters and the control logic. This terminal can also be used to supply voltage to additional  $\mu$ A2240C devices to minimize power dissipation when several timer circuits are cascaded. For circuit operation with an external clock, the regulator output can be used as the  $V_{CC}$  input terminal to power down the internal time base and reduce power dissipation. When supply voltages less than 4.5 volts are used with the internal time base, Pin 15 should be shorted to Pin 16.

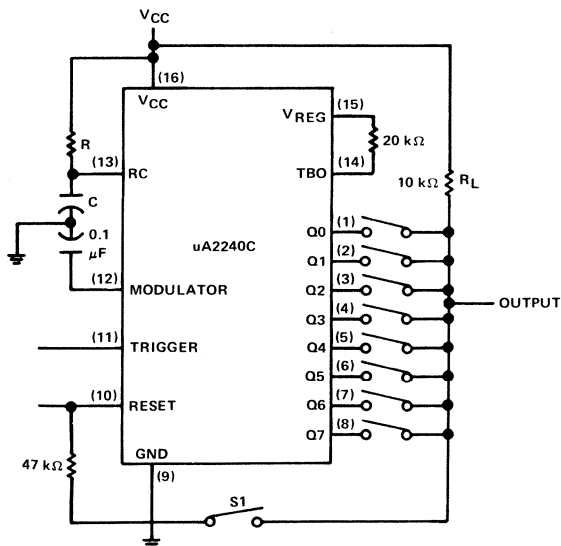


FIGURE 6—BASIC CONNECTIONS FOR TIMING APPLICATIONS

# Linear Circuits

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General Information

1

Thermal Information

2

Operational Amplifiers

3

Voltage Comparators

4

Special Functions

5

Voltage Regulators

6

Data Acquisition

7

Appendix

A



## FIXED-OUTPUT VOLTAGE REGULATORS

## positive-voltage regulators

DEVICE SERIES	OUTPUT VOLTAGE TOLERANCE	MINIMUM DIFFERENTIAL VOLTAGE	OUTPUT CURRENT RATING	PACKAGES	PAGE
LM2930-0	± 10%	0.6 V	150 mA	KC	6-45
LM2931-0	± 10%	0.6 V	150 mA	KC	6-51
LM330-0	± 4%	0.6 V	150 mA	KC	6-27
LM340-00	+ 4%	2 V	1.5 A	KC	6-33
TL780-00C	± 1%	2 V	1.5 A	KC	6-135
μA7800C	+ 4%	2 V – 3 V	1.5 A	KC	6-169
μA78L00AC	+ 5%	2 V	100 mA	LP	6-177
μA78L00C	± 10%	2 V – 2.5 V	100 mA	LP	6-177
μA78M00C	± 5%	2 V – 3 V	500 mA	KC	6-183
μA78M00M	± 5%	2 V – 3 V	500 mA	KC	6-183

## negative-voltage regulators

DEVICE SERIES	OUTPUT VOLTAGE TOLERANCE	MINIMUM DIFFERENTIAL VOLTAGE	OUTPUT CURRENT RATING	PACKAGES	PAGE
LM320-00	± 4%	2 V	1.5 A	KC	6-21
MC79L00AC	± 5%	1.7 V	100 mA	LP	6-57
MC79L00C	± 10%	1.7 V	100 mA	LP	6-57
μA7900C	± 5%	2 V – 3 V	1.5 A	KC	6-195
μA79M00C	± 5%	2 V – 3 V	1.5 A	KC	6-201
μA79M00M	± 5%	2 V – 3 V	1.5 A	KC	6-201

## available output voltage for above regulator series

DEVICE SERIES	VOLTAGE SELECTIONS													
	2.6	5.0	5.2	6.0	6.2	8.0	8.5	9.0	10.0	12.0	15.0	18.0	20.0	24.0
LM2930-0		X				X								
LM2931-0		X												
LM320-00		X								X	X			
LM330-0		X												
LM340-00		X								X	X			
MC79L00AC		X								X	X			
MC79L00C		X								X	X			
TL780-00C		X								X	X			
μA7800C		X		X		X	X		X	X	X	X		X
μA78L00AC	X	X			X	X		X	X	X	X			
μA78L00C	X	X			X	X		X	X	X	X			
μA78M00C		X		X		X			X	X	X		X	X
μA78M00M		X		X		X			X	X	X			
μA7900C		X	X	X		X				X	X	X		X
μA7900M		X	X	X		X				X	X	X		X
μA79M00C		X		X		X				X	X		X	X
μA79M00M		X		X		X				X	X			

## SELECTION GUIDE

### VARIABLE-OUTPUT VOLTAGE REGULATORS

#### positive-voltage series regulators

DEVICE NUMBER	OUTPUT VOLTAGE		MAXIMUM DIFFERENTIAL VOLTAGE	OUTPUT CURRENT RATING	PACKAGES	PAGE
	MIN	MAX				
LM217	1.2 V	37 V	$V_I - 1.2$ V	1.5 A	KC	6-11
LM317	1.2 V	37 V	$V_I - 1.2$ V	1.5 A	KC	6-11
LM350	1.2 V	33 V	$V_I - 1.2$ V	3 A	KC	6-41
TL317C	1.2 V	32 V	$V_I - 1.2$ V	100 mA	LP	6-91
TL317M	1.2 V	32 V	$V_I - 1.2$ V	100 mA	LP	6-91
TL783C	10 V	125 V	37 V	700 mA	KC	6-139
uA723C	3 V	38 V	37 V	25 mA	J, N	6-163
uA723M	3 V	38 V	37 V	25 mA	J, N	6-163

#### negative-voltage series regulators

DEVICE NUMBER	OUTPUT VOLTAGE		MAXIMUM DIFFERENTIAL VOLTAGE	OUTPUT CURRENT RATING	PACKAGES	PAGE
	MIN	MAX				
LM237	1.2 V	37 V	$V_I - 1.2$ V	1.5 A	KC	6-17
LM337	1.2 V	37 V	$V_I - 1.2$ V	1.5 A	KC	6-17

#### positive-shunt regulators

DEVICE NUMBER	SHUNT VOLTAGE		SHUNT CURRENT		TEMP COEFFICIENT RATING	PACKAGES	PAGE
	MIN	MAX	MIN	MAX			
TL430C	3 V	30 V	2 mA	100 mA	200 ppm/°C	LP	6-95
TL430I	3 V	30 V	2 mA	100 mA	200 ppm/°C	LP, P	6-95
TL431C	3 V	30 V	0.5 mA	100 mA	100 ppm/°C	LP, P	6-99
TL431I	2.55 V	36 V	1 mA	100 mA	100 ppm/°C	LP	6-99
TL431M	2.55 V	36 V	1 mA	100 mA	100 ppn/°C	JG	6-99

### PROTECTION CIRCUITS

#### undervoltage protection circuits

DEVICE NUMBER	FEATURES	TEMP RANGE	PACKAGES	PAGE
TL7702 TL7705 TL7709 TL7712 TL7715	Power-up and voltage reset generator specifically for microcomputer control supervision. These devices operate over a wide supply voltage range (3 V to 18 V) and have externally adjustable pulse duration to ensure system reset.	0°C to 70°C	D, P	6-159



**overvoltage protection circuit**

DEVICE NUMBER	FEATURES	TEMP RANGE	PACKAGES	PAGE
MC3423	Separate outputs for "crowbar" and logic circuitry, programmable time delay, TTL-level activation isolated from voltage-sensing inputs	0°C to 70°C	JG, P	6-55

**SWITCHING VOLTAGE REGULATOR/CONTROLLERS**

**general-purpose switching regulators/controllers**

	BASE DEVICE NUMBERS						
	MC35060 MC34060	SG3524 SG1524	SG3525A SG1525A	SG3527A SG1527A	TL3525A TL1525A	TL3527A TL1527A	TL497A
<b>PAGES</b>	6-61	6-69	6-81	6-81	6-149	6-149	6-119
<b>FEATURES</b>							
<b>General Features</b>							
Fixed On Time	—	—	—	—	—	—	X
Fixed Frequency PWM	X	X	X	X	X	X	X
Expandable	X	X	X	X	X	X	—
<b>Control Features</b>							
On Chip Reference	X	X	X	X	X	X	X
Precision On Chip Reference	—	—	X	X	X	X	—
Dead Time Adjust	X	—	X	X	X	X	—
Current Sense Amplifier	—	—	—	—	—	—	X
Error Amplifier	2	2	1	1	1	1	1
Operates to 40 V	X	35 V	35 V	35 V	35 V	35 V	—
Operates above 40 V	—	—	—	—	—	—	—
<b>Protection Features</b>							
On Chip Regulator	X	—	—	—	—	—	—
Internal Soft Start	—	X	X	X	X	X	—
Under Voltage Lockout	—	X	X	X	X	X	—
Inhibit Control	—	X	X	X	X	X	X
Double Pulse Protection	—	X	X	X	X	X	—
<b>Output Features</b>							
Single-ended Output	X	—	—	—	—	—	—
Double-ended Outputs	—	X	X	X	X	X	—
Totem-Pole Outputs	—	—	X	X	X	X	—
Parallelable Outputs	—	—	—	—	—	—	—
External Output Trigger	—	—	—	—	—	—	—
<b>AVAILABILITY</b>							
<b>Commercial Temp Range</b>							
Plastic (N Package)	X	X	X	X	X	X	X
Ceramic (J Package)	X	X	X	X	X	X	X
<b>Industrial Temp Range</b>							
Plastic (N Package)	—	X	X	X	X	X	X
Ceramic (J Package)	—	X	X	X	X	X	X
<b>Military Temp Range</b>							
Ceramic (J Package)	X	X	X	X	X	X	X

# SELECTION GUIDE

## SWITCHING VOLTAGE REGULATOR/CONTROLLERS

### general-purpose switching regulators/controllers

PAGES	BASE DEVICE NUMBERS					
	TL493 6-107	TL494 6-107	TL495 6-107	TL593 6-125	TL594 6-125	TL595 6-125
<b>FEATURES</b>						
<b>General Features</b>						
Fixed On time	—	—	—	—	—	—
Fixed Frequency PWM	X	X	X	X	X	X
Low Bias Current Requirements	—	—	—	—	—	—
Expandable	X	X	X	X	X	X
<b>Control Features</b>						
On Chip Reference	X	X	X	X	X	X
Precision On Chip Reference	—	—	—	X	X	X
Dead Time Adjust	X	X	X	X	X	X
Current Sense Amplifier	1	—	—	1	—	—
Error Amplifier	1	2	2	1	2	2
Operates to 40 V	X	X	X	X	X	X
Operates above 40 V	—	—	X	—	—	X
<b>Protection Features</b>						
On Chip Regulator	—	—	X	—	—	X
Internal Soft Start	—	—	—	—	—	—
Under Voltage Lockout	—	—	—	X	X	X
Inhibit Control	X	X	X	X	X	X
Double Pulse Protection	X	X	X	X	X	X
<b>Output Features</b>						
Single-ended Output	—	—	—	—	—	—
Double-ended Outputs	X	X	X	X	X	X
Totem-pole Outputs	—	—	—	—	—	—
Parallelable Outputs	X	X	X	X	X	X
External Output Trigger	—	—	X	—	—	X
<b>AVAILABILITY</b>						
<b>Commercial Temp Range</b>						
Plastic (N Package)	X	X	X	X	X	X
Ceramic (J Package)	—	X	—	—	—	—
<b>Industrial Temp Range</b>						
Plastic (N Package)	—	X	—	—	X	—
Ceramic (J Package)	—	X	—	—	X	—
<b>Military Temp Range</b>						
Ceramic (J Package)	—	X	—	X	X	—

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special-purpose regulators and controllers

DEVICE NUMBER	FUNCTION	FEATURES	PAGE
TL496	9-Volt Power Supply Controller	Operates from a variety of sources including 1- and 2-cell batteries and step-down ac line voltage.	6-115

## GLOSSARY

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### SERIES REGULATORS

#### Input Regulation

The change in output voltage, often expressed as a percentage of output voltage, for a change in input voltage from one level to another level.

NOTE: Sometimes this characteristic is normalized with respect to the input voltage change.

#### Ripple Rejection

The ratio of the peak-to-peak input ripple voltage to the peak-to-peak output ripple voltage.

NOTE: This is the reciprocal of ripple sensitivity.

#### Ripple Sensitivity

The ratio of the peak-to-peak output ripple voltage, sometimes expressed as a percentage of output voltage, to the peak-to-peak input ripple voltage.

NOTE: This is the reciprocal of ripple rejection.

#### Output Regulation

The change in output voltage, often expressed as a percentage of output voltage, for a change in load current from one level to another level.

#### Output Resistance

The output resistance under small-signal conditions.

#### Temperature Coefficient of Output Voltage ( $\alpha_{VO}$ )

The ratio of the change in output voltage, usually expressed as a percentage of output voltage, to the change in temperature. This is the average value for the total temperature change.

$$\alpha_{VO} = \pm \left[ \frac{V_O \text{ at } T_2 - V_O \text{ at } T_1}{V_O \text{ at } 25^\circ\text{C}} \right] \left[ \frac{100\%}{T_2 - T_1} \right]$$

#### Output Voltage Change with Temperature

The percentage change in the output voltage for a change in temperature. This is the net change over the total temperature range.

#### Output Voltage Long-Term Drift

The change in output voltage over a long period of time.

#### Output Noise Voltage

The rms value of the ac component of the output voltage, sometimes expressed as a percentage of the dc output voltage, with constant load and no input ripple.

#### Current-Limit Sense Voltage

The current-sense voltage at which current limiting occurs.

---

**Current-Sense Voltage**

The voltage that is a function of the load current and is normally used for control of the current-limiting circuitry.

**Dropout Voltage**

The low input-to-output differential voltage at which the circuit ceases to regulate against further reductions in input voltage.

**Feedback Sense Voltage**

The voltage that is a function of the output voltage and is used for feedback control of the regulator.

**Reference Voltage**

The voltage that is compared with the feedback sense voltage to control the regulator.

**Bias Current**

The difference between input and output currents.  
NOTE: This is sometimes referred to as quiescent current.

**Standby Current**

The input current drawn by the regulator with no output load and no reference voltage load.

**Short-Circuit Output Current**

The output current of the regulator with the output shorted to ground.

**Peak Output Current**

The maximum output current that can be obtained from the regulator due to limiting circuitry within the regulator.

**Overvoltage Shutdown Voltage**

The input voltage applied to a regulator having overvoltage shutdown protection that will cause the output voltage to go nearly to zero.

**Junction Temperature, Virtual Junction Temperature**

A temperature representing the temperature of the junction(s), field-effect transistor channel(s), or other internal point(s) of heat generation calculated on the basis of a simplified model of the thermal and electrical behavior of the semiconductor device.

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**SHUNT REGULATORS**

NOTE: These terms and symbols are based on JEDEC and IEC standards for voltage regulator diodes.

**Shunt Regulator**

A device having a voltage-current characteristic similar to that of a voltage-regulator diode; normally biased to operate in a region of low differential resistance (corresponding to the breakdown region of a regulator diode) to develop across its terminals an essentially constant voltage throughout a specified current range.

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## GLOSSARY

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### Anode

The electrode to which the regulator current flows within the regulator when it is biased for regulation.

### Cathode

The electrode from which the regulator current flows within the regulator when it is biased for regulation.

### Reference Input Voltage ( $V_{\text{ref}}$ ) (of an adjustable shunt regulator)

The voltage at the reference input terminal with respect to the anode terminal.

### Temperature Coefficient of Reference Voltage ( $\alpha V_{\text{ref}}$ )

The ratio of the change in reference voltage to the change in temperature. This is the average value for the total temperature change.

To obtain a value in ppm/°C:

$$\alpha V_{\text{ref}} = \left[ \frac{V_{\text{ref at } T_2} - V_{\text{ref at } T_1}}{V_{\text{ref at } 25^\circ\text{C}}} \right] \left[ \frac{10^6}{T_2 - T_1} \right]$$

### Regulator Voltage ( $V_Z$ )

The dc voltage across the regulator when it is biased for regulation.

### Regulator Current ( $I_Z$ )

The dc current through the regulator when it is biased for regulation.

### Regulator Current near Lower Knee of Regulation Range ( $I_{ZK}$ )

The regulator current near the lower limit of the region within which regulation occurs; this corresponds to the breakdown knee of a regulator diode.

### Regulator Current at Maximum Limit of Regulation Range ( $I_{ZM}$ )

The regulator current above which the differential resistance of the regulator significantly increases.

### Differential Regulator Resistance ( $r_z$ )

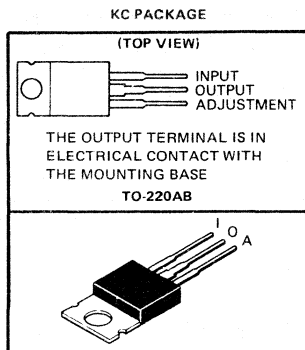
The quotient of a change in voltage across the regulator and the corresponding change in current through the regulator when it is biased for regulation.

### Noise Voltage ( $V_{nz}$ )

The rms value of the ac component of the voltage across the regulator with the regulator biased for regulation and with no input ripple.

- Output Voltage Range Adjustable from 1.2 V to 37 V
- Guaranteed Output Current Capability of 1.5 A
- Input Regulation Typically 0.01% Per Input-Volt Change
- Output Regulation Typically 0.1%
- Peak Output Current Constant Over Temperature Range of Regulator
- Popular 3-Lead TO-220AB Package
- Ripple Rejection Typically 80 dB
- Direct Replacement for National LM217 and LM317

**terminal assignments**



**description**

The LM217, and LM317 are adjustable 3-terminal positive-voltage regulators capable of supplying 1.5 amperes over a differential voltage range of 3 volts to 40 volts. They are exceptionally easy to use and require only two external resistors to set the output voltage. Both input and output regulation are better than standard fixed regulators. The devices are packaged in a standard transistor package that is easily mounted and handled.

In addition to higher performance than fixed regulators, these regulators offer full overload protection available only in integrated circuits. Included on the chip are current limit, thermal overload protection, and safe-area protection. All overload protection circuitry remains fully functional even if the adjustment terminal is disconnected. Normally, no capacitors are needed unless the device is situated far from the input filter capacitors in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. The adjustment terminal can be bypassed to achieve very high ripple rejection, which is difficult to achieve with standard 3-terminal regulators.

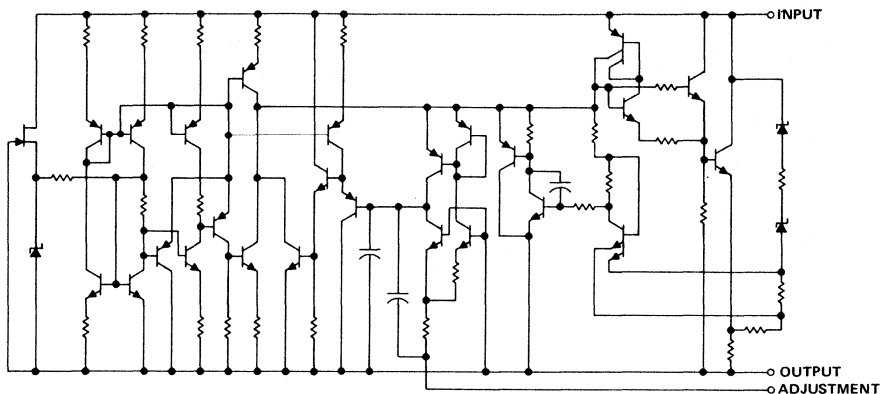
Besides replacing fixed regulators, these regulators are useful in a wide variety of other applications. The primary applications of each of these regulators is that of a programmable output regulator, but by connecting a fixed resistor between the adjustment terminal and the output terminal, each device can be used as a precision current regulator. Even though the regulator is floating and sees only the input-to-output differential voltage, use of these devices to regulate output voltages that would cause the maximum-rated differential voltage to be exceeded if the output became shorted to ground is not recommended. The TL783 or TL783A is recommended for output voltages exceeding 37 volts. Supplies with electronic shutdown can be achieved by clamping the adjustment terminal to ground, which programs the output to 1.2 volts where most loads draw little current.

The LM217 and LM317 are characterized for operation from  $-25^{\circ}\text{C}$  to  $150^{\circ}\text{C}$  and from  $0^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , respectively.

# TYPES LM217, LM317

## 3-TERMINAL ADJUSTABLE REGULATORS

schematic



absolute maximum ratings over operation temperature range (unless otherwise noted)

	LM217	LM317	UNIT
Input-to-output differential voltage, $V_I - V_O$	40	40	V
Continuous total dissipation at 25°C free-air temperature (see Note 1)	2000	2000	mW
Continuous total dissipation at (or below) 25°C case temperature (see Note 1)	20	20	W
Operating free-air, case, or virtual junction temperature range	-25 to 150	0 to 125	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260	260	°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 15 and 16. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

recommended operating conditions

	LM217		LM317		UNIT
	MIN	MAX	MIN	MAX	
Output current, $I_O$	5	1500	10	1500	mA
Operating virtual junction temperature, $T_J$	-25	150	0	125	°C

Voltage Regulators

6



# TYPES LM217, LM317

## 3-TERMINAL ADJUSTABLE REGULATORS

electrical characteristics over recommended ranges of operating virtual junction temperature  
(unless otherwise noted)

PARAMETER	TEST CONDITIONS†		LM217			LM317			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Input regulation (See Note 2)	$V_I - V_O = 3 \text{ V to } 40 \text{ V}$ , See Note 3	$T_J = 25^\circ\text{C}$ $I_O = 10 \text{ mA to } 1.5 \text{ A}$	0.01	0.02		0.01	0.04		%/V
Ripple rejection	$V_O = 10 \text{ V}$ ,	$f = 120 \text{ Hz}$	65			65			dB
	$V_O = 10 \text{ V}$ ,	$f = 120 \text{ Hz}$ 10- $\mu\text{F}$ capacitor between ADJ and ground	66	80		66	80		
Output regulation	$I_O = 10 \text{ mA to } 1.5 \text{ A}$ , $T_J = 25^\circ\text{C}$ , See Note 3	$V_O \leq 5 \text{ V}$	5	15		5	25		mV
		$V_O > 5 \text{ V}$	0.1	0.3		0.1	0.5		%
	$I_O = 10 \text{ mA to } 1.5 \text{ A}$ , See Note 3	$V_O \leq 5 \text{ V}$	20	50		20	70		mV
		$V_O > 5 \text{ V}$	0.3	1		0.3	1.5		%
Output voltage change with temperature	$T_J = \text{MIN to MAX}$		1			1			%
Output voltage long-term drift (see Note 4)	After 1000 h at $T_J = \text{MAX}$ and $V_I - V_O = 40 \text{ V}$		0.3			1			%
Output noise voltage	$f = 10 \text{ Hz to } 10 \text{ kHz}$ , $T_J = 25^\circ\text{C}$		0.003			0.003			%
Minimum output current to maintain regulation	$V_I - V_O = 40 \text{ V}$		3.5			5			mA
Peak output current	$V_I - V_O \leq 15 \text{ V}$		1.5			2.2			A
	$V_I - V_O \leq 40 \text{ V}$		0.4			0.4			
Adjustment-terminal current			50			100			$\mu\text{A}$
Change in adjustment-terminal current	$V_I - V_O = 2.5 \text{ V to } 40 \text{ V}$ , $I_O = 10 \text{ mA to } 1.5 \text{ A}$		0.2			5			$\mu\text{A}$
Reference voltage (output to ADJ)	$V_I - V_O = 3 \text{ V to } 40 \text{ V}$ , $I_O = 10 \text{ mA to } 1.5 \text{ A}$ , $P \leq 20 \text{ W}$		1.2	1.25	1.3	1.2	1.25	1.3	V

† Unless otherwise noted, these specifications apply for the following test conditions:  $V_I - V_O = 5 \text{ V}$  and  $I_O = 0.5 \text{ A}$ . For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

NOTES: 2. Input regulation is expressed here as the percentage change in output voltage per 1-volt change at the input.

3. Input regulation and output regulation are measured using pulse techniques ( $t_W \leq 10 \mu\text{s}$ , duty cycle  $\leq 5\%$ ) to limit changes in average internal dissipation. Output voltage changes due to large changes in internal dissipation must be taken into account separately.

4. Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.



# TYPES LM217, LM317 3-TERMINAL ADJUSTABLE REGULATORS

## TYPICAL APPLICATION DATA

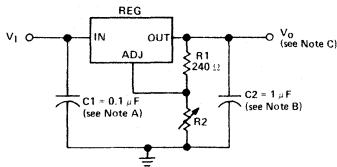


FIGURE 1—ADJUSTABLE VOLTAGE REGULATOR

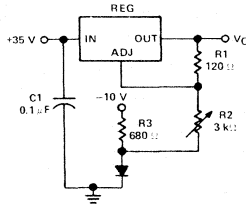
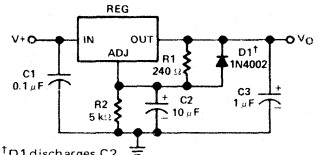


FIGURE 2—0-V to 30-V REGULATOR CIRCUIT



D1 discharges C2 if output is shorted to ground.

FIGURE 3—ADJUSTABLE REGULATOR CIRCUIT WITH IMPROVED RIPPLE REJECTION

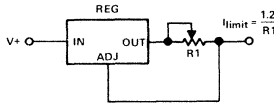


FIGURE 4—PRECISION CURRENT LIMITER CIRCUIT

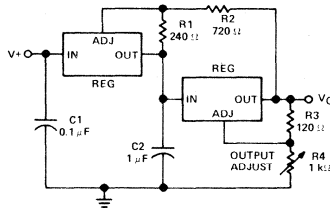


FIGURE 5—TRACKING PREREGULATOR CIRCUIT

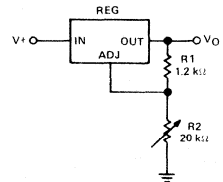
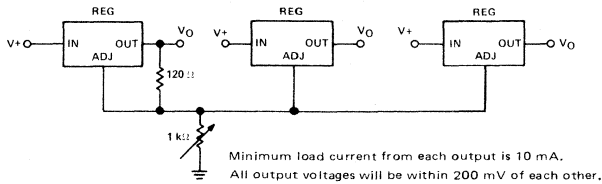


FIGURE 6—1.2 to 20-V REGULATOR CIRCUIT WITH MINIMUM PROGRAM CURRENT



Minimum load current from each output is 10 mA.  
All output voltages will be within 200 mV of each other.

FIGURE 7—ADJUSTING MULTIPLE ON-CARD REGULATORS WITH A SINGLE CONTROL

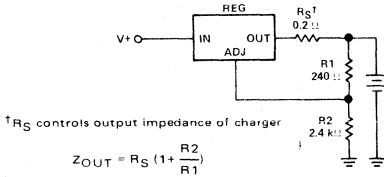
NOTES: A. Use of an input bypass capacitor is recommended if regulator is far from filter capacitors.

B. Use of an output capacitor improves transient response but is optional.

C. Output voltage is calculated from the equation:  $V_O = V_{ref} \left( 1 + \frac{R2}{RT} \right)$

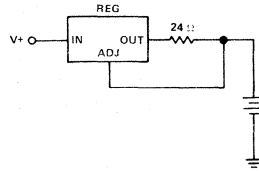
$V_{ref}$  equals the difference between the output and adjustment terminal voltages.

**TYPICAL APPLICATIONS**

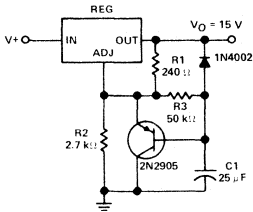


The use of  $R_S$  allows low charging rates with a fully-charged battery.

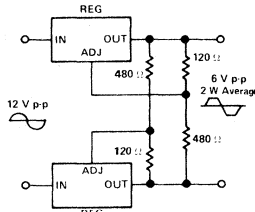
**FIGURE 8—BATTERY CHARGER CIRCUIT**



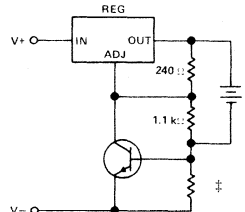
**FIGURE 9—50-mA CONSTANT-CURRENT BATTERY CHARGER CIRCUIT**



**FIGURE 10—SLOW-TURN-ON 15-V REGULATOR CIRCUIT**

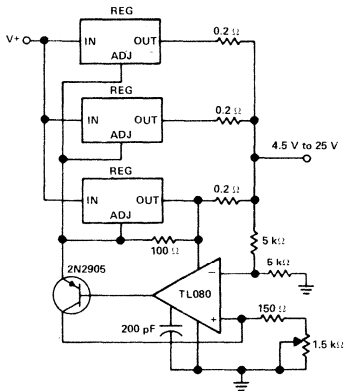


**FIGURE 11—A-C VOLTAGE REGULATOR CIRCUIT**

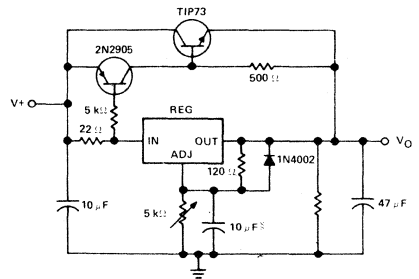


‡ This resistor sets peak current (0.6 A for 1  $\Omega$ )

**FIGURE 12—CURRENT-LIMITED 6-V CHARGER**



**FIGURE 13—ADJUSTABLE 4-A REGULATOR**



§ Minimum load current is 30 mA.  
§ Optional capacitor improves ripple rejection

**FIGURE 14—HIGH-CURRENT ADJUSTABLE REGULATOR**

**TYPES LM217, LM317**  
**3-TERMINAL ADJUSTABLE REGULATORS**

**THERMAL INFORMATION**

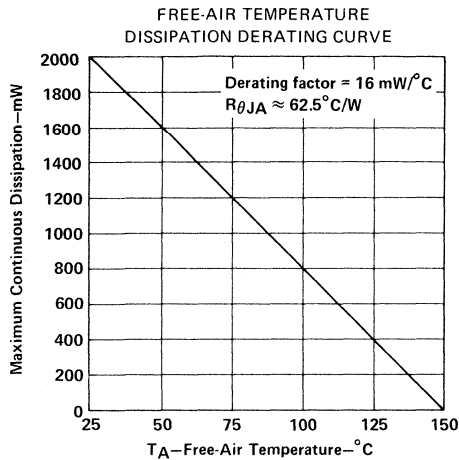


FIGURE 15

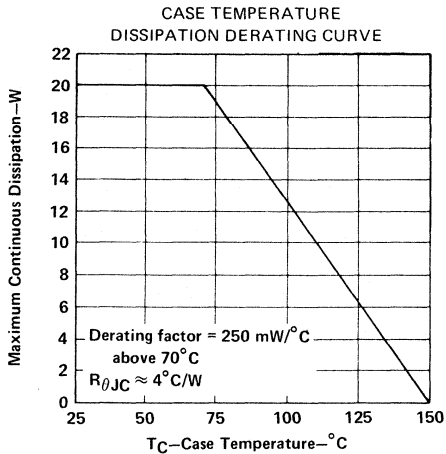
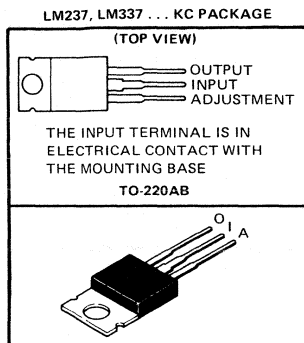


FIGURE 16

- Output Voltage Range Adjustable from  $-1.2\text{ V}$  to  $-37\text{ V}$
- Guaranteed  $I_O$  Capability of  $1.5\text{ A}$
- Input Regulation Typically  $0.01\%$  per Input-Volt Change
- Output Regulation Typically  $0.3\%$
- Peak Output Current Constant Over Temperature Range of Regulator
- Ripple Rejection Typically  $77\text{ dB}$
- Direct Replacement for National Semiconductor LM237, LM337

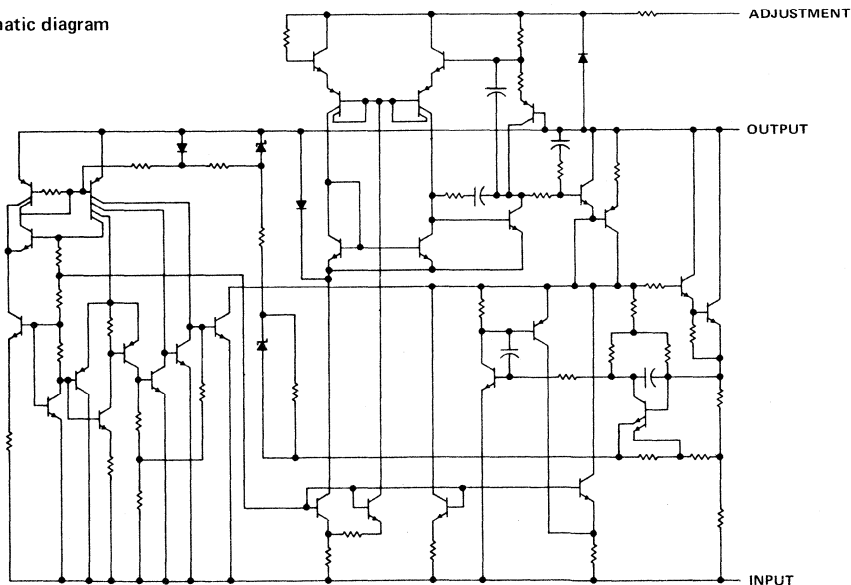


**description**

The LM237 and LM337 are adjustable 3-terminal negative-voltage regulators capable of supplying in excess of  $-1.5\text{ A}$  over an output voltage range of  $-1.2\text{ V}$  to  $-37\text{ V}$ . They are exceptionally easy to use, requiring only two external resistors to set the output voltage and one output capacitor for frequency compensation. The current design has been optimized for excellent regulation and low thermal transients. In addition the LM237 and LM337 feature internal current limiting, thermal shutdown, and safe-area compensation, making them virtually immune to blowout by overloads.

The LM237 and LM337 serve a wide variety of applications including local on-card regulation, programmable output voltage regulation, or precision current regulation. They are ideal complements to the LM217 and LM317 adjustable positive-voltage regulators.

**schematic diagram**



# TYPES LM237, LM337

## 3-TERMINAL ADJUSTABLE REGULATORS

### absolute maximum ratings over operating temperature range (unless otherwise noted)

Input-to-output differential voltage, $V_I - V_O$ .....	-40 V
Continuous total dissipation at 25°C free-air temperature (see Note 1) .....	2 W
Continuous total dissipation at (or below) 25°C case temperature (see Note 1) .....	20 W
Operating free-air, case, or virtual junction temperature range: LM237 .....	-25°C to 150°C
LM337 .....	0°C to 125°C
Storage temperature range .....	-65°C to 150°C
Lead temperature 1/16 inch from case for 10 seconds .....	260°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

Voltage Regulators

6

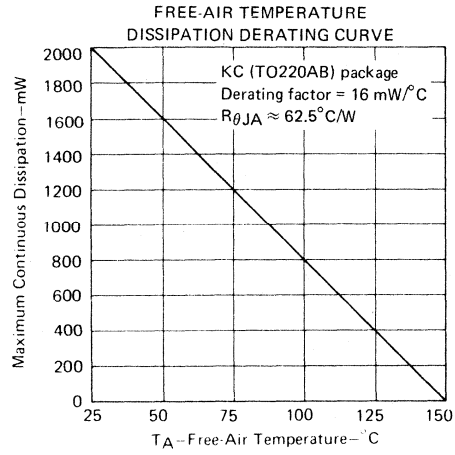


FIGURE 1

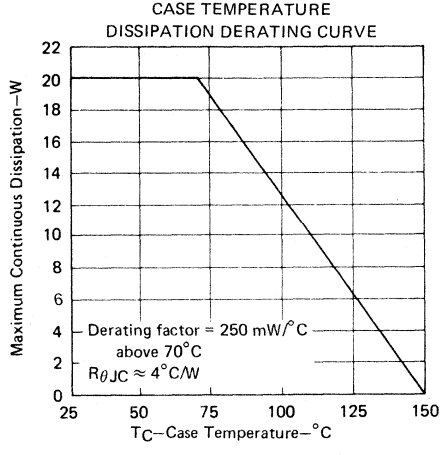


FIGURE 2

# TYPES LM237, LM337

## 3-TERMINAL ADJUSTABLE REGULATORS

### recommended operating conditions

		LM237		LM337		UNIT
		MIN	MAX	MIN	MAX	
Output current, $I_O$	$ V_I - V_O  \leq 40 \text{ V}$ , $P \leq 15 \text{ W}$	10	1500	10	1500	mA
	$ V_I - V_O  \leq 10 \text{ V}$ , $P \leq 15 \text{ W}$	6	1500	6	1500	
Operating virtual junction temperature, $T_J$		-25	150	0	125	$^{\circ}\text{C}$

### electrical characteristics over recommended ranges of operating virtual junction temperature (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	LM237			LM337			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Input regulation <sup>‡</sup>	$V_I - V_O = -3 \text{ V to } -40 \text{ V}$ , See Note 2	$T_J = 25^{\circ}\text{C}$			$T_J = 25^{\circ}\text{C}$			% / V
		$T_J = \text{MIN to MAX}$			$T_J = \text{MIN to MAX}$			
Ripple rejection	$V_O = -10 \text{ V}$ , $V_O = -10 \text{ V}$ , $C_{\text{ADJ}} = 10 \mu\text{F}$	$f = 120 \text{ Hz}$			$f = 120 \text{ Hz}$			dB
		66	77		66	77		
Output regulation	$I_O = 10 \text{ mA to } 1.5 \text{ A}$ , $T_J = 25^{\circ}\text{C}$ , See Note 2	$ V_O  \leq 5 \text{ V}$			$ V_O  \leq 5 \text{ V}$			50
		$ V_O  \geq 5 \text{ V}$			$ V_O  \geq 5 \text{ V}$			1
	$I_O = 10 \text{ mA to } 1.5 \text{ A}$ , See Note 2	$ V_O  \leq 5 \text{ V}$			$ V_O  \leq 5 \text{ V}$			70
		$ V_O  \geq 5 \text{ V}$			$ V_O  \geq 5 \text{ V}$			1.5
Output voltage change with temperature	$T_J = \text{MIN to MAX}$	0.6			0.6			%
Output voltage long-term drift (see Note 3)	After 1000 h at $T_J = \text{MAX}$ and $V_I - V_O = -40 \text{ V}$	0.3	1		0.3	1	%	
Output noise voltage	$f = 10 \text{ Hz to } 10 \text{ kHz}$ , $T_J = 25^{\circ}\text{C}$	0.003			0.003			%
Minimum output current to maintain regulation	$ V_I - V_O  \leq 40 \text{ V}$	2.5	5		2.5	10	mA	
	$ V_I - V_O  \leq 10 \text{ V}$	1.2	3		1.5	6		
Peak output current	$ V_I - V_O  \leq 15 \text{ V}$	1.5	2.2		1.5	2.2	A	
	$ V_I - V_O  \leq 40 \text{ V}$ , $T_J = 25^{\circ}\text{C}$	0.24	0.4		0.15	0.4		
Adjustment-terminal current		65	100		65	100	$\mu\text{A}$	
Change in adjustment terminal current	$V_I - V_O = -2.5 \text{ V to } -40 \text{ V}$ , $I_O = 10 \text{ mA to MAX}$ , $T_J = 25^{\circ}\text{C}$	2	5		2	5	$\mu\text{A}$	
Reference voltage (output to ADJ)	$V_I - V_O = -3 \text{ to } -40 \text{ V}$ , $I_O = 10 \text{ mA to } 1.5 \text{ A}$ , $P \leq \text{rated dissipation}$	$T_J = 25^{\circ}\text{C}$			$T_J = 25^{\circ}\text{C}$			V
		$T_J = \text{MIN to MAX}$			$T_J = \text{MIN to MAX}$			
Thermal regulation	Initial $T_J = 25^{\circ}\text{C}$ , 10-ms pulse	0.002	0.02		0.003	0.04	% / W	

<sup>†</sup> Unless otherwise noted, these specifications apply for the following test conditions  $|V_I - V_O| = 5 \text{ V}$  and  $I_O = 0.5 \text{ A}$ . For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

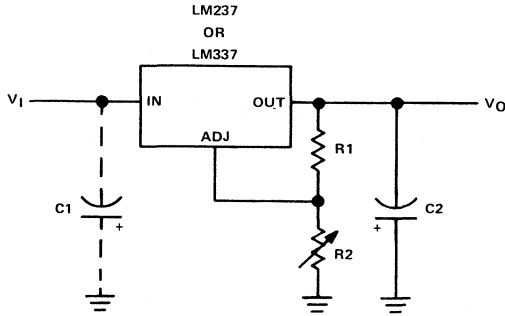
<sup>‡</sup> Input regulation is expressed here as the percentage change in output voltage per 1 volt change at the input.

NOTES: 2. Input regulation and output regulation are measured using pulse techniques ( $t_w \leq 10 \mu\text{s}$ , duty cycle  $\leq 5\%$ ) to limit changes in average internal dissipation. Output voltage changes due to large changes in internal dissipation must be taken into account separately.

3. Since long term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

**TYPES LM237, LM337**  
**3-TERMINAL ADJUSTABLE REGULATORS**

TYPICAL APPLICATION DATA



R1 is typically 120  $\Omega$ .  
 $R2 = R1 \left( \frac{-V_O}{-1.25} - 1 \right)$  where  $V_O$  is the output in volts.

C1 is a 1- $\mu$ F solid tantalum required only if the regulator is more than 10 cm (4 in.) from the power supply filter capacitor.

C2 is a 1- $\mu$ F solid tantalum or 10- $\mu$ F aluminum electrolytic required for stability.

FIGURE 3 – ADJUSTABLE NEGATIVE-VOLTAGE REGULATOR

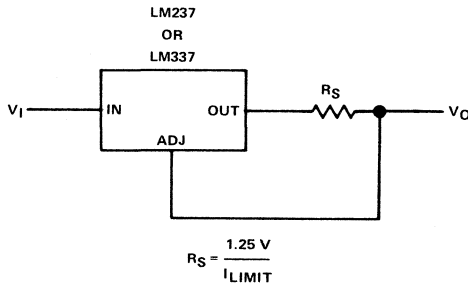
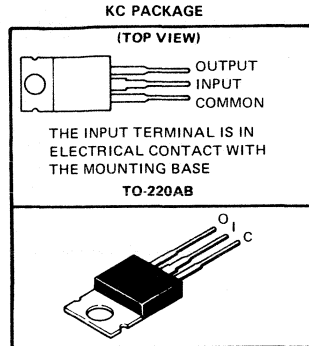


FIGURE 4 – CURRENT-LIMITING CIRCUIT



- 3-Terminal Regulators
- Internal Thermal Overload Protection
- Internal Short-Circuit Current Limiting
- Easily Adjustable to Higher Output Voltage
- Interchangeable with National Semiconductor LM320 Series

NOMINAL OUTPUT VOLTAGE	MAXIMUM OUTPUT CURRENT	REGULATOR
-5 V	1.5 A	LM320-5
-12 V	1 A	LM320-12
-15 V	1A	LM320-15

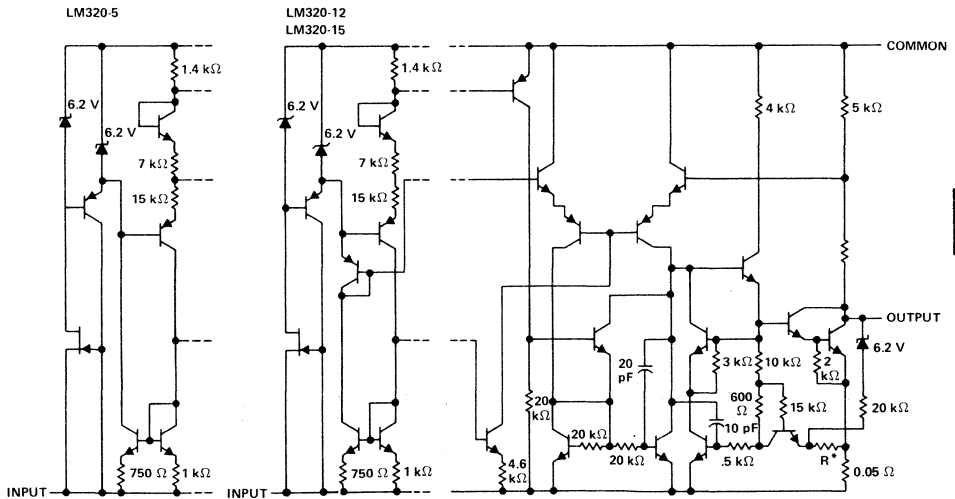


**description**

The LM320 series of three-terminal, fixed-negative-voltage monolithic integrated circuit voltage regulators are designed to provide a fixed output voltage of -5 volts, -12 volts, and -15 volts with up to 1.5 amperes of output current. Each is designed for a wide range of applications which includes on-card regulation for elimination of noise and distribution problems associated with single-point regulation.

The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. The LM320, when used as a fixed-voltage regulator, needs only one external component: a compensation capacitor at the output terminal. In addition, these devices can be used with external components to obtain adjustable output voltages and currents or as the power-pass element in precision regulators.

**schematic diagram**



For LM320-5,  $R^* = 50 \Omega$ . For LM320-12 and LM320-15,  $R^* = 150 \Omega$   
All component values are nominal.

# TYPE SERIES LM320

## 3-TERMINAL NEGATIVE-VOLTAGE REGULATORS

### absolute maximum ratings over operating temperature range (unless otherwise noted)

Input voltage: LM320-5	.....	-25 V
LM320-12	.....	-35 V
LM320-15	.....	-35 V
Input-output voltage differential	.....	25 V
Continuous total dissipation at 25°C free-air temperature (see Note 1)	.....	2 W
Continuous total dissipation at (or below) 25°C case temperature (see Note 1)	.....	15 W
Operating free-air, case, or virtual junction temperature range	.....	-55°C to 150°C
Storage temperature range	.....	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	.....	260°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

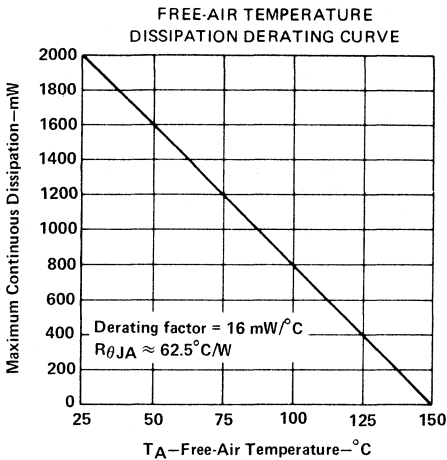


FIGURE 1

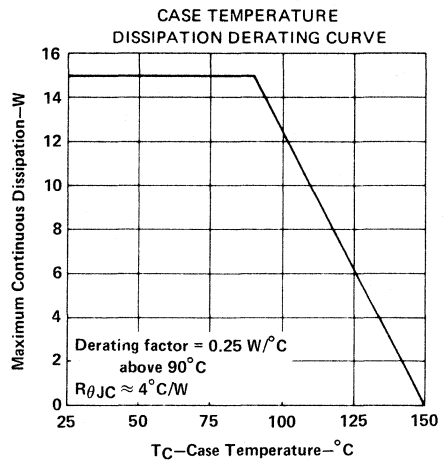


FIGURE 2

### recommended operating conditions

		MIN	MAX	UNIT
Input voltage, $V_I$	LM320-5	-7.5	-25	V
	LM320-12	-14.5	-32	
	LM320-15	-17.5	-35	
Output current, $I_O$	LM320-5		1.5	A
	LM320-12		1	
	LM320-15		1	
Operating virtual junction temperature, $T_J$		0	125	°C

## TYPE SERIES LM320 3-TERMINAL NEGATIVE-VOLTAGE REGULATORS

**LM320-5 electrical characteristics at specified virtual junction temperature,  $I_O = 5\text{ mA}$ ,  $V_I = -10\text{ V}$ , (unless otherwise noted)**

PARAMETER	TEST CONDITIONS <sup>†</sup>	MIN	TYP	MAX	UNIT
Output voltage	$T_J = 25^\circ\text{C}$	-4.8		-5.2	V
	$V_I = -7.5\text{ V to } -25\text{ V}$ , $P \leq 15\text{ W}$ , $I_O = 5\text{ mA to } 1.5\text{ A}$ , $T_J = 0^\circ\text{C to } 125^\circ\text{C}$	-4.75		-5.25	
Input regulation	$V_I = -7.5\text{ V to } -25\text{ V}$ , $T_J = 25^\circ\text{C}$		10	40	mV
Ripple rejection	$f = 120\text{ Hz}$ , $T_J = 0^\circ\text{C to } 125^\circ\text{C}$	54	64		dB
Output regulation	$I_O = 5\text{ mA to } 1.5\text{ A}$ , $T_J = 25^\circ\text{C}$		50	100	mV
Output noise voltage	$C_L = 1\ \mu\text{F}$ , $f = 10\text{ Hz to } 100\text{ kHz}$ , $T_J = 25^\circ\text{C}$		150		$\mu\text{V}$
Output voltage long-term drift (see Note 2)	After 1000 h at $T_J = 125^\circ\text{C}$ , $T_J = 25^\circ\text{C}$		10		mV
Bias current	$V_I = -7.5\text{ V to } -25\text{ V}$ , $T_J = 0^\circ\text{C to } 125^\circ\text{C}$		1	2	mA
Bias current change	$V_I = -7.5\text{ V to } -25\text{ V}$		0.1	0.4	mA
	$I_O = 5\text{ mA to } 1.5\text{ A}$ , $T_J = 25^\circ\text{C}$		0.1	0.4	

**LM320-12 electrical characteristics at specified virtual junction temperature,  $I_O = 5\text{ mA}$ ,  $V_I = -17\text{ V}$ , (unless otherwise noted)**

PARAMETER	TEST CONDITIONS <sup>†</sup>	MIN	TYP	MAX	UNIT
Output voltage	$T_J = 25^\circ\text{C}$	-11.6	-12	-12.4	V
	$V_I = -14.5\text{ V to } -32\text{ V}$ , $P \leq 15\text{ W}$ , $I_O = 5\text{ mA to } 1\text{ A}$ , $T_J = 0^\circ\text{C to } 125^\circ\text{C}$	-11.4		-12.6	
Input regulation	$V_I = -14.5\text{ V to } -32\text{ V}$ , $T_J = 25^\circ\text{C}$		4	20	mV
Ripple rejection	$f = 120\text{ Hz}$ , $T_J = 0^\circ\text{C to } 125^\circ\text{C}$	56	80		dB
Output regulation	$I_O = 5\text{ mA to } 1\text{ A}$ , $T_J = 25^\circ\text{C}$		30	80	mV
Output noise voltage	$C_L = 1\ \mu\text{F}$ , $f = 10\text{ Hz to } 100\text{ kHz}$ , $T_J = 25^\circ\text{C}$		400		$\mu\text{V}$
Output voltage long-term drift (see Note 2)	After 1000 h at $T_J = 125^\circ\text{C}$ , $T_J = 25^\circ\text{C}$		24		mV
Bias current	$V_I = -14.5\text{ V to } -32\text{ V}$ , $T_J = 0^\circ\text{C to } 125^\circ\text{C}$		2	4	mA
Bias current change	$V_I = -14.5\text{ V to } -32\text{ V}$		0.1	0.4	mA
	$I_O = 5\text{ mA to } 1\text{ A}$ , $T_J = 25^\circ\text{C}$		0.1	0.4	

**LM320-15 electrical characteristics at specified virtual junction temperature,  $I_O = 5\text{ mA}$ ,  $V_I = -20\text{ V}$ , (unless otherwise noted)**

PARAMETER	TEST CONDITIONS <sup>†</sup>	MIN	TYP	MAX	UNIT
Output voltage	$T_J = 25^\circ\text{C}$	-14.5	-15	-15.5	V
	$V_I = -17.5\text{ V to } -35\text{ V}$ , $P \leq 15\text{ W}$ , $I_O = 5\text{ mA to } 1\text{ A}$ , $T_J = 0^\circ\text{C to } 125^\circ\text{C}$	-14.3		-15.7	
Input regulation	$V_I = -17.5\text{ V to } -35\text{ V}$ , $T_J = 25^\circ\text{C}$		5	20	mV
Ripple rejection	$f = 120\text{ Hz}$ , $T_J = 0^\circ\text{C to } 125^\circ\text{C}$	56	80		dB
Output regulation	$I_O = 5\text{ mA to } 1\text{ A}$ , $T_J = 25^\circ\text{C}$		30	80	mV
Output noise voltage	$C_L = 1\ \mu\text{F}$ , $f = 10\text{ Hz to } 100\text{ kHz}$ , $T_J = 25^\circ\text{C}$		400		$\mu\text{V}$
Output voltage long-term drift (see Note 2)	After 1000 h at $T_J = 125^\circ\text{C}$ , $T_J = 25^\circ\text{C}$		30		mV
Bias current	$V_I = -17.5\text{ V to } -35\text{ V}$ , $T_J = 0^\circ\text{C to } 125^\circ\text{C}$		2	4	mA
Bias current change	$V_I = -17.5\text{ V to } -35\text{ V}$		0.1	0.4	mA
	$I_O = 5\text{ mA to } 1\text{ A}$ , $T_J = 25^\circ\text{C}$		0.1	0.4	

<sup>†</sup>All characteristics are measured with a 1- $\mu\text{F}$  capacitor across the input and a 2- $\mu\text{F}$  solid-tantalum capacitor across the output. All characteristics except ripple rejection and output noise voltage are measured using pulse techniques ( $t_w \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

NOTE 2: Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

# TYPE SERIES LM320 3-TERMINAL NEGATIVE-VOLTAGE REGULATORS

## TYPICAL CHARACTERISTICS

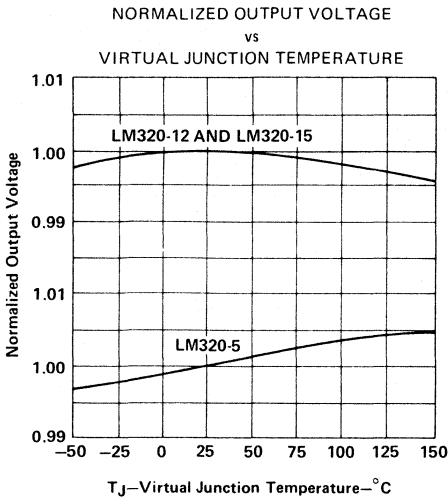


FIGURE 3

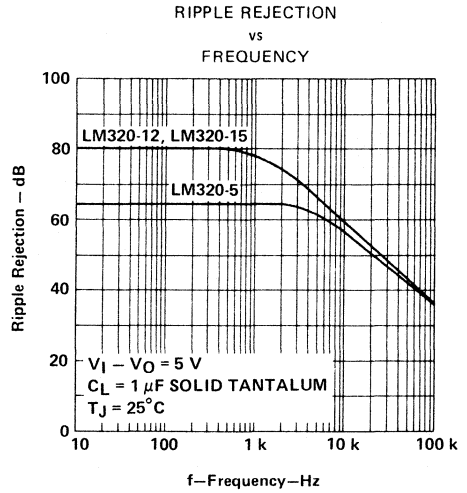


FIGURE 4

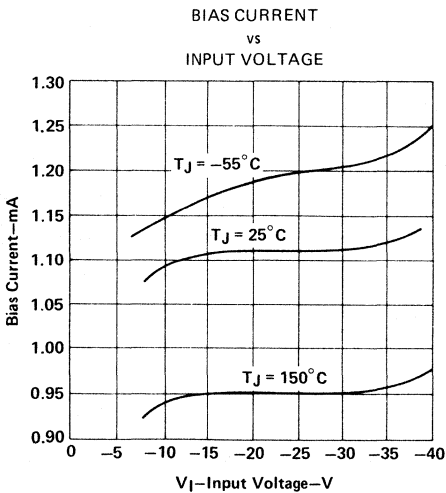


FIGURE 5

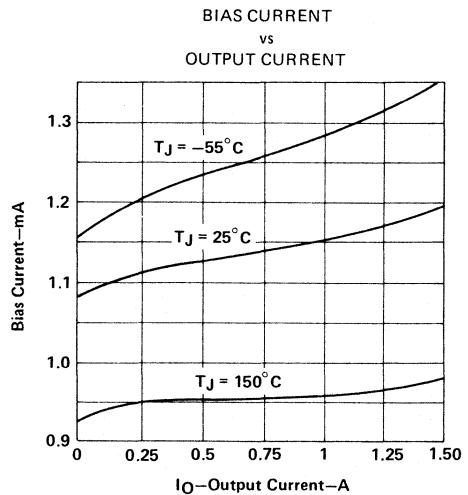


FIGURE 6



TYPICAL CHARACTERISTICS

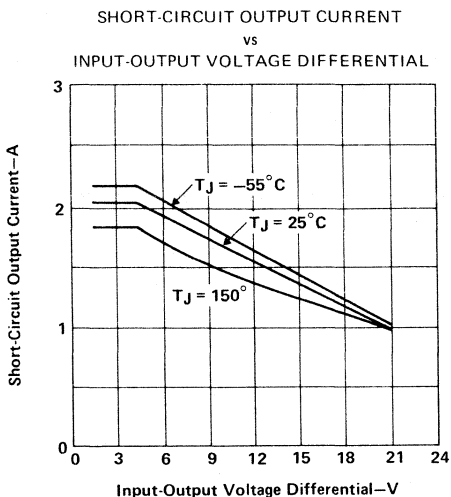


FIGURE 7

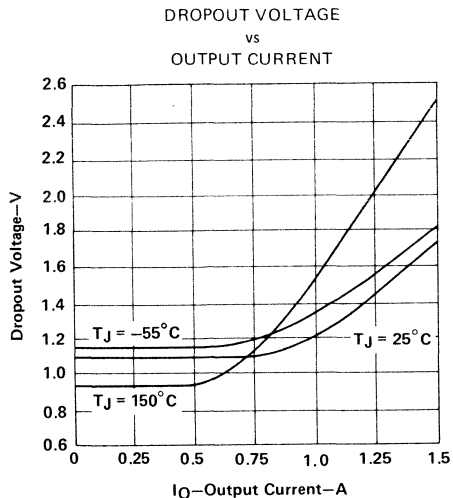


FIGURE 8

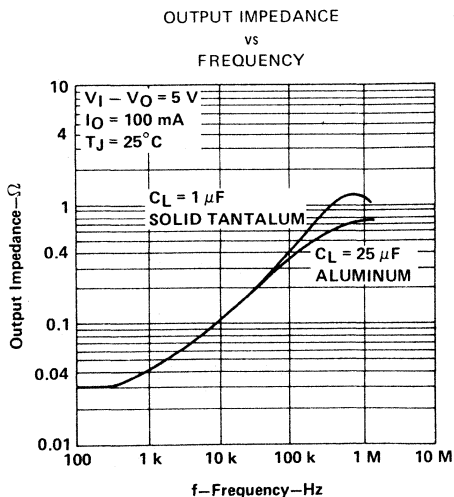


FIGURE 9



# TYPE SERIES LM320 3-TERMINAL NEGATIVE-VOLTAGE REGULATORS

## TYPICAL APPLICATION INFORMATION

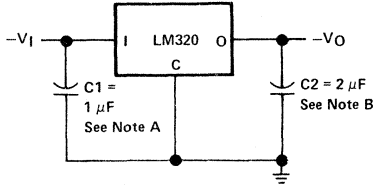


FIGURE 10 — FIXED-VOLTAGE REGULATOR

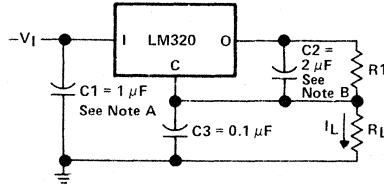


FIGURE 11 — CURRENT SOURCE REGULATOR

LM320-5	$I_L = 1 \text{ mA} + \frac{5 \text{ V}}{R_1}$
LM320-12KC	$I_L = 2 \text{ mA} + \frac{12 \text{ V}}{R_1}$
LM320-15KC	$I_L = 2 \text{ mA} + \frac{15 \text{ V}}{R_1}$

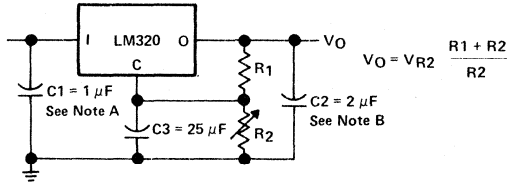


FIGURE 12 — ADJUSTABLE OUTPUT REGULATOR

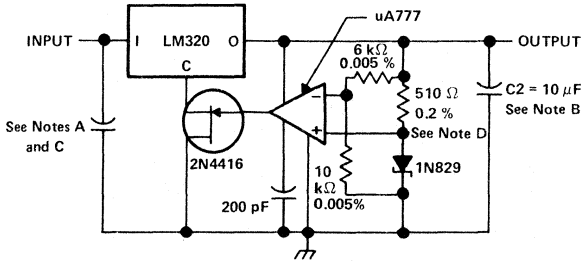
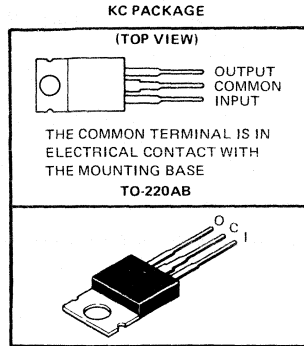


FIGURE 13 — HIGH-STABILITY REGULATOR

- NOTES: A. Capacitor C1 is required if the regulator is not located within 75 mm (3 inches) of the power supply filter.  
 B. Capacitor C2 is required for stability. For the value given, the capacitor must be solid tantalum but a 25- $\mu$ F aluminum electrolytic may be substituted. Values given may be increased without limit.  
 C. In Figure 13 capacitor C1 is solid tantalum.  
 D. This resistor determines zener current. Adjust to minimize thermal drift.

- Input-Output Differential Less than 0.6 V
- Output Current of 150 mA
- Reverse Polarity Protection
- Line Transient Protection
- Internal Short-Circuit Current Limiting
- Internal Thermal Overload Protection
- Mirror-Image Insertion Protection
- Direct Replacement for National LM330T-5.0



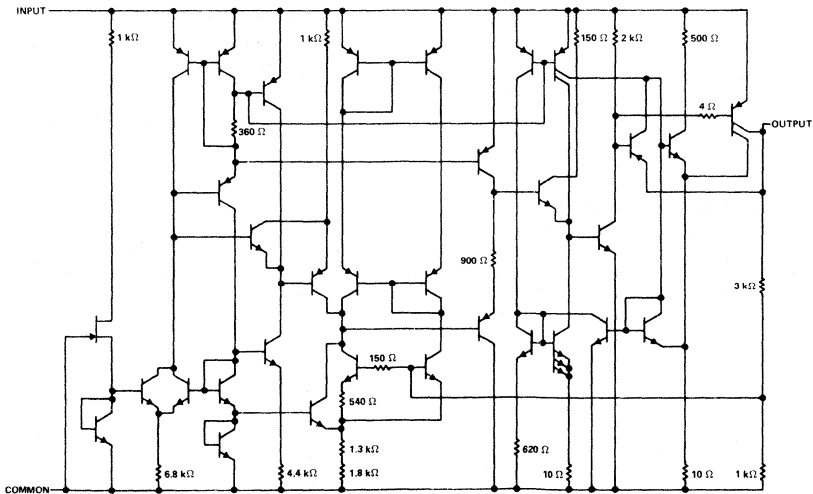
**description**

The LM330 3-terminal positive regulator features an ability to source 150 milliamperes of output current with an input-output differential of 0.6 volt or less. Familiar regulator features such as current limit and thermal overload protection are also provided.

The LM330 has low dropout voltage making it useful for certain battery applications. For example, since the low dropout voltage allows a longer battery discharge before the output falls out of regulation, a battery supplying the regulator input voltage may discharge to 5.6 volts and still properly regulate the system and load voltage. The LM330 protects both itself and the regulated system from reverse installation of batteries.

Other protection features include line transient protection above 40 volts, where the output actually shuts down to avoid damaging internal and external circuits. The LM330 regulator cannot be harmed by temporary mirror-image insertion.

**schematic diagram**



# TYPE LM330

## 3-TERMINAL POSITIVE REGULATOR

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Continuous input voltage	26 V
Transient input voltage <sup>1</sup> t = 1 s	50 V
t = 100 ms	60 V
Continuous total dissipation at 25°C free-air temperature (see Note 1)	2 W
Continuous total dissipation at (or below) case temperature (see Note 1)	20 W
Operating free-air, case, or virtual junction temperature	-55°C to 150°C
Storage temperature	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

FREE-AIR TEMPERATURE  
DISSIPATION DERATING CURVE

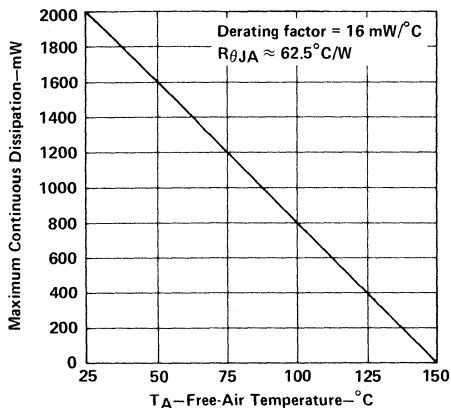


FIGURE 1

CASE TEMPERATURE  
DISSIPATION DERATING CURVE

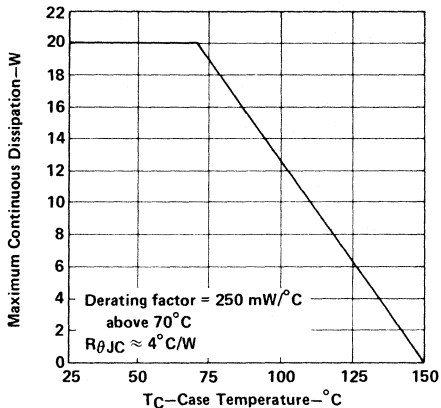


FIGURE 2

### recommended operating conditions

		MIN	MAX	UNIT
I <sub>O</sub>	Output current	5	150	mA
T <sub>A</sub>	Operating virtual junction temperature	0	100	°C





## TYPE LM330 3-TERMINAL POSITIVE REGULATOR

electrical characteristics at 25°C virtual junction temperature,  $V_I = 14\text{ V}$ ,  $I_O = 150\text{ mA}$ ,  
(unless otherwise noted)

PARAMETERS	TEST CONDITIONS <sup>†</sup>		MIN	TYP	MAX	UNIT
Output voltage	$V_I = 6\text{ V to }26\text{ V}$ ,	$I_O = 5\text{ mA to }150\text{ mA}$ ,	4.8	5	5.2	V
	$T_J = 0^\circ\text{C to }100^\circ\text{C}$		4.75		5.25	
Input regulation	$I_O = 5\text{ mA}$	$V_I = 9\text{ V to }16\text{ V}$		7	25	mV
		$V_I = 6\text{ V to }26\text{ V}$		30	60	
Ripple rejection	$f = 120\text{ Hz}$			56		dB
Output regulation	$I_O = 5\text{ mA to }150\text{ mA}$			14	50	mV
Output voltage long-term drift <sup>‡</sup>	After 1000 h at $T_J = 100^\circ\text{C}$			20		mV
Dropout voltage	$I_O = 150\text{ mA}$			0.32	0.6	V
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$			50		$\mu\text{V}$
Output voltage with input polarity reversed	$R_L = 100\ \Omega$	$V_I = -30\text{ V}$ , $t = 100\text{ ms}$		> -0.3		V
		$V_I = -12\text{ V}$ , DC		> -0.3		
Output voltage with input transient	$V_I = 60\text{ V}$ ,	$t = 100\text{ ms}$		< 5.5		V
	$V_I = 50\text{ V}$ ,	$t = 1\text{ s}$		< 5.5		
Bias current with input transient	$R_L = 100\ \Omega$	$V_I = 40\text{ V}$ , $t = 1\text{ s}$		14		mA
		$V_I = -6\text{ V}$ , $t = 1\text{ s}$		-80		
Overvoltage shutdown voltage			26	45		V
Output impedance	$I_O = 100\text{ mA}$ , $I_O = 10\text{ mA (rms)}$ , $f = 100\text{ Hz to }10\text{ kHz}$			200		$\text{m}\Omega$
Bias current	$I_O = 10\text{ mA}$			3.5	7	mA
	$I_O = 50\text{ mA}$			5	11	
	$I_O = 150\text{ mA}$			18	40	
Bias current change	$V_I = 6\text{ V to }26\text{ V}$			10		%
Peak output current			150	420	700	mA

<sup>†</sup>Unless otherwise specified, all characteristics except ripple rejection and noise voltage measurements are measured using pulse techniques ( $t_w \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ) with a capacitor of  $0.1\ \mu\text{F}$  across the input and a capacitor of  $10\ \mu\text{F}$  across the output. Output voltage changes due to changes in internal temperature must be taken into account separately.

<sup>‡</sup>Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.



# TYPE LM330 3-TERMINAL POSITIVE REGULATOR

## TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE  
VS  
VIRTUAL JUNCTION TEMPERATURE

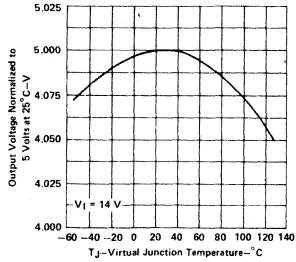


FIGURE 3

OUTPUT VOLTAGE  
VS  
INPUT VOLTAGE

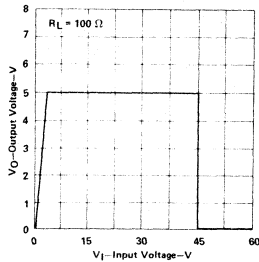


FIGURE 4

OUTPUT VOLTAGE  
VS  
INPUT VOLTAGE

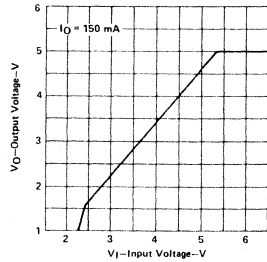


FIGURE 5

PEAK OUTPUT CURRENT  
VS  
INPUT VOLTAGE

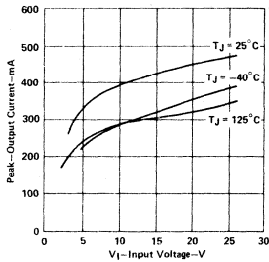


FIGURE 6

RIPPLE REJECTION  
VS  
FREQUENCY

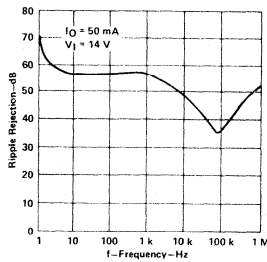


FIGURE 7

RIPPLE REJECTION  
VS  
OUTPUT CURRENT

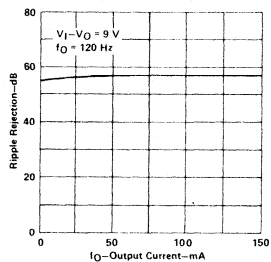


FIGURE 8

DROPOUT VOLTAGE  
VS  
VIRTUAL JUNCTION TEMPERATURE

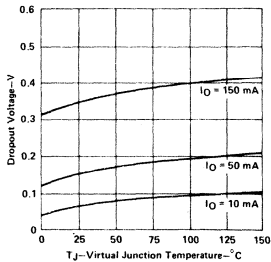


FIGURE 9

DROPOUT VOLTAGE  
VS  
OUTPUT CURRENT

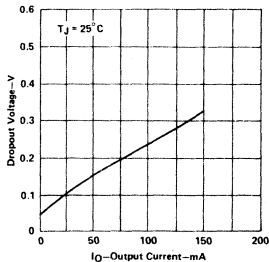


FIGURE 10

OUTPUT IMPEDANCE  
VS  
FREQUENCY

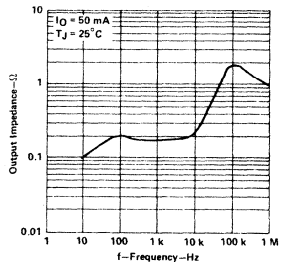


FIGURE 11

TYPICAL CHARACTERISTICS

INPUT CURRENT  
VS  
INPUT VOLTAGE

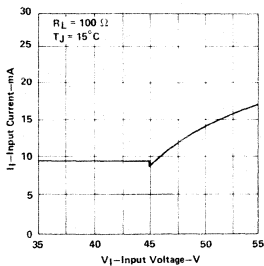


FIGURE 12

LINE TRANSIENT RESPONSE

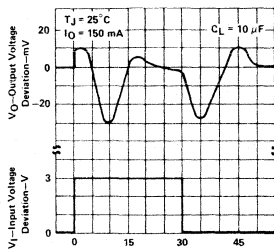


FIGURE 13

INPUT CURRENT  
VS  
REVERSE INPUT VOLTAGE

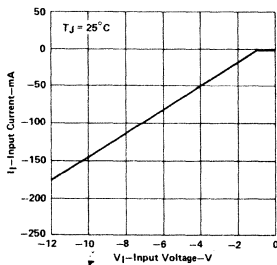


FIGURE 14

OUTPUT VOLTAGE  
VS  
REVERSE INPUT VOLTAGE

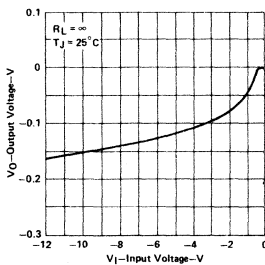


FIGURE 15

LOAD TRANSIENT RESPONSE

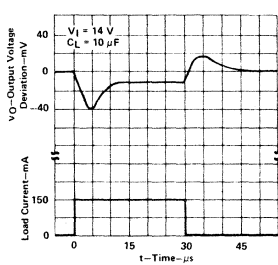


FIGURE 16

BIAS CURRENT  
VS  
OUTPUT CURRENT

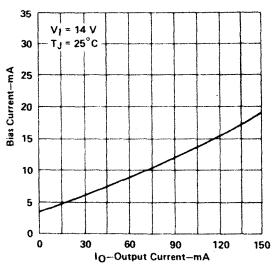


FIGURE 17

BIAS CURRENT  
VS  
VIRTUAL JUNCTION TEMPERATURE

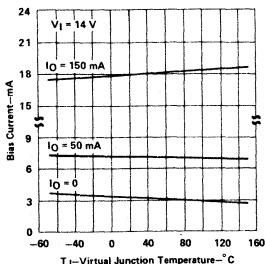


FIGURE 18

BIAS CURRENT  
VS  
INPUT VOLTAGE

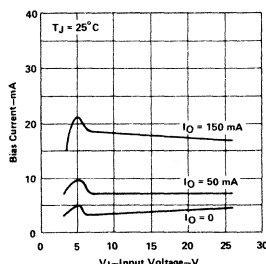
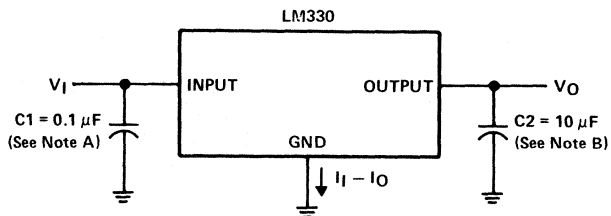


FIGURE 19

# TYPE LM330

## 3-TERMINAL POSITIVE REGULATOR

### TYPICAL APPLICATION DATA



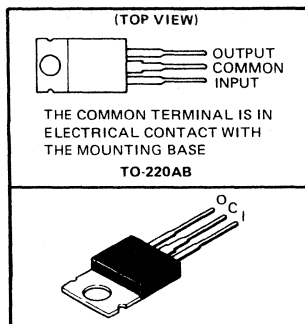
- NOTES: A. Use of  $C1$  is required if the regulator is not located in close proximity to the supply filter.
- B. Capacitor  $C2$  must be located as close as possible to the regulator and may be an aluminum or tantalum type capacitor. The minimum capacitance that will provide stability is  $10 \mu\text{F}$ . The capacitor must be rated for operation at  $-40^\circ\text{C}$  to guarantee stability to that extreme.

FIGURE 20

- 3-Terminal Regulators
- Output Current up to 1.5 A
- No External Components
- Internal Thermal Overload
- High Power Dissipation Capability
- Internal Short-Circuit Current Limiting
- Output Transistor Safe-Area Compensation
- Output Load Regulation . . . 0.3% Typ
- Direct Replacements for National LM340 Series

NOMINAL OUTPUT VOLTAGE	REGULATOR
5 V	LM340-5
12 V	LM340-12
15 V	LM340-15

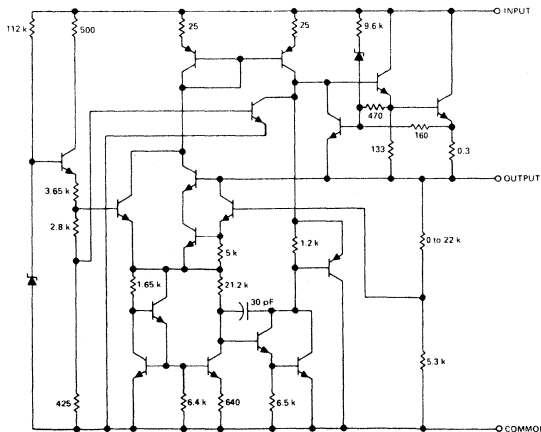
**KC PACKAGE**



**description**

This series of fixed-voltage monolithic integrated-circuit voltage regulators is designed for a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Any of these regulators can deliver up to 1.5 amperes of output current. The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. In addition to use as fixed-voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents and also as the power-pass element in precision regulators.

**schematic**



Resistor values shown are nominal and in ohms.



## SERIES LM340 POSITIVE-VOLTAGE REGULATORS

LM340-12 electrical characteristics at specified virtual junction temperature,  $V_I = 19\text{ V}$ ,  $I_O = 1\text{ A}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		MIN	TYP	MAX	UNIT
	$I_O = 5\text{ mA to }1\text{ A}$	$25^\circ\text{C}$				
Output voltage	$V_I = 14.5\text{ V to }27\text{ V}$ , $P \leq 15\text{ W}$	$I_O = 5\text{ mA to }1\text{ A}$ , $0^\circ\text{C to }125^\circ\text{C}$	11.5	12	12.5	V
			11.4		12.6	
Input regulation	$I_O = 500\text{ mA}$	$V_I = 14.5\text{ V to }30\text{ V}$	$25^\circ\text{C}$	4	120	mV
		$V_I = 15\text{ V to }27\text{ V}$	$0^\circ\text{C to }125^\circ\text{C}$		120	
	$I_O = 1\text{ A}$	$V_I = 14.6\text{ V to }27\text{ V}$	$25^\circ\text{C}$		120	
		$V_I = 16\text{ V to }22\text{ V}$	$0^\circ\text{C to }125^\circ\text{C}$		120	
Ripple rejection	$V_I = 15\text{ V to }25\text{ V}$ , $f = 120\text{ Hz}$	$I_O \leq 1\text{ A}$	$25^\circ\text{C}$	55	72	dB
		$I_O \leq 500\text{ mA}$	$0^\circ\text{C to }125^\circ\text{C}$	55		
Output regulation	$I_O = 250\text{ mA to }750\text{ mA}$	$25^\circ\text{C}$			60	mV
	$I_O = 5\text{ mA to }1.5\text{ A}$			12	120	
	$I_O = 5\text{ mA to }1\text{ A}$	$0^\circ\text{C to }125^\circ\text{C}$			120	
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$	$25^\circ\text{C}$		75		$\mu\text{V}$
Dropout voltage	$I_O = 1\text{ A}$	$25^\circ\text{C}$		2		V
Temperature coefficient of output voltage	$I_O = 5\text{ mA}$	$0^\circ\text{C to }125^\circ\text{C}$		-1.5		mV/ $^\circ\text{C}$
Output impedance	$f = 1\text{ kHz}$	$25^\circ\text{C}$		18		$\text{m}\Omega$
Bias current	$I_O \leq 1\text{ A}$	$25^\circ\text{C}$			8	mA
		$0^\circ\text{C to }125^\circ\text{C}$			8.5	
Bias current change	$V_I = 14.8\text{ V to }27\text{ V}$ , $I_O \leq 1\text{ A}$	$25^\circ\text{C}$			1	mA
		$V_I = 14.5\text{ V to }30\text{ V}$ , $I_O \leq 500\text{ mA}$			1	
	$I_O = 5\text{ mA to }1\text{ A}$	$0^\circ\text{C to }125^\circ\text{C}$			0.5	
Peak output current		$25^\circ\text{C}$		2.4		A
Short-circuit current		$25^\circ\text{C}$		1.5		A

<sup>†</sup> All characteristics are measured with a capacitor across the input of  $0.22\ \mu\text{F}$  and a capacitor across the output of  $0.1\ \mu\text{F}$ . All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# SERIES LM340 POSITIVE-VOLTAGE REGULATORS

LM340-15 electrical characteristics at specified virtual junction temperature,  $V_I = 23\text{ V}$ ,  $I_O = 1\text{ A}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MIN	TYP	MAX	UNIT
Output voltage	$I_O = 5\text{ mA to }1\text{ A}$	$25\text{ }^\circ\text{C}$	14.4	15	15.6	V
	$V_I = 17.5\text{ V to }30\text{ V}$ , $P \leq 15\text{ W}$	$I_O = 5\text{ mA to }1\text{ A}$ , $0\text{ }^\circ\text{C to }125\text{ }^\circ\text{C}$	14.25		15.75	
Input regulation	$I_O = 500\text{ mA}$	$V_I = 17.5\text{ V to }30\text{ V}$	$25\text{ }^\circ\text{C}$	4	150	mV
		$V_I = 18.5\text{ V to }30\text{ V}$	$0\text{ }^\circ\text{C to }125\text{ }^\circ\text{C}$		150	
	$I_O = 1\text{ A}$	$V_I = 17.7\text{ V to }30\text{ V}$	$25\text{ }^\circ\text{C}$		150	
		$V_I = 20\text{ V to }26\text{ V}$	$0\text{ }^\circ\text{C to }125\text{ }^\circ\text{C}$		75	
Ripple rejection	$V_I = 18.5\text{ V to }28.5\text{ V}$ , $f = 120\text{ Hz}$	$I_O \leq 1\text{ A}$	$25\text{ }^\circ\text{C}$	54	70	dB
		$I_O \leq 500\text{ mA}$	$0\text{ }^\circ\text{C to }125\text{ }^\circ\text{C}$	54		
Output regulation	$I_O = 250\text{ mA to }750\text{ mA}$	$25\text{ }^\circ\text{C}$			75	mV
	$I_O = 5\text{ mA to }1.5\text{ A}$			12	150	
	$I_O = 5\text{ mA to }1\text{ A}$		$0\text{ }^\circ\text{C to }125\text{ }^\circ\text{C}$			
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$	$25\text{ }^\circ\text{C}$		90		$\mu\text{V}$
Dropout voltage	$I_O = 1\text{ A}$	$25\text{ }^\circ\text{C}$		2		V
Temperature coefficient of output voltage	$I_O = 5\text{ mA}$	$0\text{ }^\circ\text{C to }125\text{ }^\circ\text{C}$		-1.8		mV/°C
Output impedance	$f = 1\text{ kHz}$	$25\text{ }^\circ\text{C}$		19		m $\Omega$
Bias current	$I_O \leq 1\text{ A}$	$25\text{ }^\circ\text{C}$		8		mA
		$0\text{ }^\circ\text{C to }125\text{ }^\circ\text{C}$			8.5	
Bias current change	$V_I = 17.9\text{ V to }30\text{ V}$ , $I_O \leq 1\text{ A}$	$25\text{ }^\circ\text{C}$		1		mA
		$0\text{ }^\circ\text{C to }125\text{ }^\circ\text{C}$	$V_I = 17.5\text{ V to }30\text{ V}$ , $I_O \leq 500\text{ mA}$		1	
	$I_O = 5\text{ mA to }1\text{ A}$				0.5	
Peak output current		$25\text{ }^\circ\text{C}$		2.4		A
Short-circuit current		$25\text{ }^\circ\text{C}$		1.2		A

† All characteristics are measured with a capacitor across the input of  $0.22\text{ }\mu\text{F}$  and a capacitor across the output of  $0.1\text{ }\mu\text{F}$ . All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

**SERIES LM340  
POSITIVE-VOLTAGE REGULATORS**

**TYPICAL CHARACTERISTICS**

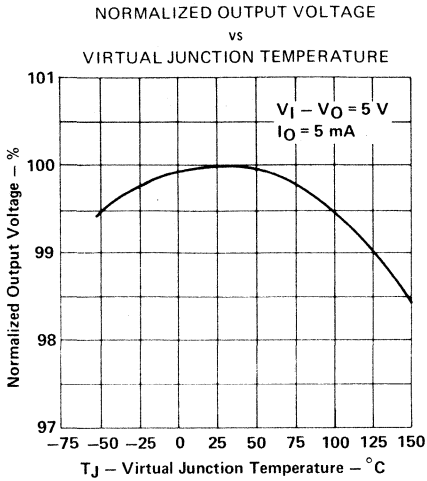


FIGURE 3

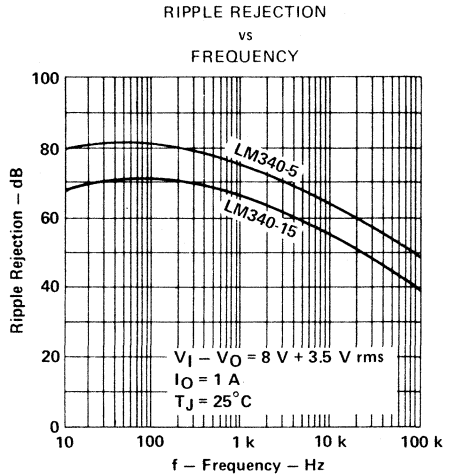


FIGURE 4

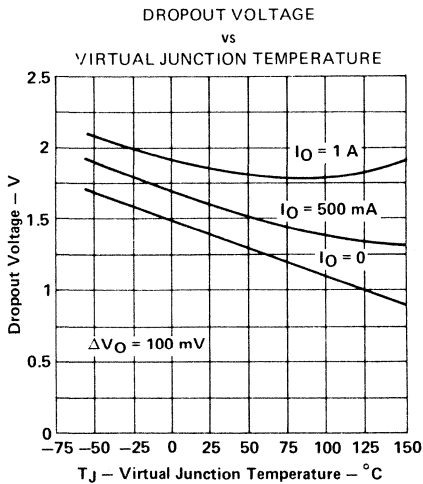


FIGURE 5

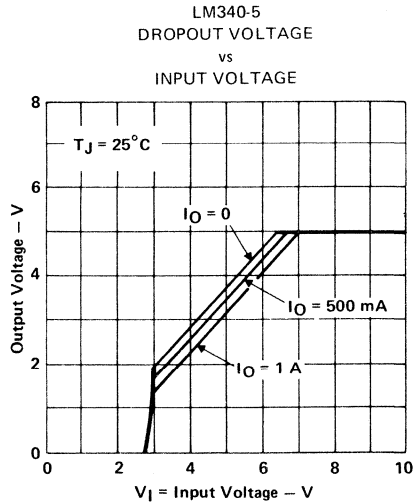
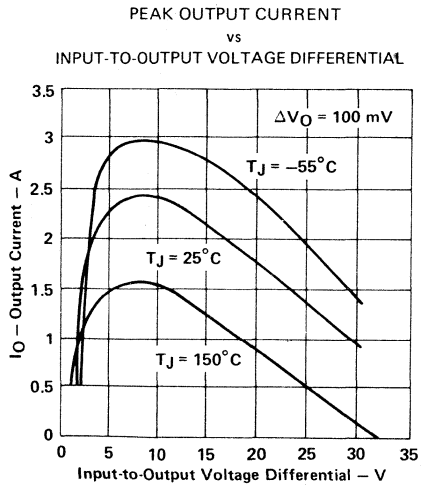
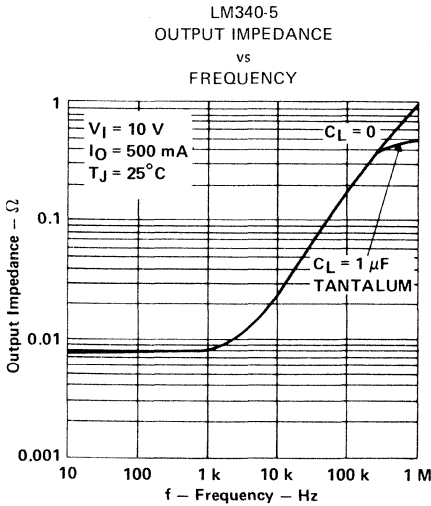
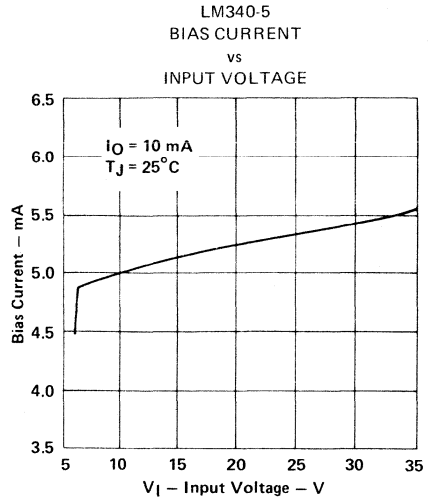
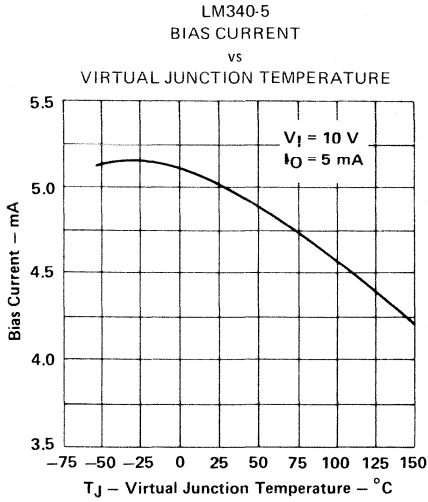


FIGURE 6



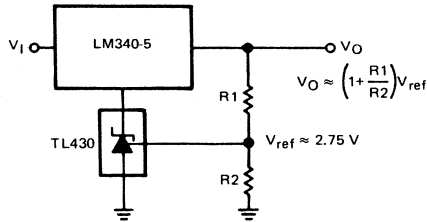


**TYPICAL CHARACTERISTICS**

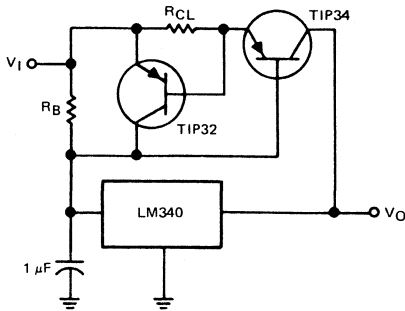


**SERIES LM340  
POSITIVE-VOLTAGE REGULATORS**

**TYPICAL APPLICATION DATA**



**FIGURE 11—ADJUSTABLE SUPPLY WITH STABLE OUTPUT FROM 8 VOLTS TO 35 VOLTS**



**FIGURE 12—OUTPUT CURRENT BOOST CIRCUIT**

The boost circuit takes over at a level determined by  $R_B$ .

$$R_B \approx \frac{0.6 \text{ V}}{I_B}$$

where  $I_B$  is the LM340 operating level.

Maximum current limit  $I_{CL}$  is determined by  $R_{CL}$ .

$$R_{CL} \approx \frac{0.6 \text{ V}}{I_{CL}}$$

Example: If  $I_B$  is selected to be

0.5 A, then

$R_B = 1.2 \Omega$ .

If  $I_{CL}$  is 3 A, then

$R_{CL} = 0.2 \Omega$ .

- Adjustable Output . . . 1.2 V to 33 V
- 3-A Output Current Capability
- Line Regulation . . . 0.005%/V Typ
- Load Regulation . . . 0.1% Typ
- Current Limit Constant with Temperature
- Guaranteed Thermal Regulation
- Direct Replacement for National Semiconductor LM350

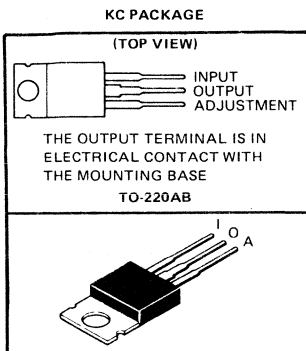
**description**

The LM350 is an adjustable 3-terminal positive-voltage regulator capable of supplying 3 amperes over an output voltage range of 1.2 volts to 33 volts. The device is easy to use and requires only two external resistors to set the output voltage. Both input and output regulation are better than standard fixed regulators.

In addition to higher performance than fixed regulators, the LM350 offers full overload protection available only in integrated circuits. Included on the chip current limit, thermal overload protection, and safe-area protection. All overload protection circuitry remains fully functional even if the adjustment terminal is disconnected. Normally, no capacitors are needed unless the device is situated far from the input filter capacitors in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. The adjustment terminal can be bypassed to achieve very high ripple rejection, which is difficult to achieve with standard 3-terminal regulators.

Besides replacing fixed regulators, the LM350 is useful in a wide variety of other applications. Even though the regulator is floating and sees only the input-to-output differential voltage, use of these devices to regulate voltages that would cause the maximum-rated differential voltage to be exceeded if the output became shorted to ground is not recommended. The TL783 or TL783A is recommended for output voltages exceeding 33 volts. The primary application of the LM350 is that of a programmable output regulator, but by connecting a fixed resistor between the adjustment terminal and the output terminal, this device can be used as a precision current regulator. Supplies with electronic shutdown can be achieved by clamping the adjustment terminal to ground, which programs the output to 1.2 volts where most loads draw little current.

The LM350 is characterized for operation from 0°C to 125°C.



# TYPE LM350

## 3-AMP ADJUSTABLE REGULATOR

### absolute maximum ratings over operating temperature range (unless otherwise noted)

Input-to-output differential voltage	35 V
Continuous total power dissipation at 25°C free-air temperature (see Note 1)	2 W
Continuous total power dissipation at (or below) 25°C case temperature (see Note 1)	30 W
Operating free-air, case, or virtual junction temperature range	-55°C to 150°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	260°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

### recommended operating conditions

	MIN	MAX	UNIT
Output current, $I_O$		3	A
Operating virtual junction temperature, $T_J$	0	125	°C

### electrical characteristics over recommended ranges of operating virtual junction temperature,

$V_I - V_O = 5 \text{ V}$ ,  $I_O = 1.5 \text{ A}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
Input regulation (see Note 2)	$V_I - V_O = 3 \text{ V to } 35 \text{ V}$ See Note 3	$T_J = 25^\circ\text{C}$		0.005	0.03	%/ $V$
		$T_J = 0^\circ\text{C to } 125^\circ\text{C}$		0.02	0.07	
Ripple rejection	$V_O = 10 \text{ V}$ , $V_O = 10 \text{ V}$ , 10- $\mu\text{F}$ capacitor between ADJ and ground	$f = 120 \text{ Hz}$		65		dB
		$f = 120 \text{ Hz}$		66		
Output regulation	$I_O = 10 \text{ mA to } 3 \text{ A}$ , $T_J = 25^\circ\text{C}$ , See Note 3	$V_O \leq 5 \text{ V}$		5	25	mV
		$V_O > 5 \text{ V}$		0.1	0.5	%
	$I_O = 10 \text{ mA to } 3 \text{ A}$ , See Note 3	$V_O \leq 5 \text{ V}$		20	70	mV
$V_O > 5 \text{ V}$		0.3	1.5	%		
Output voltage change with temperature	$T_J = 0^\circ\text{C to } 125^\circ\text{C}$			1		%
Thermal regulation	$t_w = 20 \text{ ms}$			0.002	0.03	%/W
Output voltage long-term drift (see Note 4)	After 1000 h at $T_J = 125^\circ\text{C}$			0.3	1	%
Output noise voltage	$f = 10 \text{ Hz to } 10 \text{ kHz}$ , $T_J = 25^\circ\text{C}$			0.003		%
Minimum output current to maintain regulation	$V_I - V_O = 35 \text{ V}$			3.5	10	mA
Peak output current	$V_I - V_O \leq 10 \text{ V}$			3	4.5	A
	$V_I - V_O = 30 \text{ V}$ , $T_J = 25^\circ\text{C}$			0.25	1	
Adjustment-terminal current				EO	100	$\mu\text{A}$
Change in adjustment-terminal current	$V_I - V_O = 3 \text{ V to } 35 \text{ V}$ , $I_O = 10 \text{ mA to } 3 \text{ A}$			0.2	5	$\mu\text{A}$
Reference voltage (output to ADJ)	$V_I - V_O = 3 \text{ V to } 35 \text{ V}$ , $I_O = 10 \text{ mA to } 3 \text{ A}$ , $P \leq 30 \text{ W}$	1.2	1.25	1.3		V

NOTES: 2. Input regulation is expressed as the percentage change in output voltage per 1-volt change at the input.

3. Input regulation and output regulation are measured using pulse techniques ( $t_w \leq 10 \mu\text{s}$ , duty cycle  $\leq 5\%$ ) to limit changes in average internal dissipation. Output voltage changes due to large changes in internal dissipation must be taken into account separately.

4. Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.



THERMAL INFORMATION

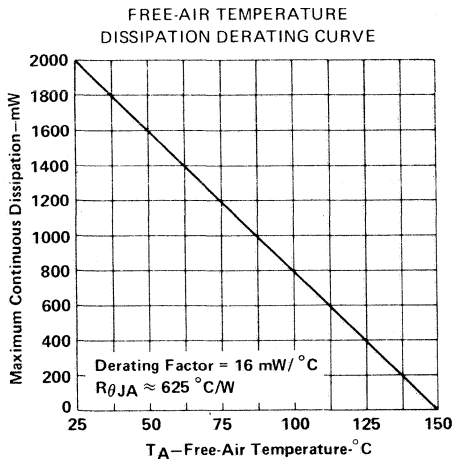


FIGURE 1

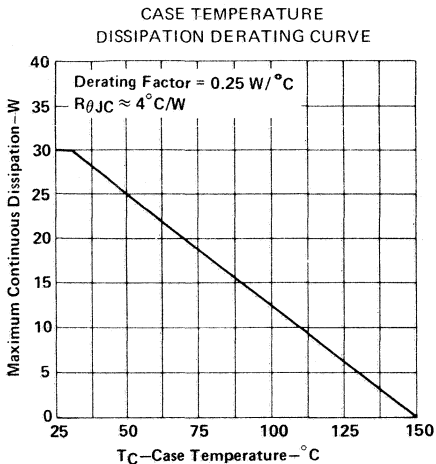


FIGURE 2

TYPICAL CHARACTERISTICS

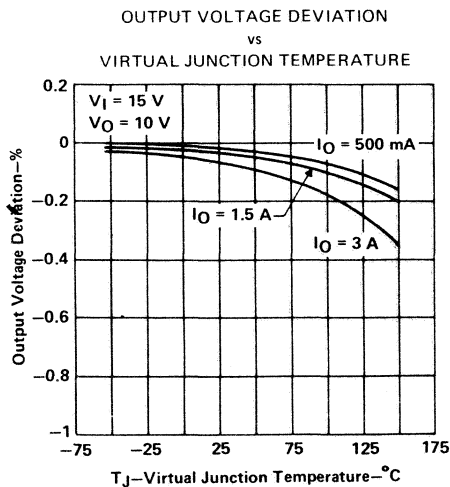


FIGURE 3

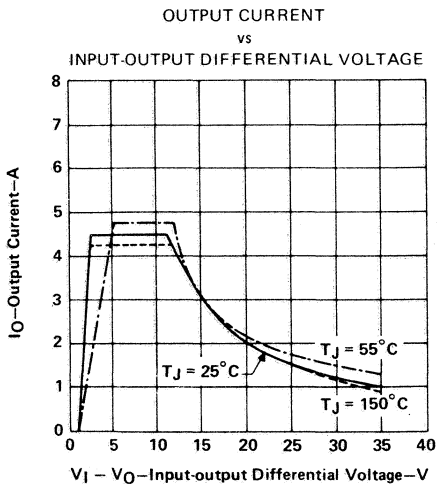


FIGURE 4

# TYPE LM350 3-AMP ADJUSTABLE REGULATOR

## TYPICAL CHARACTERISTICS

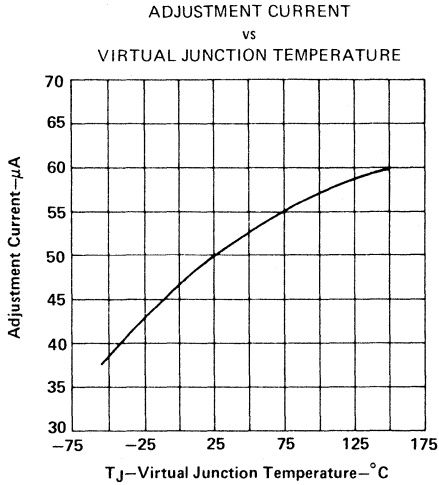


FIGURE 5

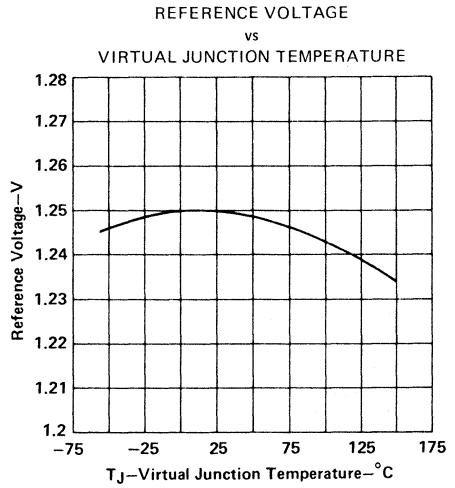
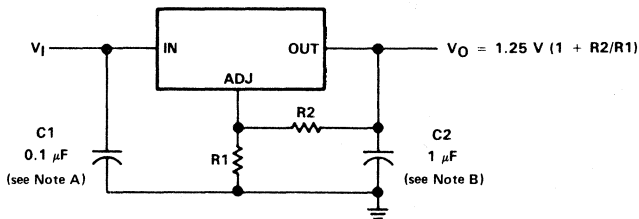


FIGURE 6

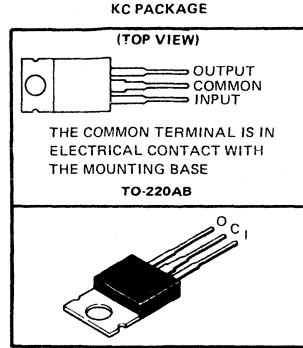
## TYPICAL APPLICATION DATA



- NOTES: A. Capacitor C1 is required if regulator is not located in close proximity to the power supply amplifier.  
B. Capacitor C2 may be used to improve transient response.



- Input-Output Differential Less than 0.6 V
- Output Current of 150 mA
- Reverse Battery Protection
- Line Transient Protection
- 40-Volt Load-Dump Protection
- Internal Short-Circuit Current Limiting
- Internal Thermal Overload Protection
- Mirror-Image Insertion Protection
- Direct Replacement for National LM2930 Series



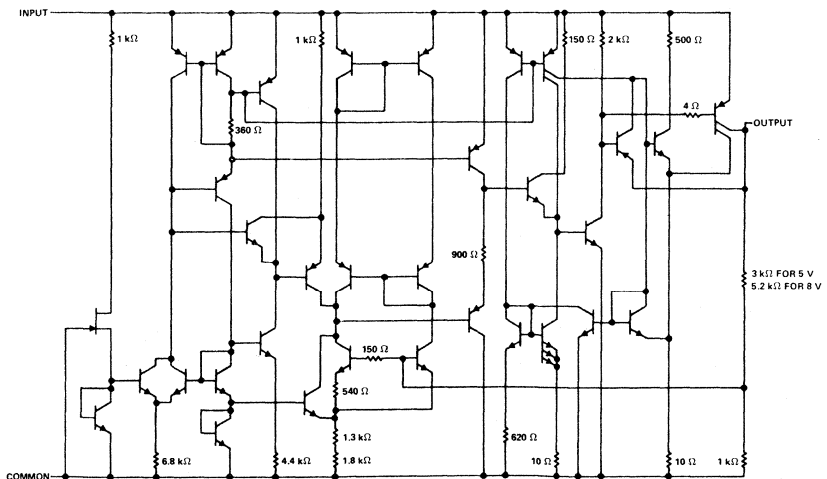
**description**

The LM2930-5 and LM2930-8 are 3-terminal positive regulators that provide fixed 5-volt and 8-volt regulated outputs. Each features the ability to source 150 milliamperes of output current with an input-output differential of 0.6 volt or less. Familiar regulator features such as current limit and thermal overload protection are also provided.

The LM2930 series has low voltage dropout making it useful for certain battery applications. For example, the low voltage dropout feature allows a longer battery discharge before the output falls out of regulation; the battery supplying the regulator input voltage may discharge to 5.6 volts and still properly regulate the system and load voltage. Supporting this feature, the LM2930 series protects both itself and the regulated system from reverse battery installation or two-battery jumps.

Other protection features include line transient protection for load-dump of up to 40 volts. In this case the regulator shuts down to avoid damaging internal and external circuits. The LM2930 series regulator cannot be harmed by temporary mirror-image insertion.

**schematic diagram**



All component values are nominal.

# TYPES LM2930-5, LM2930-8

## 3-TERMINAL POSITIVE REGULATORS

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Continuous input voltage	26 V
Transient input voltage: $t = 1 \text{ s}$	40 V
Continuous reverse input voltage	-6 V
Transient reverse input voltage: $t = 100 \text{ ms}$	-12 V
Continuous total dissipation at 25°C free-air temperature (see Note 1)	2 W
Continuous total dissipation at (or below) 25°C case-temperature (see Note 1)	20 W
Operating free-air, case, or virtual junction temperature	-40°C to 150°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case to 10 seconds	260°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variation in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

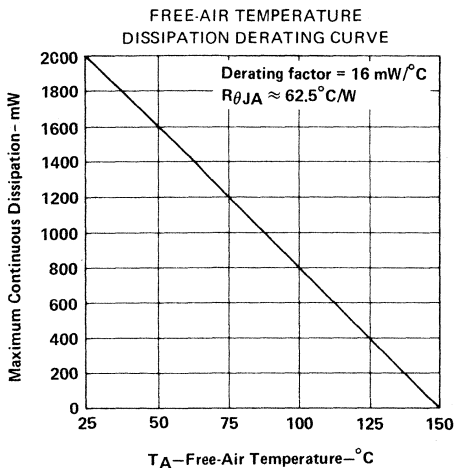


FIGURE 1

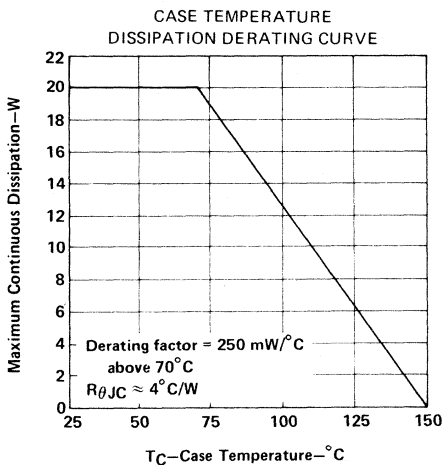


FIGURE 2

### recommended operating conditions

		MIN	MAX	UNIT
$I_O$	Output current		150	mA
$T_J$	Operating virtual junction temperature	-40	125	°C



## TYPES LM2930-5, LM2930-8 3-TERMINAL POSITIVE REGULATORS

**LM2930-5 electrical characteristics at 25°C virtual junction temperature,  $V_I = 14\text{ V}$ ,  $I_O = 150\text{ mA}$ , (unless otherwise noted)**

PARAMETER	TEST CONDITIONS <sup>†</sup>		MIN	TYP	MAX	UNIT
Output voltage	$V_I = 6\text{ V to }26\text{ V}$ , $T_J = -40^\circ\text{C to }125^\circ\text{C}$	$I_O = 5\text{ mA to }150\text{ mA}$ ,	4.5	5	5.5	V
Input regulation	$I_O = 5\text{ mA}$	$V_I = 9\text{ V to }16\text{ V}$ $V_I = 6\text{ V to }26\text{ V}$		7 30	25 80	mV
Ripple rejection	$f = 120\text{ Hz}$			56		dB
Output regulation	$I_O = 5\text{ mA to }150\text{ mA}$			14	50	mV
Output voltage long-term drift <sup>‡</sup>	After 1000 h at $T_J = 125^\circ\text{C}$			20		mV
Dropout voltage	$I_O = 150\text{ mA}$			0.32	0.6	V
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$			60		$\mu\text{V}$
Output voltage during line transients	$V_I = -12\text{ V to }40\text{ V}$ , $R_L = 100\ \Omega$		-0.3		5.5	V
Output impedance	$I_O = 100\text{ mA}$ , $I_O = 10\text{ mA (rms)}$ , $f = 100\text{ Hz to }10\text{ kHz}$			200		$\text{m}\Omega$
Bias current	$I_O = 10\text{ mA}$ $I_O = 150\text{ mA}$			4 18	7 40	mA
Peak output current			150	300	700	mA

**LM2930-8 electrical characteristics at 25°C virtual junction temperature,  $V_I = 14\text{ V}$ ,  $I_O = 150\text{ mA}$ , (unless otherwise noted)**

PARAMETER	TEST CONDITIONS <sup>†</sup>		MIN	TYP	MAX	UNIT
Output voltage	$V_I = 9.4\text{ V to }26\text{ V}$ , $T_J = -40^\circ\text{C to }125^\circ\text{C}$	$I_O = 5\text{ mA to }150\text{ mA}$ ,	7.2	8	8.8	V
Input regulation	$I_O = 5\text{ mA}$	$V_I = 9.4\text{ V to }16\text{ V}$ $V_I = 9.4\text{ V to }26\text{ V}$		12 50	50 100	V
Ripple rejection	$f = 120\text{ Hz}$			52		dB
Output regulation	$I_O = 5\text{ mA to }150\text{ mA}$			25	50	mV
Output voltage long-term drift <sup>‡</sup>	After 1000 h at $T_J = 125^\circ\text{C}$			30		mV
Dropout voltage	$I_O = 150\text{ mA}$			0.32	0.6	V
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$			90		$\mu\text{V}$
Output voltage during line transients	$V_I = -12\text{ V to }40\text{ V}$ , $R_L = 100\ \Omega$		-0.3		8.8	V
Output impedance	$I_O = 100\text{ mA}$ , $I_O = 10\text{ mA (rms)}$ , $f = 100\text{ Hz to }10\text{ kHz}$			300		$\text{m}\Omega$
Bias current	$I_O = 10\text{ mA}$ $I_O = 150\text{ mA}$			4 18	7 40	mA
Peak output current			150	300	700	mA

<sup>†</sup> Unless otherwise specified, all characteristics, except ripple rejection and noise voltage measurements, are measured using pulse techniques ( $t_w \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ) with a capacitor of  $0.1\ \mu\text{F}$  across the input and a capacitor of  $10\ \mu\text{F}$  across the output. Output voltage changes due to changes in internal temperature must be taken into account separately.

<sup>‡</sup> Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

# TYPES LM2930-5, LM2930-8 3-TERMINAL POSITIVE REGULATORS

## TYPICAL CHARACTERISTICS

NORMALIZED OUTPUT VOLTAGE  
VS  
VIRTUAL JUNCTION TEMPERATURE

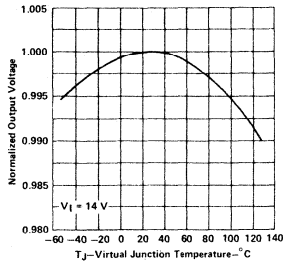


FIGURE 3

LM2930-5  
OUTPUT VOLTAGE  
VS  
INPUT VOLTAGE

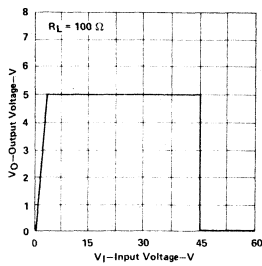


FIGURE 4

LM2930-8  
OUTPUT VOLTAGE  
VS  
INPUT VOLTAGE

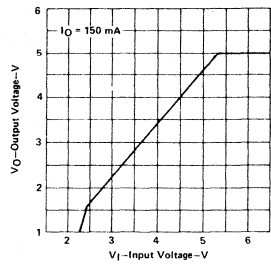


FIGURE 5

RIPPLE REJECTION  
VS  
FREQUENCY

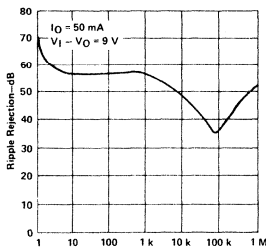


FIGURE 6

RIPPLE REJECTION  
VS  
OUTPUT CURRENT

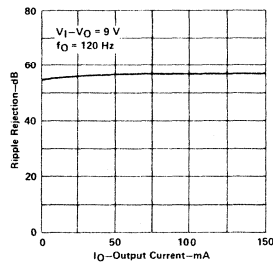


FIGURE 7

DROPOUT VOLTAGE  
VS  
VIRTUAL JUNCTION TEMPERATURE

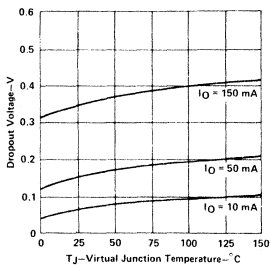


FIGURE 8

DROPOUT VOLTAGE  
VS  
OUTPUT CURRENT

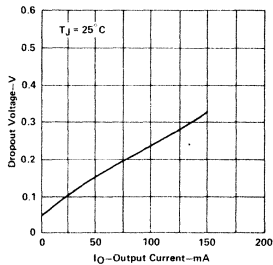


FIGURE 9

OUTPUT IMPEDANCE  
VS  
FREQUENCY

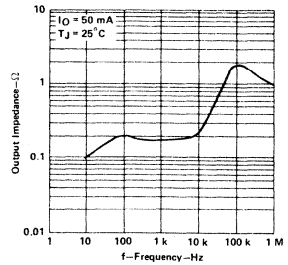


FIGURE 10



TYPICAL CHARACTERISTICS

INPUT CURRENT  
VS  
INPUT VOLTAGE

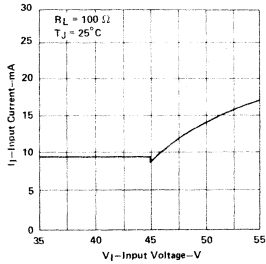


FIGURE 11

LINE TRANSIENT RESPONSE

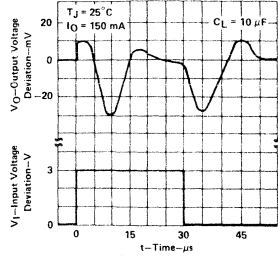


FIGURE 12

INPUT CURRENT  
VS  
REVERSE INPUT VOLTAGE

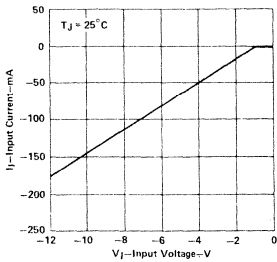


FIGURE 13

OUTPUT VOLTAGE  
VS  
REVERSE INPUT VOLTAGE

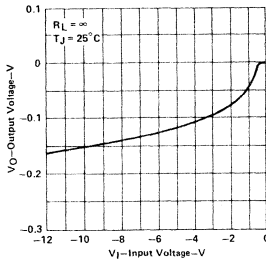


FIGURE 14

LOAD TRANSIENT RESPONSE

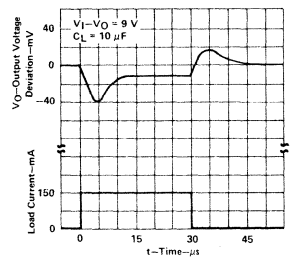


FIGURE 15  
LM2905-5

BIAS CURRENT  
VS  
OUTPUT CURRENT

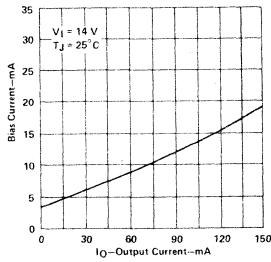


FIGURE 16

BIAS CURRENT  
VS  
VIRTUAL JUNCTION TEMPERATURE

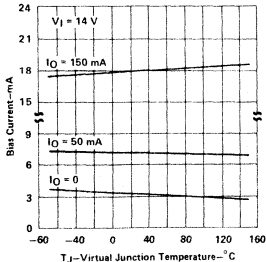


FIGURE 17

BIAS CURRENT  
VS  
INPUT VOLTAGE

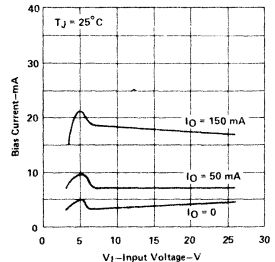
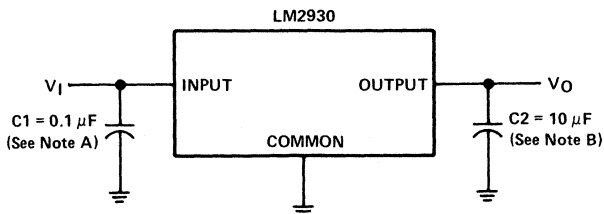


FIGURE 18

# TYPES LM2930-5, LM2930-8

## 3-TERMINAL POSITIVE REGULATORS

### TYPICAL APPLICATION DATA



NOTES: A. Use of  $C1$  is required if the regulator is not located in close proximity to the supply filter.

B. Capacitor  $C2$  must be located as close as possible to the regulator and may be an aluminum or tantalum type capacitor. The minimum value required for stability is  $10 \mu\text{F}$ . The capacitor must be rated for operation at  $-40^\circ\text{C}$  to guarantee stability to that extreme.

FIGURE 19

- Input-Output Differential Less than 0.6 V
- Output Current of 150 mA
- Reverse Battery Protection
- Very Low Quiescent Current
- 60-Volt Load-Dump Protection
- Internal Short-Circuit Current Limiting
- Internal Thermal Overload Protection
- Mirror-Image Insertion Protection
- Reverse Transient Protection to -50 V
- Direct Replacement for National LM2931-5

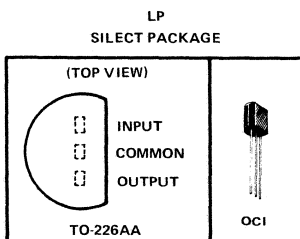
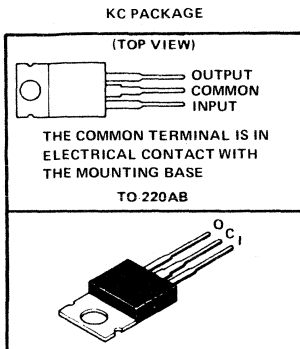
**description**

The LM2931-5 is a 3-terminal positive voltage regulator that provides a 5-volt regulated output. It features the ability to source 150 milliamperes of output current with an input-output differential of 0.6 volt or less. Familiar regulator features such as current limit and thermal overload protection are also provided.

The LM2931-5 has low voltage dropout making it useful for certain battery applications. For example, the low-voltage-dropout feature allows a longer battery discharge before the output falls out of regulation; the battery supplying the regulator input voltage may discharge to 5.6 volts and still properly regulate the system and load voltage. Supporting this feature, the LM2931-5 protects both itself and the regulated system from reverse battery installation or two-battery jumps. The very low quiescent current feature is especially useful in battery powered applications.

Other protection features include line transient protection for load-dump of up to 60 volts. In this case the regulator shuts down to avoid damaging internal and external circuits. The LM2931-5 regulator is virtually immune to temporary mirror-image insertion.

The LM2931-5 is characterized for operation from -40°C to 150°C.



# TYPE LM2931-5

## 3-TERMINAL POSITIVE VOLTAGE REGULATOR

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Continuous input voltage	26 V
Transient input voltage: $t = 1 \text{ s}$	60 V
Continuous reverse input voltage	-15 V
Transient reverse input voltage: $t = 100 \text{ ms}$	-50 V
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 1)	
LP package	775 mW
KC package	2 W
Continuous total dissipation at (or below) 25°C case temperature (see Note 1)	
LP package	1.6 W
KC package	4 W
Operating free-air, case, or virtual junction temperature	-40°C to 150°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

NOTE 1: For operation above 25°C free-air temperature, refer to Figures 1, 2, 3, and 4. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variation in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

### recommended operating conditions

	MIN	TYP	MAX	UNIT
Output current, $I_O$			150	mA
Operating virtual junction temperature, $T_J$	-40		125	°C

### electrical characteristics at 25°C virtual junction temperature, $V_I = 14 \text{ V}$ , $I_O = 10 \text{ mA}$ , (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	MIN	TYP	MAX	UNIT
Output voltage	$V_I = 6 \text{ V to } 26 \text{ V}$ , $I_O \leq 150 \text{ mA}$ , $T_J = -40^\circ\text{C to } 125^\circ\text{C}$	4.75	5	5.25	V
Input regulation	$I_O = 10 \text{ mA}$ , $V_I = 9 \text{ V to } 16 \text{ V}$ $V_I = 6 \text{ V to } 26 \text{ V}$		2	10	mV
Ripple rejection	$f = 120 \text{ Hz}$		80		dB
Output regulation	$I_O = 5 \text{ mA to } 150 \text{ mA}$		14	50	mV
Output voltage long-term drift <sup>‡</sup>	After 100 h at $T_J = 125^\circ\text{C}$		20		mV
Dropout voltage	$I_O = 10 \text{ mA}$		0.05	0.2	V
	$I_O = 150 \text{ mA}$		0.3	0.6	
Output noise voltage	$f = 10 \text{ Hz to } 100 \text{ kHz}$		500		$\mu\text{V rms}$
Bias current	$V_I = 6 \text{ V to } 26 \text{ V}$ , $I_O = 10 \text{ mA}$ , $T_J = -40^\circ\text{C to } 125^\circ\text{C}$		0.4	1	mA
	$V_I = 14 \text{ V}$ , $I_O = 150 \text{ mA}$ , $T_J = 25^\circ\text{C}$		15		

<sup>†</sup>Unless otherwise specified, all characteristics, except ripple rejection and noise voltage measurements, are measured using pulse techniques ( $t_w \leq 10 \text{ ms}$ , duty cycle  $\leq 5\%$ ) with a capacitor of 0.1  $\mu\text{F}$  across the input and a capacitor of 100  $\mu\text{F}$  across the output. Output voltage changes due to changes in internal temperature must be taken into account separately.

<sup>‡</sup>Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.



THERMAL INFORMATION

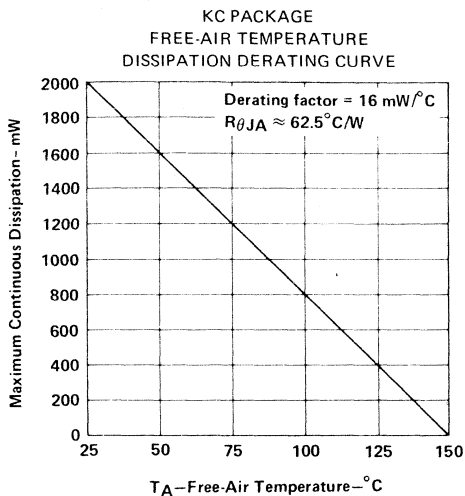


FIGURE 1

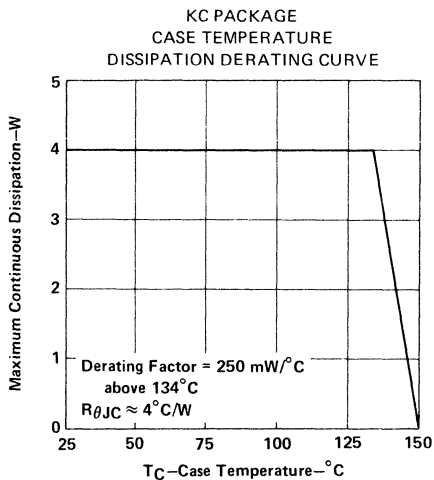


FIGURE 2

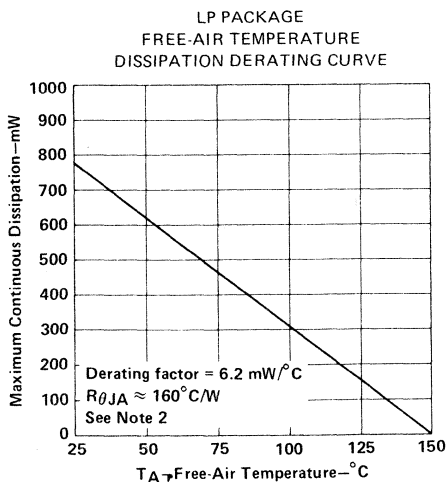


FIGURE 3

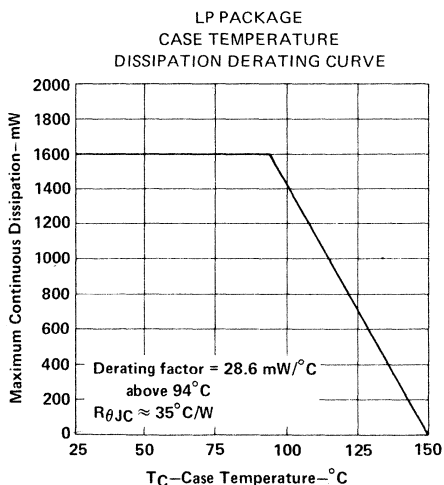


FIGURE 4

NOTE 2: This curve for the LP package is based on thermal resistance,  $R_{\theta JA}$ , measured in still air with the device mounted in an Augat socket. The bottom of the package was 3/8 inch above the socket.







# TYPE MC3423

## OVERVOLTAGE-SENSING CIRCUIT

### absolute maximum ratings

Supply voltage, $V_{CC}$ (see Note 1)	40 V
Sense 1 voltage	6.5 V
Sense 2 voltage	6.5 V
Remote activate input voltage	7 V
Output current, $I_O$	300 mA
Continuous dissipation at (or below) 25°C free-air temperature (see Note 2): JG package	825 mW
P package	1000 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C

- NOTES: 1. Voltage values are measured with respect to the  $V_{EE}$  terminal.  
 2. For operating above 25°C free-air temperature, refer to the Dissipation Derating Table. In the JG package, MC3423 chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
JG (Glass-Mounted Chip)	825 mW	6.6 mW/°C	25°C
P	1000 mW	8 mW/°C	25°C

### recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, $V_{CC}$	4.5	40	V
High-level input voltage, remote activate input	2		V
Low-level input voltage, remote activate input		0.5	V

### electrical characteristics over operating free-air temperature range, $V_{CC} = 5\text{ V to }36\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output voltage	Remote Activate at 2 V, $I_O = 100\text{ mA}$	$V_{CC} - 2.2$	$V_{CC} - 1.8$		V
Indicator low-level output voltage	Remote Activate at 2 V, $I_O = 1.6\text{ mA}$		0.1	0.4	V
Threshold voltage of either sense input	$T_A = 25^\circ\text{C}$	2.45	2.6	2.75	V
Temperature coefficient of input threshold voltage			0.06		%/°C
Source current (pin 4)	Sense 1 at 3 V, Pin 4 at 1.3 V	0.1	0.22	0.3	mA
High-level input current, Remote Activate input	$V_{CC} = 5\text{ V}$ , $V_I = 2\text{ V}$		5	40	$\mu\text{A}$
Low-level input current, Remote Activate input	$V_{CC} = 5\text{ V}$ , $V_I = 0.8\text{ V}$		-120	-180	$\mu\text{A}$
Supply current	Outputs open		6	10	mA
Propagation delay time, Remote Activate input to Output	$T_A = 25^\circ\text{C}$		0.5		$\mu\text{s}$
Output current rate of rise	$T_A = 25^\circ\text{C}$		400		mA/ $\mu\text{s}$

Voltage Regulators



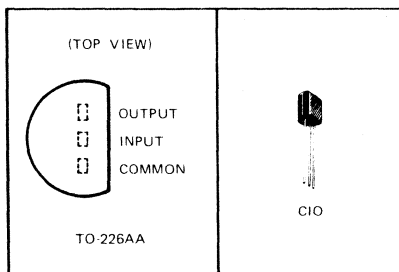
- 3-Terminal Regulators
- Output Current up to 100 mA
- No External Components Required
- Internal Thermal Overload Protection
- Internal Short Circuit Current Limiting
- Direct Replacement for Motorola MC79L00 Series
- Available in 5% or 10% Selections

NOMINAL OUTPUT VOLTAGE	5% OUTPUT VOLTAGE TOLERANCE	10% OUTPUT VOLTAGE TOLERANCE
-5 V	MC79L05AC	MC79L05C
-12 V	MC79L12AC	MC79L12C
-15 V	MC79L15AC	MC79L15C

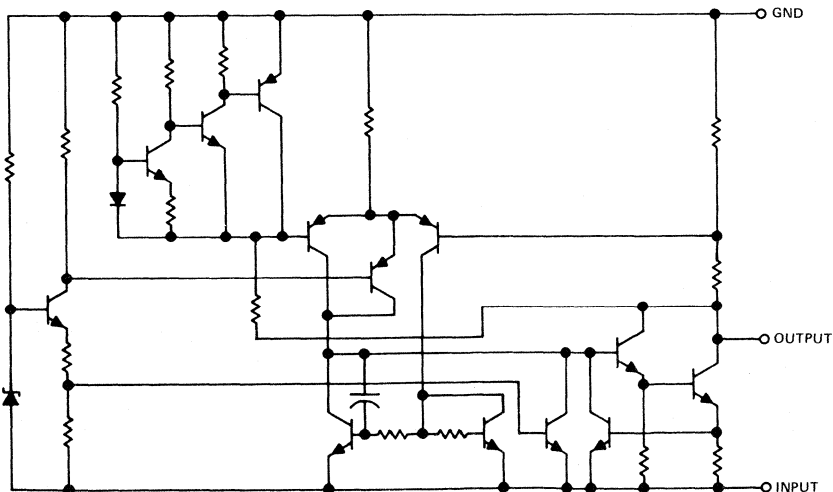
**description**

This series of fixed-voltage monolithic integrated-circuit voltage regulators is designed for a wide range of applications. These include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. In addition, they can be used to control series pass elements to make high-current voltage-regulator circuits. One of these regulators can deliver up to 100 mA of output current. The internal current-limiting and thermal-shutdown features make them essentially immune to overload. When used as a replacement for a Zener-diode and resistor combination, these devices can provide an effective improvement in output impedance of two orders of magnitude and lower bias current.

LP SILECT PACKAGE



**schematic**



Voltage Regulators



# SERIES MC79L00 NEGATIVE-VOLTAGE REGULATORS

absolute maximum ratings over operating temperature range (unless otherwise noted)

	MC79L05	MC79L12 MC79L15	UNIT
Input voltage	-30	-35	V
Continuous total dissipation at 25°C free-air temperature (see Note 1)	775	775	mW
Continuous total dissipation at (or below) 25°C case temperature (see Note 1)	1600	1600	mW
Operating free-air, case, or virtual junction temperature range	0 to 150	0 to 150	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	260	260	°C

NOTE 1: For operation above 25°C free air temperature, refer to Dissipation Derating Curves, Figure 1 and Figure 2.

FREE-AIR TEMPERATURE  
DISSIPATION DERATING CURVE

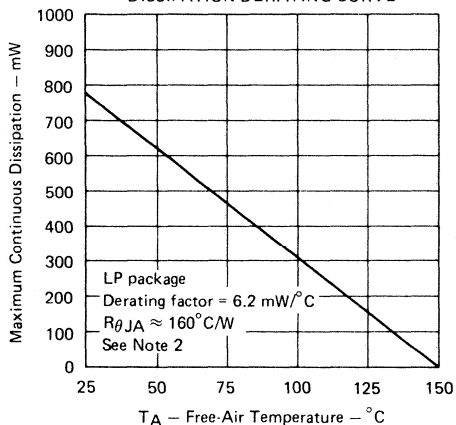


FIGURE 1

CASE TEMPERATURE  
DISSIPATION DERATING CURVE

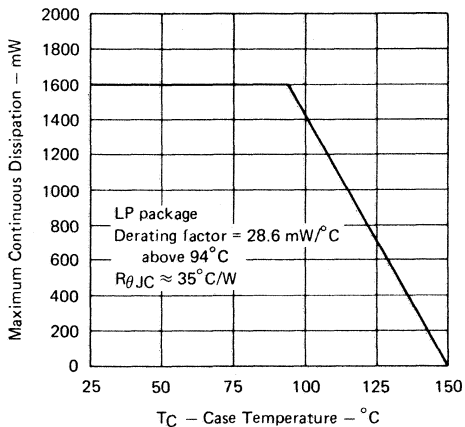


FIGURE 2

NOTE 2: This curve for the LP package is based on thermal resistance,  $R_{\theta JA}$ , measured in still air with the device mounted in an Augat socket. The bottom of the package was 3/8 inch above the socket.

## recommended operating conditions

		MIN	MAX	UNIT
Input voltage, $V_I$	MC79L05	-7	-20	V
	MC79L12	-14.5	-27	
	MC79L15	-17.5	-30	
Output current, $I_O$			100	mA
Operating virtual junction temperature, $T_J$		0	125	°C

## SERIES MC79L00 NEGATIVE-VOLTAGE REGULATORS

MC79L05 electrical characteristics at specified virtual junction temperature,  
 $V_I = -10\text{ V}$ ,  $I_O = 40\text{ mA}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MC79L05C			MC79L05AC			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage		25°C	-4.6	-5	-5.4	-4.8	-5	-5.2	V
	$V_I = -7\text{ V to }-20\text{ V}$ , $I_O = 1\text{ mA to }40\text{ mA}$	0°C to 125°C	-4.5		-5.5	-4.75		-5.25	
	$V_I = -10\text{ V}$ , $I_O = 1\text{ mA to }70\text{ mA}$	0°C to 125°C	-4.5		-5.5	-4.75		-5.25	
Input regulation	$V_I = -7\text{ V to }-20\text{ V}$	25°C			200			150	mV
	$V_I = -8\text{ V to }-20\text{ V}$				150			100	
Ripple rejection	$V_I = -8\text{ V to }-18\text{ V}$ , $f = 120\text{ Hz}$	25°C	40	49		41	49		dB
Output regulation	$I_O = 1\text{ mA to }100\text{ mA}$	25°C			60			60	mV
	$I_O = 1\text{ mA to }40\text{ mA}$				30			30	
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$	25°C			40			40	µV
Dropout voltage	$I_O = 40\text{ mA}$	25°C			1.7			1.7	V
Bias current		25°C			6			6	mA
		125°C			5.5			5.5	
Bias current change	$V_I = -8\text{ V to }-20\text{ V}$	0°C to 125°C			1.5			1.5	mA
	$I_O = 1\text{ mA to }40\text{ mA}$				0.2			0.1	

MC79L12 electrical characteristics at specified virtual junction temperature,  
 $V_I = -19\text{ V}$ ,  $I_O = 40\text{ mA}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MC79L12C			MC79L12AC			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage		25°C	-11.1	-12	-12.9	-11.5	-12	-12.5	V
	$V_I = -14.5\text{ to }-27\text{ V}$ , $I_O = 1\text{ mA to }40\text{ mA}$	0°C to 125°C	-10.8		-13.2	-11.4		-12.6	
	$V_I = -19\text{ V}$ , $I_O = 1\text{ mA to }70\text{ mA}$	0°C to 125°C	-10.8		-13.2	-11.4		-12.6	
Input regulation	$V_I = -14.5\text{ to }-27\text{ V}$	25°C			250			250	mV
	$V_I = -16\text{ V to }-27\text{ V}$				200			200	
Ripple rejection	$V_I = -15\text{ V to }-25\text{ V}$ , $f = 120\text{ Hz}$	25°C	36	42		37	42		dB
Output regulation	$I_O = 1\text{ mA to }100\text{ mA}$	25°C			100			100	mV
	$I_O = 1\text{ mA to }40\text{ mA}$				50			50	
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$	25°C			80			80	µV
Dropout voltage	$I_O = 40\text{ mA}$	25°C			1.7			1.7	V
Bias current		25°C			6.5			6.5	mA
		125°C			6			6	
Bias current change	$V_I = -16\text{ V to }-27\text{ V}$	0°C to 125°C			1.5			1.5	mA
	$I_O = 1\text{ mA to }40\text{ mA}$				0.2			0.1	

† All characteristics are measured with a 0.33 µF capacitor across the input and a 0.1 µF capacitor across the output. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_{\text{ON}} \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# SERIES MC79L00 NEGATIVE-VOLTAGE REGULATORS

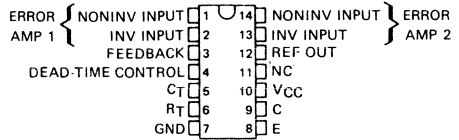
MC79L15 electrical characteristics at specified virtual junction temperature,  
 $V_I = -23\text{ V}$ ,  $I_O = 40\text{ mA}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MC79L15C			MC79L15AC			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage		25°C	-13.8	-15	-16.2	-14.4	-15	-15.6	V
	$V_I = -17.5\text{ V to } -30\text{ V}$ , $I_O = 1\text{ mA to } 40\text{ mA}$	0°C to 125°C	-13.5		-16.5	-14.25		-15.75	
	$V_I = -23\text{ V}$ , $I_O = 1\text{ mA to } 70\text{ mA}$	0°C to 125°C	-13.5		-16.5	-14.25		-15.75	
Input regulation	$V_I = -17.5\text{ V to } -30\text{ V}$	25°C				300			mV
	$V_I = -20\text{ V to } -30\text{ V}$					250			
Ripple rejection	$V_I = -18.5\text{ V to } -28.5\text{ V}$ , $f = 120\text{ Hz}$	25°C	33	39		34	39		dB
Output regulation	$I_O = 1\text{ mA to } 100\text{ mA}$	25°C				150			mV
	$I_O = 1\text{ mA to } 40\text{ mA}$					75			
Output noise voltage	$f = 10\text{ Hz to } 100\text{ kHz}$	25°C				90			µV
Dropout voltage	$I_O = 40\text{ mA}$	25°C				1.7			V
Bias current		25°C				6.5			mA
		125°C				6			
Bias current change	$V_I = -20\text{ V to } -30\text{ V}$	0°C to 125°C				1.5			mA
	$I_O = 1\text{ mA to } 40\text{ mA}$					0.1			

† All characteristics are measured with a 0.33-µF capacitor across the input and a 0.1 µF capacitor across the output. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

- Complete PWM Power Control Circuitry
- Uncommitted Output for 200-mA Sink or Source Current
- Variable Dead-Time Provides Control Over Total Range
- Internal Regulator Provides a Stable 5-V Reference Supply
- Circuit Architecture Provides Easy Synchronization
- Direct Replacements for Motorola MC35060 and MC34060

J OR N  
DUAL-IN-LINE PACKAGE  
(TOP VIEW)



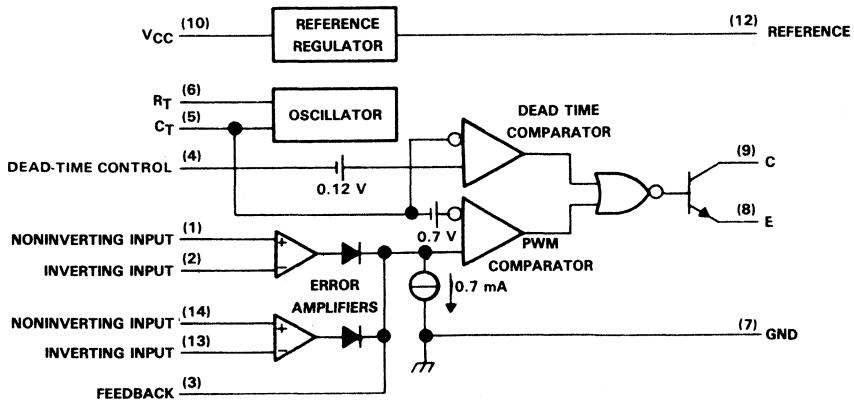
NC—No internal connections

**description**

The MC35060 and MC34060 incorporate on a single monolithic chip all the functions required in the construction of a pulse-width-modulation control circuit. Designed primarily for power supply control, each of the devices contains an on-chip 5-volt regulator, two error amplifiers, an adjustable oscillator, and a dead-time control comparator. The uncommitted output transistor provides either common-emitter or emitter-follower output capability. The internal amplifiers exhibit a common-mode voltage range from  $-0.3$  volt to  $V_{CC} - 2$  volts. The dead-time control comparator has a fixed offset that provides approximately 5% dead time unless externally altered. The on-chip oscillator may be bypassed by terminating  $R_T$  (pin 6) to the reference output and providing a sawtooth input to  $C_T$  (pin 5), or it may be used to drive the common MC35060 or MC34060 circuitry and provide a sawtooth input for associated control circuitry in multiple rail power supplies.

The MC35060 is characterized for operation over the full military temperature range of  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ . The MC34060 is characterized for operation from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

**functional block diagram**



All voltage and current values shown are nominal.

# TYPES MC35060, MC34060

## PULSE-WIDTH-MODULATION CONTROL CIRCUITS

absolute maximum ratings over operation temperature range (unless otherwise noted)

	MC35060	MC34060	UNIT
Supply voltage, $V_{CC}$ (see Note 1)	42	42	V
Amplifier input voltages	$V_{CC} + 0.3$	$V_{CC} + 0.3$	V
Collector output voltage	42	42	V
Collector output current	250	250	mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	1000	1000	mW
Operating free-air temperature range	-55 to 125	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N package		260	°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
 2. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J package, MC35060 chips are alloy-mounted and MC34060 chips are glass-mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	1000 mW	11.0 mW/°C	59°C
J (Glass-Mounted Chip)	1000 mW	8.2 mW/°C	28°C
N	1000 mW	9.2 mW	41°C

recommended operating conditions

	MC35060		MC34060		UNIT
	MIN	MAX	MIN	MAX	
Supply voltage, $V_{CC}$	7	40	7	40	V
Amplifier input voltages, $V_I$	-0.3	$V_{CC} - 2$	-0.3	$V_{CC} - 2$	V
Collector output voltage, $V_O$		40		40	V
Collector output current (each transistor)		200		200	mA
Reference output current		10		10	mA
Current into feedback terminal		0.3		0.3	mA
Timing capacitor, $C_T$	0.47	10 000	0.47	10 000	nF
Timing resistor, $R_T$	1.8	500	1.8	500	kΩ
Oscillator frequency	1	200	1	200	kHz
Operating free-air temperature, $T_A$	-55	125	0	70	°C



# TYPES MC35060, MC34060 PULSE-WIDTH-MODULATION CONTROL CIRCUITS

electrical characteristics over recommended operating free-air temperature range,  $V_{CC} = 15\text{ V}$ ,  $f = 10\text{ kHz}$  (unless otherwise noted)

## reference section

PARAMETER	TEST CONDITIONS <sup>†</sup>	MC35060			MC34060			UNIT
		MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	
Output voltage ( $V_{ref}$ )	$I_O = 1\text{ mA}$	4.75	5	5.25	4.75	5	5.25	V
Input regulation	$V_{CC} = 7\text{ V to }40\text{ V}$ , $T_A = 25^\circ\text{C}$	2 25			2 25			mV
Output regulation	$I_{IO} = 1\text{ to }10\text{ mA}$ , $T_A = 25^\circ\text{C}$	1 15			1 15			mV
Output voltage change with temperature	$\Delta T_A = \text{MIN to MAX}$	0.2 2			0.2 2.6			%
Short-circuit output current <sup>§</sup>	$V_{ref} = 0$	10	35	50	35			mA

## oscillator section

PARAMETER	TEST CONDITIONS <sup>†</sup>	MC35060			MC34060			UNIT
		MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	
Frequency	$C_T = 0.001\ \mu\text{F}$ , $R_T = 47\text{ k}\Omega$	25			25			kHz
Standard deviation of frequency <sup>¶</sup>	$C_T = 0.001\ \mu\text{F}$ , $R_T = 47\text{ k}\Omega$	3			3			%
Frequency change with voltage	$V_{CC} = 7\text{ V to }40\text{ V}$ , $T_A = 25^\circ\text{C}$	0.1			0.1			%
Frequency change with temperature	$C_T = 0.001\ \mu\text{F}$ , $R_T = 47\text{ k}\Omega$ , $\Delta T_A = \text{MIN to MAX}$	4			2			%

## dead-time control-section (see figure 1)

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT	
Input bias current (pin 4)	$V_I = 0\text{ to }5.25\text{ V}$	-2		-10	$\mu\text{A}$	
Maximum duty cycle	$V_I(\text{pin } 4) = 0$	$C_T = 0.1\ \mu\text{F}$ , $R_T = 12\text{ k}\Omega$	90	96	100	%
		$C_T = 0.1\ \mu\text{F}$ , $R_T = 47\text{ k}\Omega$	92 100			%
Input threshold voltage (pin 4)	Zero duty cycle	3		3.3	V	
	Maximum duty cycle	0				

## error-amplifier sections

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
Input offset voltage	$V_O(\text{pin } 3) = 2.5\text{ V}$	2		10	mV
Input offset current	$V_O(\text{pin } 3) = 2.5\text{ V}$	25		250	nA
Input bias current	$V_O(\text{pin } 3) = 2.5\text{ V}$	0.2		1	$\mu\text{A}$
Common-mode input voltage range	$V_{CC} = 7\text{ V to }40\text{ V}$	-0.3 to $V_{CC}-2$			V
Open-loop voltage amplification	$\Delta V_O = 3\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $V_O = 0.5\text{ V to }3.5\text{ V}$	70	95		dB
Unit-gain bandwidth		800			kHz
Common-mode rejection ratio	$V_{CC} = 40\text{ V}$	65	80		dB
Output sink current (pin 3)	$V_{ID} = -15\text{ mV to }-5\text{ V}$ , $V_{I(\text{pin } 3)} = 0.5\text{ V}$	0.3	0.7		mA
Output source current (pin 3)	$V_{ID} = 15\text{ mV to }5\text{ V}$ , $V_{I(\text{pin } 3)} = 3.5\text{ V}$	-2			mA

## output section

PARAMETER	TEST CONDITIONS	MC35060			MC34060			UNIT
		MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	
Collector off-state current	$V_{CE} = 40\text{ V}$ , $V_{CC} = 40\text{ V}$	2 100			2 100			$\mu\text{A}$
Emitter off-state current	$V_{CC} = V_C = 40\text{ V}$ , $V_E = 0$	-150			-100			$\mu\text{A}$
Collector-emitter saturation voltage	Common-emitter	$V_E = 0$ , $I_C = 200\text{ mA}$	1.1	1.5	1.1	1.3	V	
	Emitter follower	$V_C = 15\text{ V}$ , $I_E = -200\text{ mA}$	1.5	2.5	1.5	2.5		

<sup>†</sup>For conditions shown as MIN or MAX, use the appropriate value specified under recommended operation conditions.

<sup>‡</sup>All typical values except for temperature coefficients are at  $T_A = 25^\circ\text{C}$ .

<sup>§</sup>Duration of the short-circuit should not exceed one second.

<sup>¶</sup>Standard deviation is a measure of the statistical distribution about the mean as derived from the formula  $\sigma = \sqrt{\frac{\sum_{i=1}^N (x_i - \bar{x})^2}{N-1}}$

# TYPES MC35060, MC34060

## PULSE-WIDTH-MODULATION CONTROL CIRCUITS

electrical characteristics over recommended operating free-air temperature range,  $V_{CC} = 15\text{ V}$ ,  $f = 10\text{ kHz}$  (unless otherwise noted)

pwm comparator section (see figure 1)

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>‡</sup>	MAX	UNIT
Input threshold voltage (pin 3)	Zero duty cycle		4	4.5	V
Input sink current (pin 3)	$V_{(\text{pin } 3)} = 0.7\text{ V}$	0.3	0.7		mA

total device

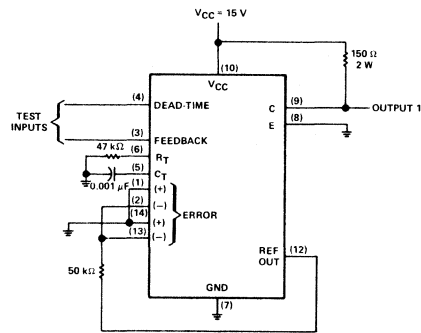
PARAMETER	TEST CONDITIONS	MIN	TYP <sup>‡</sup>	MAX	UNIT
Standby supply current	Pin 6 at $V_{\text{ref}}$ , All other inputs and outputs open	$V_{CC} = 15\text{ V}$		6	10
		$V_{CC} = 40\text{ V}$		9	15
Average supply current	$V_{(\text{pin } 4)} = 2\text{ V}$ , See Figure 1		7.5		mA

switching characteristics,  $T_A = 25^\circ\text{C}$

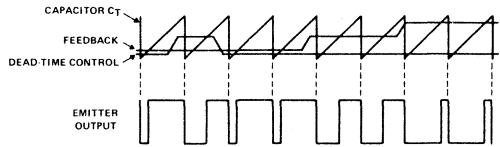
PARAMETER	TEST CONDITIONS	MIN	TYP <sup>‡</sup>	MAX	UNIT
Output voltage rise time	Common-emitter configuration,		100	200	ns
Output voltage fall time	See Figure 3		25	100	ns
Output voltage rise time	Emitter-follower configuration,		100	200	ns
Output voltage fall time	See Figure 4		40	100	ns

<sup>‡</sup>All typical values except for temperature coefficients are at  $T_A = 25^\circ\text{C}$ .

### PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



TIMING WAVEFORMS

FIGURE 1 — DEAD-TIME AND FEEDBACK CONTROL



PARAMETER MEASUREMENT INFORMATION

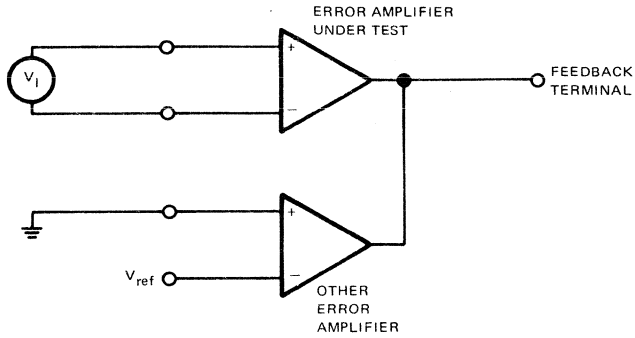


FIGURE 2 — ERROR-AMPLIFIER CHARACTERISTICS

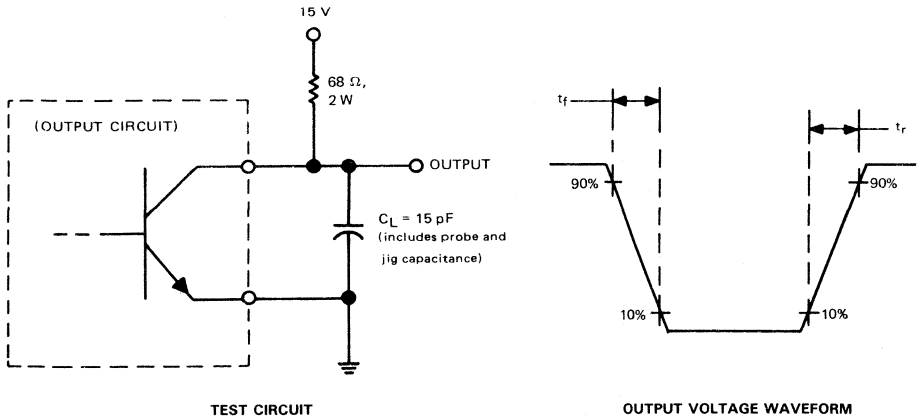


FIGURE 3 — COMMON-EMITTER CONFIGURATION

# TYPES MC35060, MC34060 PULSE-WIDTH-MODULATION CONTROL CIRCUITS

## PARAMETER MEASUREMENT INFORMATION

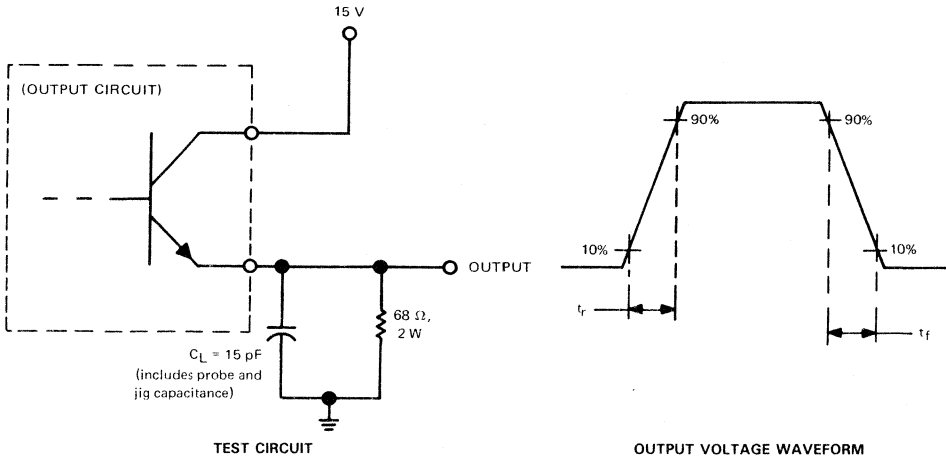


FIGURE 4 – EMITTER-FOLLOWER CONFIGURATION

## TYPICAL CHARACTERISTICS

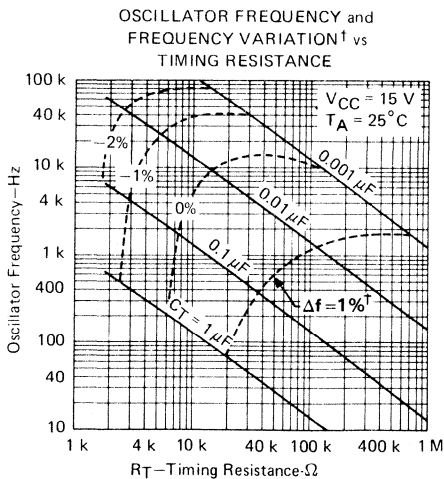


FIGURE 5

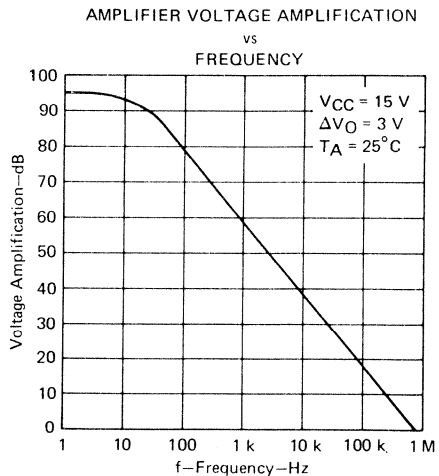
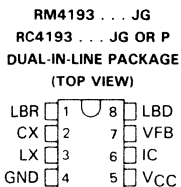


FIGURE 6

<sup>†</sup>Frequency variation ( $\Delta f$ ) is the change in oscillator frequency that occurs over the full temperature range.



- High Efficiency . . . 80% Typ
- Low Bias Current . . . 135  $\mu$ A
- Adjustable Output . . . 2.5 V to 24 V
- Output Current . . . 150 mA
- Internal Reference . . . 1.3 V  $\pm$  5%
- Remote Shutdown Capabilities
- Interchangeable with Raytheon RM4193 and RC4193



**description**

The RM4193 and RC4193 are monolithic micropower switching regulators designed to provide all the functions required to make a complete low-power switching regulator primarily for battery operated instruments. The RM4193 and RC4193 offer the system designer the flexibility of tailoring the circuit to the application. Typical applications include step-up switching regulation, step-down switching regulation, and inverting switch regulation. The devices each contain a 1.3-volt temperature-compensated band-gap reference, an adjustable free-running oscillator, voltage comparator, low battery detection circuitry, and a 150-milliampere output-switch transistor.

**FUNCTION TABLE**

PIN	FUNCTION	DESCRIPTION
1	LBR	Low battery resistor
2	CX	External capacitor
3	LX	External inductor
4	GND	Ground
5	VCC	Supply voltage
6	IC	Reference set control
7	VFB	Feedback voltage
8	LBD	Low battery detector

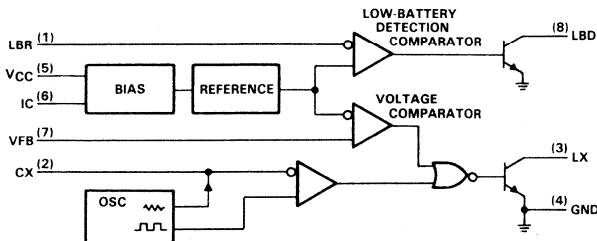
For most applications, these regulators can achieve up to 80% efficiency while operating over a wide supply voltage range from 2.4 volts to 24 volts at an ultra-low bias current drain of 135 microamperes. The RM4193 and RC4193 have an adjustable 100-hertz to 160-kilohertz free-running oscillator that provides the drive circuitry for the on-chip 150-milliampere output-switch transistor. An external capacitor on pin 2 determines the oscillator frequency.

The low-battery detection circuitry contains an open-collector output transistor that can be used to activate a liquid crystal display whenever the battery voltage drops below a programmed level. This programmed level is determined by the selection of external resistors connected to pin 1.

The regulator will shut off when pin 6 (IC) is below 0.5 volt. The shut-off feature is useful in battery-backup applications requiring operation only when the line power is removed. Another use of this feature is connecting a zener diode between pin 6 and the battery line to shut down the regulator whenever the battery voltage drops below a predetermined level.

The RM4193 will be characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The RC4193 will be characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

**functional block diagram**



PRODUCT PREVIEW

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# TYPES SG1524, SG2524, SG3524 REGULATING PULSE WIDTH MODULATORS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply Voltage, $V_{CC}$ (see Notes 1 and 2)	40 V
Collector Output Current	100 mA
Reference Output Current	50 mA
Current Through $C_T$ Terminal	-5 mA
Continuous Total Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	1000 mW
Operating Free-Air Temperature Range: SG1524	-55°C to 125°C
SG2524	-25°C to 85°C
SG3524	0°C to 70°C
Storage Temperature Range	-65°C to 150°C

- NOTES: 1. All voltage values are with respect to network ground terminal.  
 2. The reference regulator may be bypassed for operation from a fixed 5-volt supply by connecting the  $V_{CC}$  and reference output pins both to the supply voltage. In this configuration the maximum supply voltage is 6 volts.  
 3. For operation above 25°C free-air temperature refer to Figures 16 and 17. In the J package, SG1524 chips are alloy mounted; SG2524 and SG3524 chips are glass mounted.

## recommended operating conditions

	SG1524		SG2524		SG3524		UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	
Supply voltage, $V_{CC}$	8	40	8	40	8	40	V
Reference output current	0	50	0	50	0	50	mA
Current thru $C_T$ terminal	-0.03	-2	-0.03	-2	-0.03	-2	mA
Timing resistor, $R_T$	1.8	100	1.8	100	1.8	100	k $\Omega$
Timing capacitor, $C_T$	0.001	0.1	0.001	0.1	0.001	0.1	$\mu$ F
Operating free-air temperature	-55	125	-25	85	0	70	°C

electrical characteristics over recommended operating free-air temperature range,  $V_{CC} = 20$  V,  $f = 20$  kHz (unless otherwise noted)

## reference section

PARAMETER	TEST CONDITIONS <sup>†</sup>	SG1524			SG2524			SG3524			UNIT
		MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	
Output voltage		4.8	5	5.2	4.8	5	5.2	4.6	5	5.4	V
Input regulation	$V_{CC} = 8$ to 40 V	10	20		10	20		10	30		mV
Ripple rejection	$f = 120$ Hz	66			66			66			dB
Output regulation	$I_O = 0$ to 20 mA	20	50		20	50		20	50		mV
Output voltage change with temperature	$T_A = \text{MIN to MAX}$	0.6	2		0.3	1		0.3	1		%
Short-circuit output current <sup>§</sup>	$V_{ref} = 0$	100			100			100			mA

<sup>†</sup> For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

<sup>‡</sup> All typical values except output voltage change with temperature are at  $T_A = 25^\circ\text{C}$ .

<sup>§</sup> Duration of the short circuit should not exceed one second.



# TYPES SG1524, SG2524, SG3524 REGULATING PULSE WIDTH MODULATORS

electrical characteristics over recommended operating free-air temperature range,  $V_{CC} = 20\text{ V}$ ,  $f = 20\text{ kHz}$  (unless otherwise noted)

## oscillator section

PARAMETER	TEST CONDITIONS†	MIN	TYP‡	MAX	UNIT
Frequency	$C_T = 0.001\ \mu\text{F}$ , $R_T = 2\ \text{k}\Omega$		450		kHz
Standard deviation of frequency §	All values of voltage, temperature, resistance, and capacitance constant		5		%
Frequency change with voltage	$V_{CC} = 8\text{ to }40\text{ V}$ , $T_A = 25\text{ }^\circ\text{C}$			1	%
Frequency change with temperature	$T_A = \text{MIN to MAX}$			2	%
Output amplitude at pin 3			3.5		V
Output pulse width at pin 3	$C_T = 0.01\ \mu\text{F}$		0.5		$\mu\text{s}$

## error amplifier section

PARAMETER	TEST CONDITIONS	SG1524, SG2524			SG3524			UNIT
		MIN	TYP‡	MAX	MIN	TYP‡	MAX	
Input offset voltage	$V_{IC} = 2.5\text{ V}$		0.5	5		2	10	mV
Input bias current	$V_{IC} = 2.5\text{ V}$		2	10		2	10	$\mu\text{A}$
Open-loop voltage amplification		72	80		60	80		dB
Common-mode input voltage range	$T_A = 25\text{ }^\circ\text{C}$	1.8 to 3.4			1.8 to 3.4			V
Common-mode rejection ratio			70			70		dB
Unity-gain bandwidth			3			3		MHz
Output swing	$T_A = 25\text{ }^\circ\text{C}$	0.5		3.8	0.5		3.8	V

## output section

PARAMETER	TEST CONDITIONS	MIN	TYP‡	MAX	UNIT
Collector-emitter breakdown voltage		40			V
Collector off-state current	$V_{CE} = 40\text{ V}$		0.01	50	$\mu\text{A}$
Collector-emitter saturation voltage	$I_C = 50\text{ mA}$		1	2	V
Emitter output voltage	$V_C = 20\text{ V}$ , $I_E = -250\ \mu\text{A}$	17	18		V
Turn-off voltage rise time	$R_C = 2\ \text{k}\Omega$		0.2		$\mu\text{s}$
Turn-on voltage fall time	$R_C = 2\ \text{k}\Omega$		0.1		$\mu\text{s}$

## comparator section

PARAMETER	TEST CONDITIONS	MIN	TYP‡	MAX	UNIT
Maximum duty cycle, each output		45			%
Input threshold voltage at pin 9	Zero duty cycle		1		V
	Maximum duty cycle		3.5		
Input bias current			-1		$\mu\text{A}$

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ All typical values except for temperature coefficients are at  $T_A = 25\text{ }^\circ\text{C}$ .

§ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula  $\sigma = \sqrt{\frac{\sum_{i=1}^N (X_i - \bar{X})^2}{N - 1}}$

# TYPES SG1524, SG2524, SG3524 REGULATING PULSE WIDTH MODULATORS

electrical characteristics over recommended operating free-air temperature range,  $V_{CC} = 20\text{ V}$ ,  $f = 20\text{ kHz}$  (unless otherwise noted)

current limiting section

PARAMETER	TEST CONDITIONS	SG1524, SG2524			SG3524			UNIT
		MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	
Input voltage range (either input)		-1			-1			V
		to			to			
		+1			+1			
Sense voltage at $T_A = 25^\circ\text{C}$	$V(\text{pin } 2) - V(\text{pin } 1) \geq 50\text{ mV}$ ,	190	200	210	180	200	220	mV
Temperature coefficient of sense voltage	$V(\text{pin } 9) = 2\text{ V}$	0.2			0.2			mV/°C

total device

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>‡</sup>	MAX	UNIT
Standby current	$V_{CC} = 40\text{ V}$ , Pin 2 at 2 V, Pins 1,4,7,8,9,11,14 grounded, All other inputs and outputs open		8	10	mA

<sup>‡</sup>All typical values except for temperature coefficients are at  $T_A = 25^\circ\text{C}$ .

## PARAMETER MEASUREMENT INFORMATION

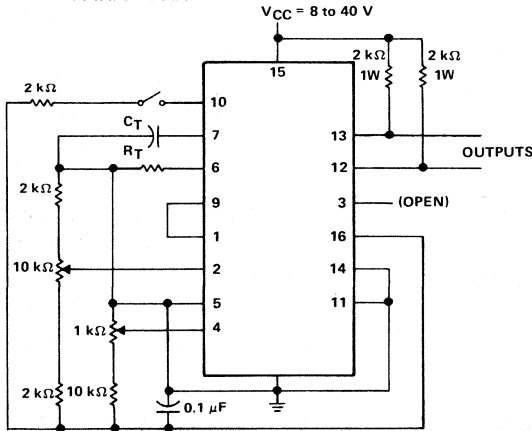


FIGURE 1—GENERAL TEST CIRCUIT

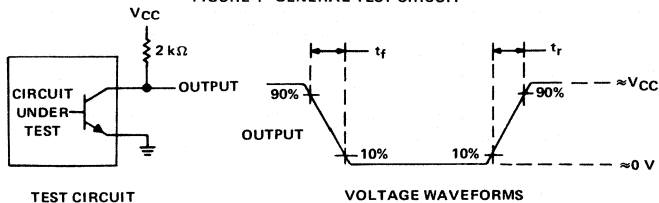
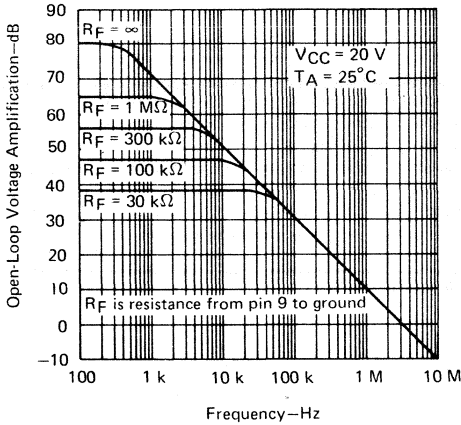


FIGURE 2—SWITCHING TIMES

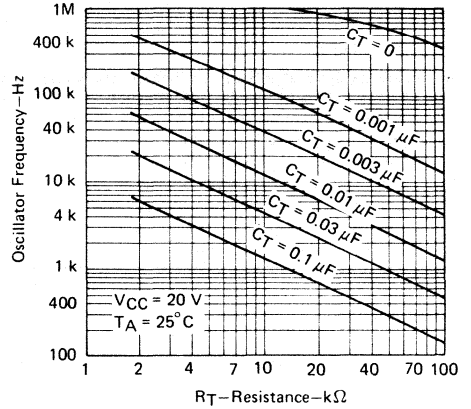
**TYPICAL CHARACTERISTICS**

**OPEN-LOOP VOLTAGE AMPLIFICATION  
OF ERROR AMPLIFIER  
vs  
FREQUENCY**



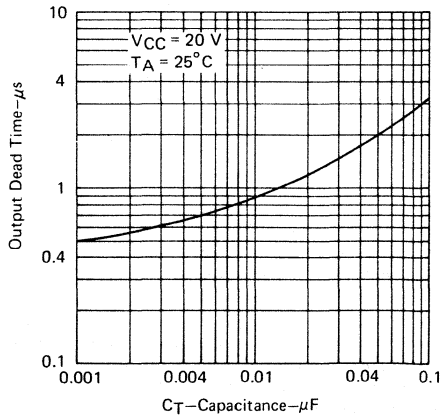
**FIGURE 3**

**OSCILLATOR FREQUENCY  
vs  
TIMING RESISTANCE**



**FIGURE 4**

**OUTPUT DEAD TIME  
vs  
TIMING CAPACITANCE VALUE**



**FIGURE 5**

# TYPES SG1524, SG2524, SG3524 REGULATING PULSE WIDTH MODULATORS

---

## PRINCIPLES OF OPERATION

The SG1524<sup>†</sup> is a fixed-frequency pulse-width-modulation voltage-regulator control circuit. The regulator operates at a fixed frequency that is programmed by one timing resistor  $R_T$  and one timing capacitor  $C_T$ .  $R_T$  establishes a constant charging current for  $C_T$ . This results in a linear voltage ramp at  $C_T$ , which is fed to the comparator providing linear control of the output pulse width by the error amplifier. The SG1524 contains an on-board 5-volt regulator that serves as a reference as well as supplying the SG1524's internal regulator control circuitry. The internal reference voltage is divided externally by a resistor ladder network to provide a reference within the common-mode range of the error amplifier as shown in Figure 6, or an external reference may be used. The output is sensed by a second resistor divider network and the error signal is amplified. This voltage is then compared to the linear voltage ramp at  $C_T$ . The resulting modulated pulse out of the high-gain comparator is then steered to the appropriate output pass transistor (Q1 or Q2) by the pulse-steering flip-flop, which is synchronously toggled by the oscillator output. The oscillator output pulse also serves as a blanking pulse to assure both outputs are never on simultaneously during the transition times. The width of the blanking pulse is controlled by the value of  $C_T$ . The outputs may be applied in a push-pull configuration in which their frequency is half that of the base oscillator, or paralleled for single-ended applications in which the frequency is equal to that of the oscillator. The output of the error amplifier shares a common input to the comparator with the current-limiting and shut-down circuitry and can be overridden by signals from either of these inputs. This common point is also available externally and may be employed to control the gain of, or to compensate, the error amplifier, or to provide additional control to the regulator.

---

## TYPICAL APPLICATION DATA

### oscillator

The oscillator controls the frequency of the SG1524 and is programmed by  $R_T$  and  $C_T$  as shown in Figure 4.

$$f = \frac{1.15}{R_T C_T}$$

where  $R_T$  is in kilohms  
 $C_T$  is in microfarads  
 $f$  is in kilohertz

Practical values of  $C_T$  fall between 0.001 and 0.1 microfarad. Practical values of  $R_T$  fall between 1.8 and 100 kilohms. This results in a frequency range typically from 140 hertz to 500 kilohertz.

### blanking

The output pulse of the oscillator is used as a blanking pulse at the output. This pulse width is controlled by the value of  $C_T$  as shown in Figure 5. If small values of  $C_T$  are required, the oscillator output pulse width may still be maintained by applying a shunt capacitance from pin 3 to ground.

### synchronous operation

When an external clock is desired, a clock pulse of approximately 3 volts can be applied directly to the oscillator output terminal. The impedance to ground at this point is approximately 2 kilohms. In this configuration  $R_T C_T$  must be selected for a clock period slightly greater than that of the external clock.

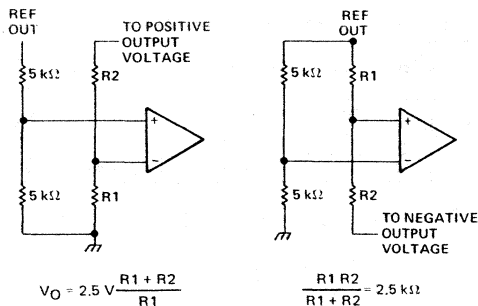
If two or more SG1524 regulators are to be operated synchronously, all oscillator output terminals should be tied together. The oscillator programmed for the minimum clock period will be the master from which all the other SG1524's operate. In this application, the  $C_T R_T$  values of the slaved regulators must be set for a period approximately 10% longer than that of the master regulator. In addition,  $C_T$  (master) = 2  $C_T$  (slave) to ensure that the master output pulse, which occurs first, has a wider pulse width and will subsequently reset the slave regulators.

<sup>†</sup> Throughout these discussions, references to SG1524 apply also to SG2524 and SG3524.

**TYPICAL APPLICATION DATA**

**voltage reference**

The 5-volt internal reference may be employed by use of an external resistor divider network to establish a reference within the error amplifiers common-mode voltage range (1.8 to 3.4 volts) as shown in Figure 6, or an external reference may be applied directly to the error amplifier. For operation from a fixed 5-volt supply, the internal reference may be bypassed by applying the input voltage to both the  $V_{CC}$  and  $V_{REF}$  terminals. In this configuration, however, the input voltage is limited to a maximum of 6 volts.



**FIGURE 6—ERROR AMPLIFIER BIAS CIRCUITS**

**error amplifier**

The error amplifier is a differential-input transconductance amplifier. The output is available for dc gain control or ac phase compensation. The compensation node (pin 9) is a high-impedance node ( $R_L = 5$  megohms). The gain of the amplifier is  $A_V = (0.002 \Omega^{-1}) R_L$  and can easily be reduced from a nominal 10,000 by an external shunt resistance from pin 9 to ground. Refer to Figure 3 for data.

**compensation**

Pin 9, as discussed above, is made available for compensation. Since most output filters will introduce one or more additional poles at frequencies below 200 hertz, which is the pole of the uncompensated amplifier, introduction of a zero to cancel one of the output filter poles is desirable. This can best be accomplished with a series RC circuit from pin 9 to ground in the range of 50 kilohms and 0.001 microfarads. Other frequencies can be canceled by use of the formula  $f \approx 1/RC$ .

**shut down circuitry**

Pin 9 can also be employed to introduce external control of the SG1524. Any circuit that can sink 200 microamperes can pull the compensation terminal to ground and thus disable the SG1524.

In addition to constant-current limiting, pins 4 and 5 may also be used in transformer-coupled circuits to sense primary current and shorten an output pulse should transformer saturation occur. Pin 5 may also be grounded to convert pin 4 into an additional shutdown terminal.

# TYPES SG1524, SG2524, SG3524 REGULATING PULSE WIDTH MODULATORS

## TYPICAL APPLICATION DATA

### current limiting

A current-limiting sense amplifier is provided in the SG1524. The current-limiting sense amplifier exhibits a threshold of 200 millivolts and must be applied in the ground line since the voltage range of the inputs is limited to +1 volt to -1 volt. Caution should be taken to ensure the -1-volt limit is not exceeded by either input, otherwise damage to the device may result.

Fold-back current limiting can be provided with the network shown in Figure 7. The current-limit schematic is shown in Figure 8.

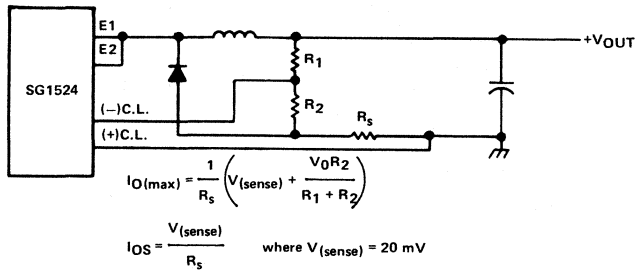


FIGURE 7—FOLDBACK CURRENT LIMITING FOR SHORTED OUTPUT CONDITIONS

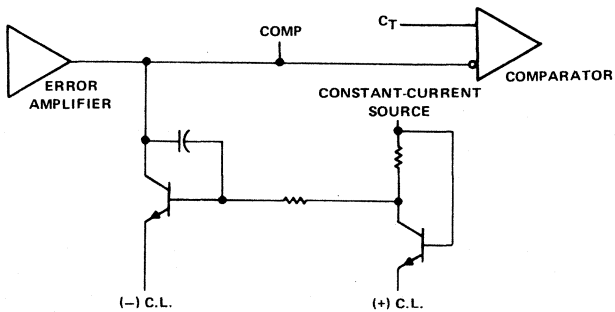


FIGURE 8—CURRENT-LIMIT SCHEMATIC

### output circuitry

The SG1524 contains two identical n-p-n transistors the collectors and emitters of which are uncommitted. Each transistor has antisaturation circuitry that limits the current through that transistor to a maximum of 100 milliamperes for fast response.

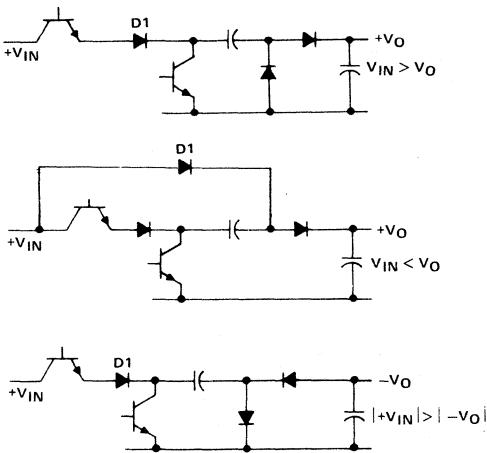
**TYPICAL APPLICATION DATA**

**general**

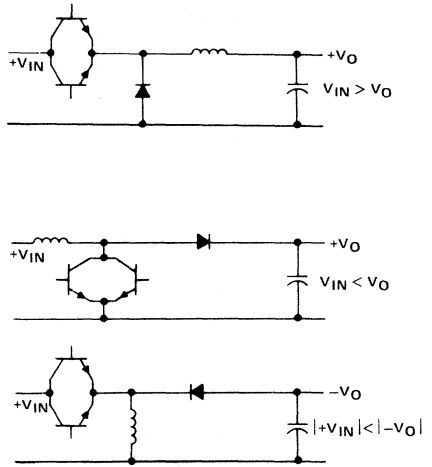
There are a wide variety of output configurations possible when considering the application of the SG1524 as a voltage regulator control circuit. They can be segregated into three basic categories:

1. Capacitor-diode-coupled voltage multipliers
2. Inductor-capacitor-implemented single-ended circuits
3. Transformer-coupled circuits

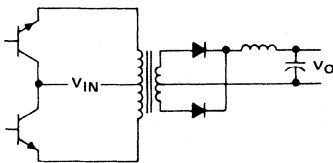
Examples of these categories are shown in Figures 9, 10 and 11, respectively. Detailed diagrams of specific applications are shown in Figures 12 through 15.



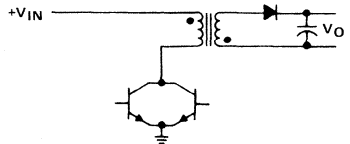
**FIGURE 9—CAPACITOR-DIODE-COUPLED VOLTAGE-MULTIPLIER OUTPUT STAGES**



**FIGURE 10—SINGLE-ENDED INDUCTOR CIRCUIT**



**PUSH PULL**



**FLYBACK**

**FIGURE 11—TRANSFORMER-COUPLED OUTPUTS**

**TYPES SG1524, SG2524, SG3524  
REGULATING PULSE WIDTH MODULATORS**

**TYPICAL APPLICATION DATA**

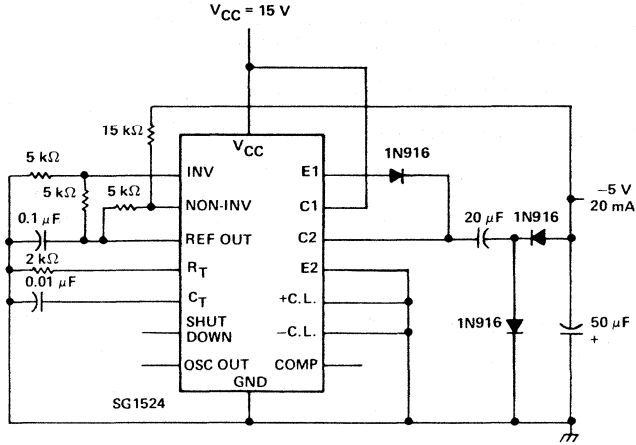


FIGURE 12—CAPACITOR-DIODE OUTPUT CIRCUIT

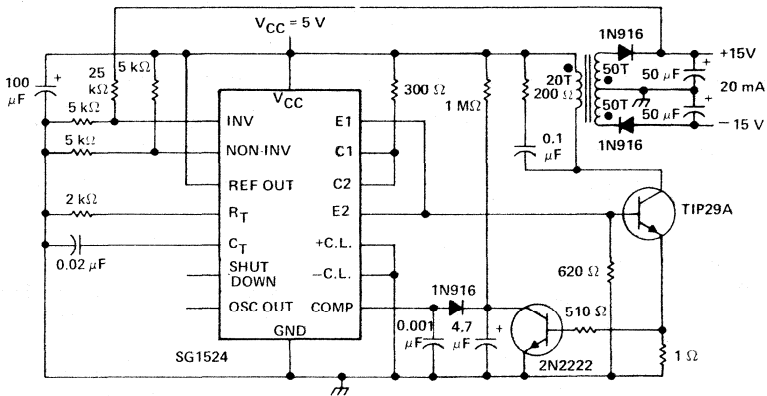


FIGURE 13—FLYBACK CONVERTER CIRCUIT

Voltage Regulators

6



**TYPES SG1524, SG2524, SG3524  
REGULATING PULSE WIDTH MODULATORS**

**TYPICAL APPLICATION DATA**

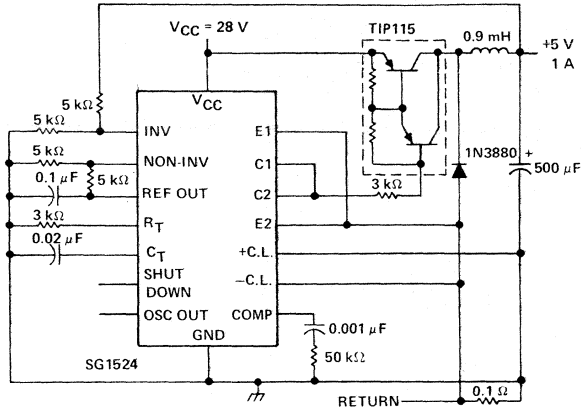


FIGURE 14—SINGLE-ENDED LC CIRCUIT

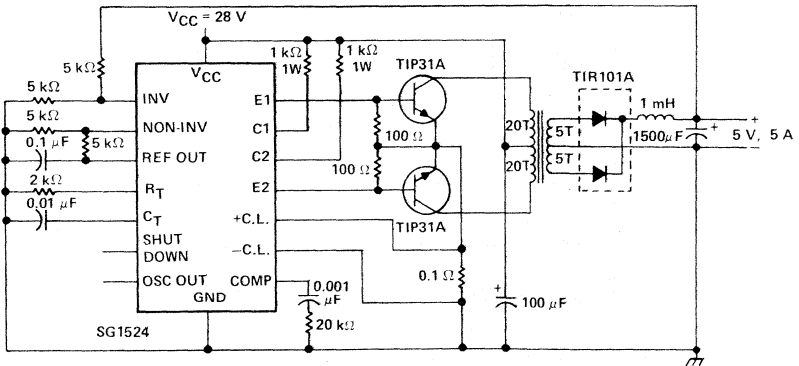


FIGURE 15—PUSH-PULL TRANSFORMER-COUPLED CIRCUIT

**TYPES SG1524, SG2524, SG3524  
REGULATING PULSE WIDTH MODULATORS**

**THERMAL INFORMATION**

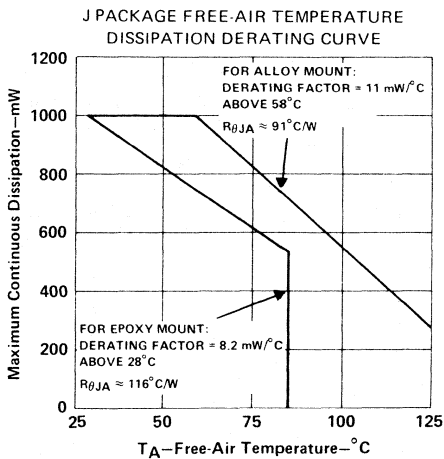


FIGURE 16

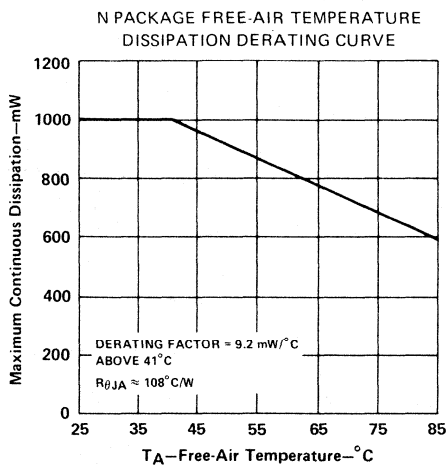


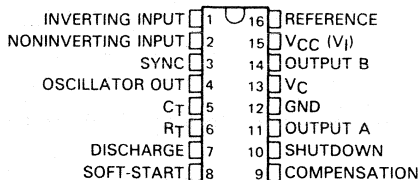
FIGURE 17

- Complete PWM Power Control Circuitry
- 8-Volt to 35-Volt Operation
- 5.1-Volt Reference Trimmed to  $\pm 1\%$
- Frequency Range . . . 100 Hz to 500 Hz
- Adjustable Deadtime Control
- Under-Voltage Lockout for Low  $V_{CC}$  Conditions
- Latched PWM Prevents Multiple Pulses
- Dual Sink or Source Output Drivers
- Direct Replacements for Silicon General SG1525A/SG1527A Series

SG1525A, SG1527A . . . J  
SG2525A, SG2527A . . . J OR N  
SG3525A, SG3527A . . . J OR N

DUAL-IN-LINE PACKAGE

(TOP VIEW)



**output logic**

SG1525A, SG2525A, SG3525A . . . NOR  
SG1527A, SG2527A, SG3527A . . . OR

**description**

The SG1525A/SG1527A series of pulse-width modulation integrated circuits are designed to offer improved performance and lower external parts count when used to implement various types of switching power supplies. Each device includes an on-chip 5.1-volt reference, error amplifier, programmable oscillator, pulse-steering flip-flop, a latched comparator under-voltage lockout, shutdown circuitry, and complementary source or sink outputs. The on-chip 5.1-volt reference is trimmed to  $\pm 1\%$  initial accuracy, serves as a reference output, and supplies the internal regulator control circuitry. The input common-mode range of the error amplifier includes the reference voltage, which eliminates the need for external divider resistors.

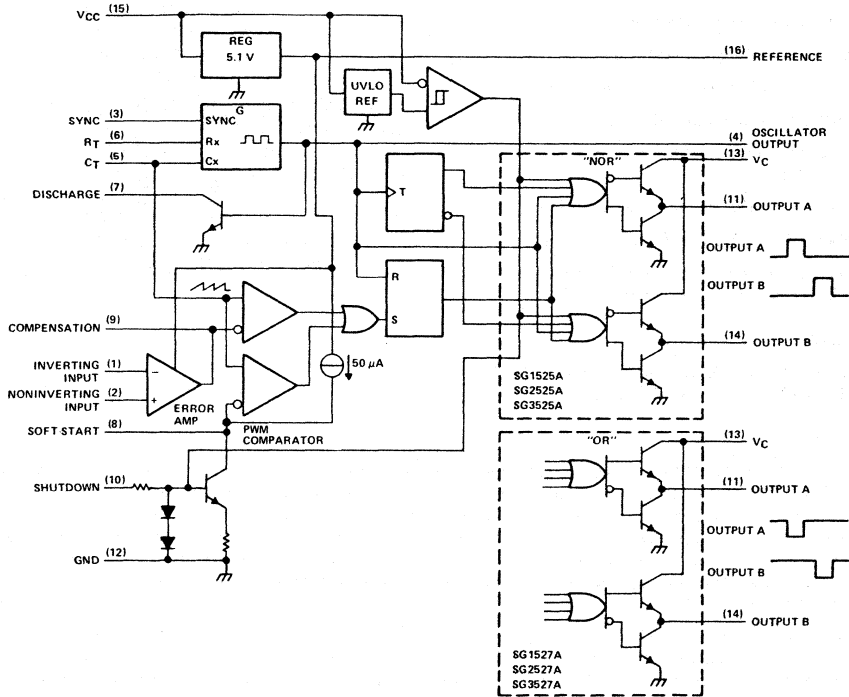
The oscillator operates at a fixed frequency determined by one timing resistor  $R_T$  and one timing capacitor  $C_T$ . The timing resistor establishes the constant charging current for  $C_T$ , resulting in a linear voltage ramp at  $C_T$ , which is fed to the PWM comparator providing linear control of the output pulse duration by the error amplifier. A Sync input to the oscillator allows for external synchronization or for multiple units to be slaved together. A single external resistor between the  $C_T$  pin and the Discharge pin provides a wide range of dead-time adjustment. These devices also feature built-in soft-start circuitry that requires only an external timing capacitor. The Shutdown pin controls both the soft-start and the output drivers, and provides instantaneous turn-off with soft-start recycle for slow turn-on. The soft-start and output driver circuitry are also controlled by the under-voltage lockout circuit, which, during low-input supply voltage of less than that required for normal operation, keeps the soft-start capacitor discharged and the output drivers off.

Another unique feature is the S-R latch following the PWM comparator. This feature enables the output drivers to be turned off any time the PWM pulse is terminated. The latch is reset with each clock pulse. However, the PWM outputs will remain turned off for the duration of the period if the PWM comparator output is in a low-level state. The SG1525A, SG2525A, and SG3525A output stages feature NOR logic, resulting in a low output for an off-state. The SG1527A, SG2527A, and SG3527A output stages feature OR logic, resulting in a high-level output for an off-state. The output stages are totem-pole designs capable of sourcing or sinking 200 milliamperes of output current.

The SG1525A and SG1527A are characterized for operation over the full military temperature range of  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ . The SG2525A and SG2527A are characterized for operation from  $-25^\circ\text{C}$  to  $85^\circ\text{C}$ . The SG3525A and SG3527A are characterized for operation for  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

# TYPES SG1525A, SG1527A, SG2525A, SG2527A, SG3525A, SG3527A PULSE-WIDTH MODULATION CONTROLLERS

functional block diagram (positive logic)



**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage, $V_{CC}$ (see Note 1)	40 V
Collector voltage, $V_C$	40 V
Logic input voltage range sync and shutdown	-0.3 V to 5.5 V
Analog input voltage range error amplifier inputs	-0.3 V to $V_{CC}$
Output current, $I_O$	500 mA
Reference output current, $I_{REF}$	50 mA
Current through $C_T$ terminal	-5 mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	1000 mW
Operating free-air temperature range: SG1525A, SG1527A	-55°C to 125°C
SG2525A, SG2527A	-25°C to 85°C
SG3525A, SG3527A	0°C to 70°C
Operating virtual junction temperature range	0°C to 150°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J Package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N Package	260°C

NOTES: 1. All voltage values are with respect to network ground terminal.

2. For operating above 25°C free-air temperature, see Dissipation Derating Curves, Figures 1 and 2. In the J package, SG1525A and SG1527A chips are alloy-mounted; SG2525A, SG2527A, SG3525A, and SG3527A chips are epoxy mounted.

# TYPES SG1525A, SG1527A, SG2525A, SG2527A, SG3525A, SG3527A PULSE-WIDTH MODULATION CONTROLLERS

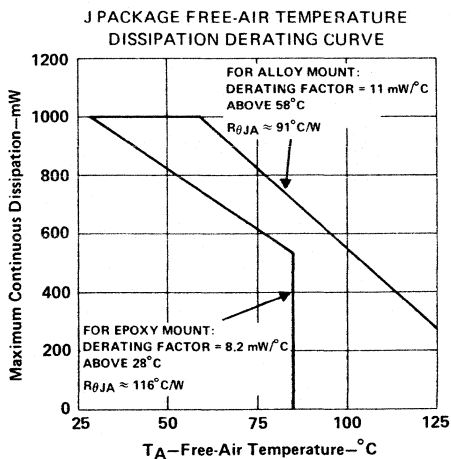


FIGURE 1

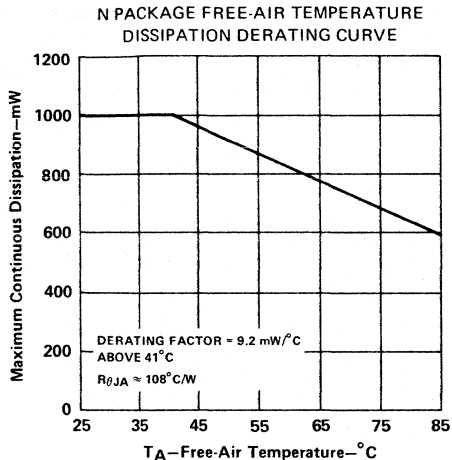


FIGURE 2

## recommended operating conditions

PARAMETER	SG1525A, SG1527A		SG2525A, SG2527A		SG3525A, SG3527A		UNIT	
	MIN	MAX	MIN	MAX	MIN	MAX		
Supply voltage, $V_{CC}$	8	35	8	35	8	35	V	
Collector voltage, $V_C$	4.5	35	4.5	35	4.5	35	V	
Output current, $I_O$	Steady state	0	±100	0	±100	0	±100	mA
	Peak	0	±400	0	±400	0	±400	
Reference output current, $I_{REF}$	0	20	0	20	0	20	mA	
Oscillator frequency range	100	500	100	500	100	500	kHz	
Timing resistor, $R_T$	2	150	2	150	2	150	kΩ	
Timing capacitor, $C_T$	0.001	0.1	0.001	0.1	0.001	0.1	μF	
Dead-time resistor, $R_D$	0	500	0	500	0	500	Ω	
Operating free-air temperature range, $T_A$	-55	125	-25	85	0	70	°C	

# TYPES SG1525A, SG1527A, SG2525A, SG2527A, SG3525A, SG3527A PULSE-WIDTH MODULATION CONTROLLERS

electrical characteristics over recommended operating free-air temperature range,  $V_{CC} = 20\text{ V}$   
(unless otherwise noted)

## reference section

PARAMETER	TEST CONDITIONS	SG1525A, SG1527A SG2525A, SG2527A			SG3525A, SG3527A			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage	$T_J = 25^\circ\text{C}$	5.05	5.1	5.15	5	5.1	5.2	V
	$V_{CC} = 8\text{ V to }35\text{ V}$ , $I_O = 0\text{ to }20\text{ mA}$	5		5.2	4.95		5.25	
Input regulation	$V_{CC} = 8\text{ V to }35\text{ V}$		14	20		14	20	mV
Output regulation	$I_O = 0\text{ to }20\text{ mA}$		5	50		5	50	mV
Output voltage change with temperature			24	50		24	50	mV
Output voltage long-term drift (see Note 3)	After 1000 h at $T_J = 125^\circ\text{C}$		25	50		25	50	mV
Output noise voltage (RMS)	$f = 10\text{ Hz to }10\text{ kHz}$ , $T_J = 25^\circ\text{C}$		40	200		40	200	$\mu\text{V}$
Short-circuit output current	$V_O = 0\text{ V}$ , $T_J = 25^\circ\text{C}$		80	100		80	100	mA

## oscillator section

PARAMETER	TEST CONDITIONS	SG1525A, SG1527A SG2525A, SG2527A			SG3525A, SG3527A			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Maximum frequency	$R_T = 2\text{ k}\Omega$ , $C_T = 1\text{ nF}$	400		100	400		100	kHz
Minimum frequency	$R_T = 150\text{ k}\Omega$ , $C_T = 0.1\text{ }\mu\text{F}$			100			100	Hz
Initial frequency error	$R_T = 3.6\text{ k}\Omega$ , $R_D = 0\text{ }\Omega$ , $C_T = 0.1\text{ }\mu\text{F}$ , $f = 40\text{ kHz}$ , $T_A = 25^\circ\text{C}$		$\pm 2\%$	$\pm 6\%$		$\pm 2\%$	$\pm 6\%$	
Frequency change with supply voltage	$V_{CC} = 8\text{ V to }35\text{ V}$		$\pm 0.3\%$	$\pm 1\%$		$\pm 1\%$	$\pm 2\%$	
Frequency change with temperature	$T_A = \text{MIN to MAX}$		$\pm 3\%$	$\pm 6\%$		$\pm 3\%$	$\pm 6\%$	
Output amplitude at Pin 4	$R_T = 3.6\text{ k}\Omega$ , $R_D = 0\text{ }\Omega$ , $C_T = 0.1\text{ }\mu\text{F}$ , $f = 40\text{ kHz}$	3	3.5		3	3.5		V
Output pulse duration at Pin 4	$R_T = 3.5\text{ k}\Omega$ , $R_D = 0\text{ }\Omega$ , $C_T = 0.1\text{ }\mu\text{F}$ , $f = 40\text{ kHz}$ , $T_J = 25^\circ\text{C}$	0.3	0.5	1	0.3	0.6	1	$\mu\text{s}$
Input threshold voltage at Pin 3		1.2	2	2.8	1.2	2	2.8	V
Input current at Pin 3	$V_{(Pin3)} = 3.5\text{ V}$		1.6	2.5		1.6	2.5	mA
Current through Pin 5 due to internal current mirror	Current through Pin 6 = 6 mA	1.7	2	2.2	1.7	2	2.2	mA

NOTE 3: Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

# TYPES SG1525A, SG1527A, SG2525A, SG2527A, SG3525A, SG3527A PULSE-WIDTH MODULATION CONTROLLERS

electrical characteristics over recommended operating free-air temperature range,  $V_{CC} = 20\text{ V}$   
(unless otherwise noted)

## error amplifier section

PARAMETER	TEST CONDITIONS	SG1525A, SG1527A SG2525A, SG2527A			SG3525A, SG3527A			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
High-level output voltage		3.8	5.6		3.8	5.6		V
Low-level output voltage			0.2	0.5		0.2	0.5	V
Input offset voltage			0.5	5		2	10	mV
Input bias current			1	10		1	10	$\mu\text{A}$
Input offset current				1			1	$\mu\text{A}$
Open-loop voltage amplification	$R_L \geq 10\text{ M}$	60	75		60	75		dB
Common-mode rejection ratio	$V_{IC} = 1.5\text{ V to } 5.2\text{ V}$	60	75		60	75		dB
Supply voltage rejection ratio	$V_{CC} = 8\text{ V to } 35\text{ V}$	50	60		50	60		dB
Gain-bandwidth product	$A_V = 0\text{ dB}, T_J = 25^\circ\text{C}$	1	2		1	2		MHz

## comparator section

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input threshold voltage	$R_T = 3.6\text{ k}\Omega$ , $R_D = 0\ \Omega$ , $C_T = 10\text{ nF}, f = 40\text{ kHz}$	0.6	0.9	3.3	3.6
	Duty cycle = 0%				
	Duty cycle = MAX				
Input bias current			0.5	1	$\mu\text{A}$

## soft-start section

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Soft-start voltage	$V_I$ at Pin 10 = 2 V		0.4	0.6	V
Soft-start current	$V_I$ at Pin 10 = 0 V	25	50	80	$\mu\text{A}$
Input current, Shutdown	$V_I$ at Pin 10 = 2.5 V		0.4	1	mA

## output section

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
High-level output voltage	$I_{OH} = -20\text{ mA}$	18	19		V
	$I_{OH} = -100\text{ mA}$	17	18		
Low-level output voltage	$I_{OL} = 20\text{ mA}$		0.2	0.4	V
	$I_{OL} = 100\text{ mA}$		1	2	
Under-voltage lockout voltage	$V_I$ at Pins 8 and 9 = high	6	7	8	V
Collector cutoff current (see Note 4)	$V_C = 35\text{ V}, I_O = 100\text{ mA}$			200	$\mu\text{A}$
Output pulse rise time	$C_L = 1\text{ nF}, T_J = 25^\circ\text{C}$		100	600	ns
Output pulse fall time	$C_L = 1\text{ nF}, T_J = 25^\circ\text{C}$		50	300	ns
Shutdown delay time	$V_I$ at Pin 10 = 3 V, capacitance at pin 8 = 0, $T_J = 25^\circ\text{C}$		0.2	0.5	$\mu\text{s}$

NOTE 4: Collector cutoff current specifications apply only for the SG1525A, SG2525A, and SG3525A devices.

## total device

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Minimum duty cycle				0%	
Maximum duty cycle		45%	49%		
Standby current	$V_{CC} = 35\text{ V}$		14	20	mA

**TYPES SG1525A, SG1527A, SG2525A, SG2527A, SG3525A, SG3527A  
PULSE-WIDTH MODULATION CONTROLLERS**

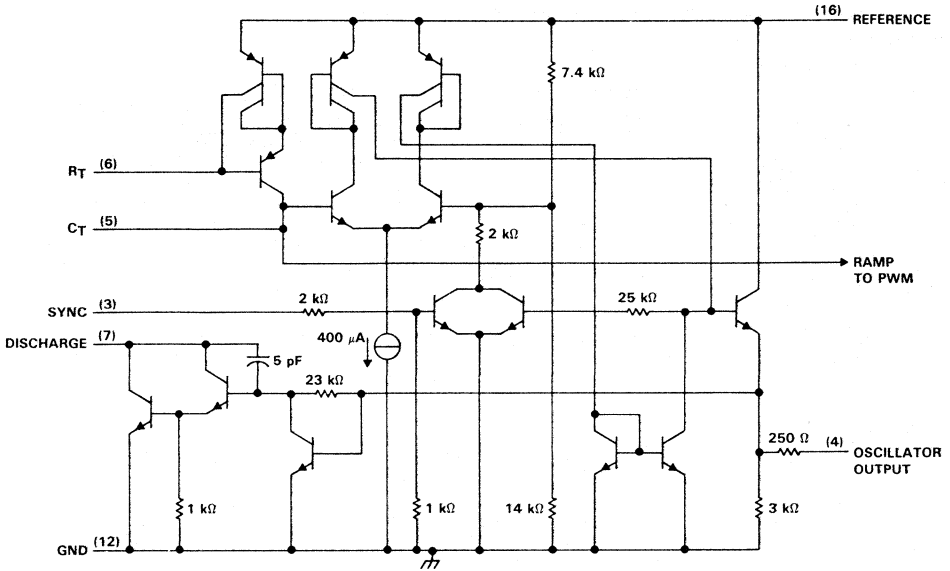


FIGURE 3 — OSCILLATOR SCHEMATIC DIAGRAM

**TYPICAL CHARACTERISTICS**

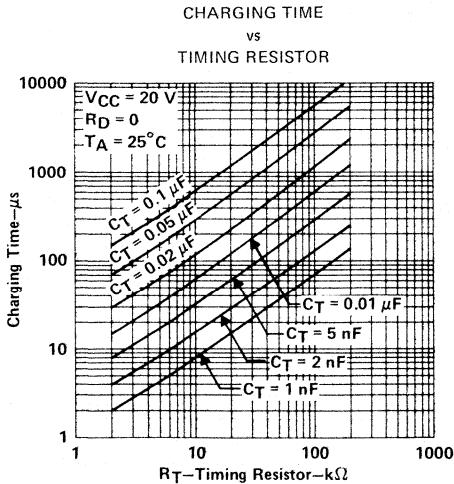


FIGURE 4

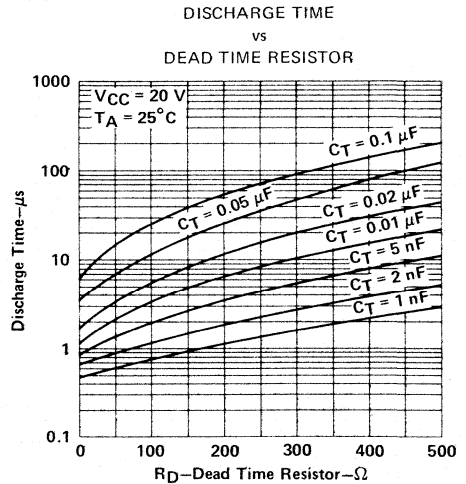


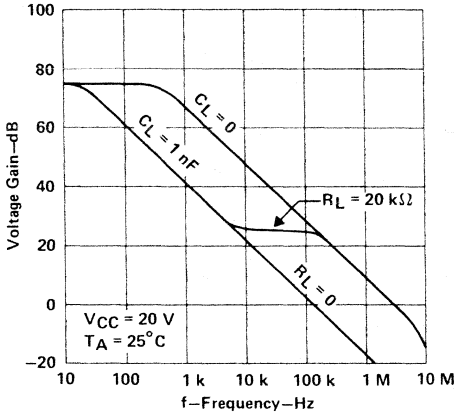
FIGURE 5



**TYPES SG1525A, SG1527A, SG2525A, SG2527A, SG3525A, SG3527A  
PULSE-WIDTH MODULATION CONTROLLERS**

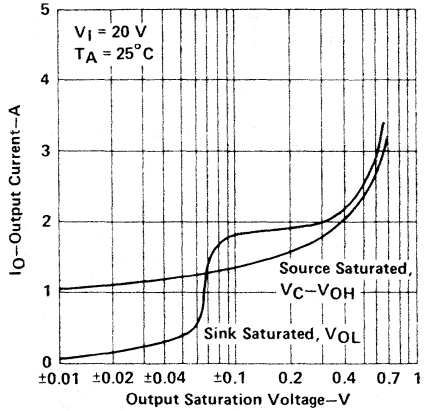
**TYPICAL CHARACTERISTICS**

**ERROR AMPLIFIER OPEN-LOOP  
FREQUENCY RESPONSE**

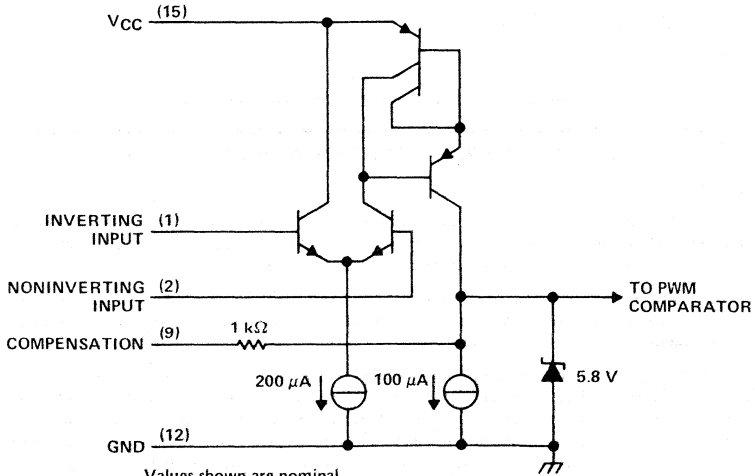


**FIGURE 6**

**SG1525A OUTPUT SATURATION VOLTAGE  
vs  
OUTPUT CURRENT**



**FIGURE 7**



**FIGURE 8 — ERROR AMPLIFIER SCHEMATIC DIAGRAM**

# TYPES SG1525A, SG1527A, SG2525A, SG2527A, SG3525A, SG3527A PULSE-WIDTH MODULATION CONTROLLERS

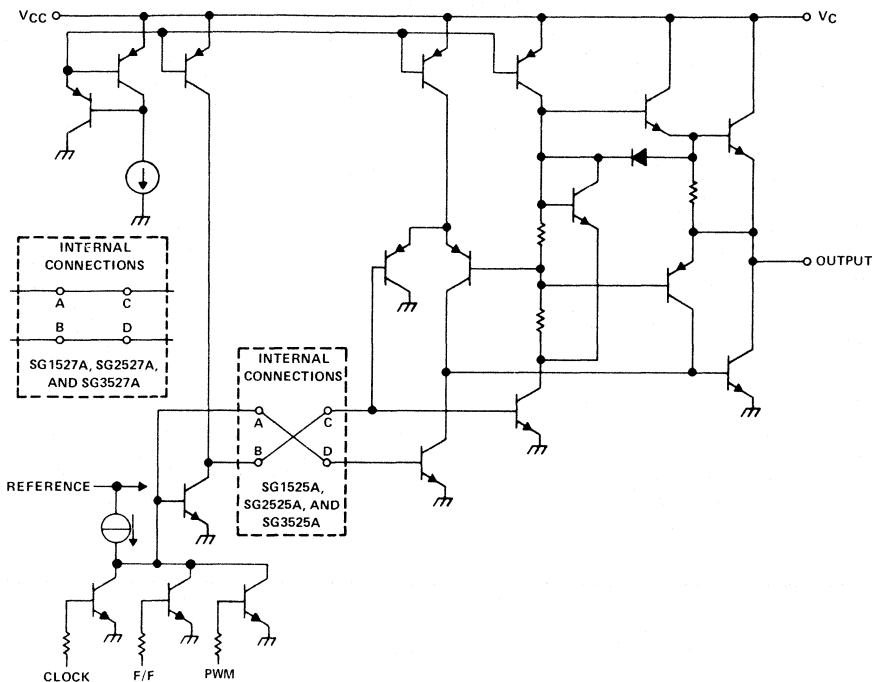


FIGURE 9 – OUTPUT CIRCUIT SCHEMATIC DIAGRAM

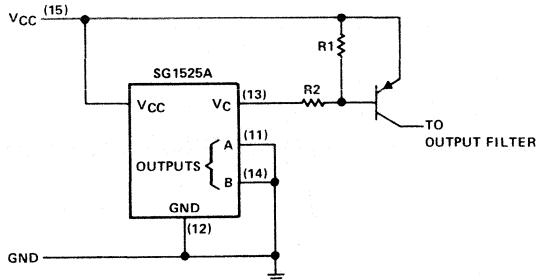
## TYPICAL APPLICATION DATA

### shutdown options

1. Use an external transistor or open-collector comparator to pull down on the Compensation terminal (Pin 9). This will set the PWM latch and turn off both driver outputs. If the shutdown signal is momentary, pulse-by-pulse protection will be accomplished as the PWM latch is reset with each clock pulse.
2. The same results may be accomplished by pulling down on the Soft-Start terminal (Pin 8) with the only difference being that on this pin shutdown will not affect the amplifier compensation network, but must discharge any soft-start capacitance.
3. Application of a positive-going signal to the Shutdown terminal (Pin 10) will provide the most rapid shutdown of the driver outputs but will not immediately set the PWM latch if there is a capacitor at the Soft-Start terminal. The capacitor will discharge but at a current twice the charging current. The PWM latch can be set on a pulse-by-pulse basis by the shutdown terminal if there is no external capacitance on the Soft-start terminal (Pin 8). Slow turn-on may still be accomplished by connecting an external capacitor, blocking diode, and charging resistor to the Compensation terminal (Pin 9).

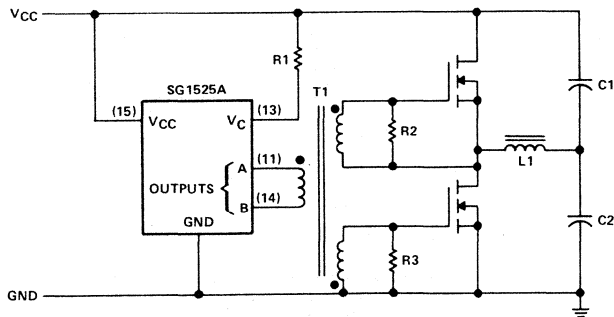
# TYPES SG1525A, SG1527A, SG2525A, SG2527A, SG3525A, SG3527A PULSE-WIDTH MODULATION CONTROLLERS

## TYPICAL APPLICATION DATA



For single-ended supplies, the driver outputs are grounded. The  $V_C$  terminal is switched to ground by the totem-pole source transistors on the alternate oscillator cycles.

FIGURE 10 — SINGLE-ENDED CIRCUIT

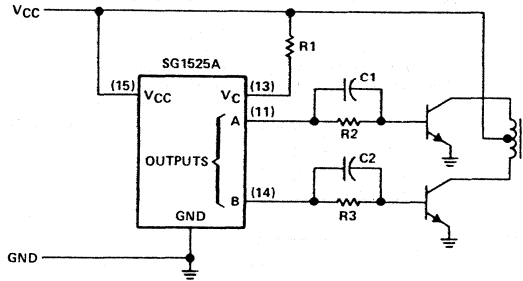


Low-power transformers can be directly driven by the SG1525A. Automatic reset occurs during deadtime when both ends of the primary winding are switched to ground.

FIGURE 11 — TRANSFORMER-COUPLED CIRCUIT

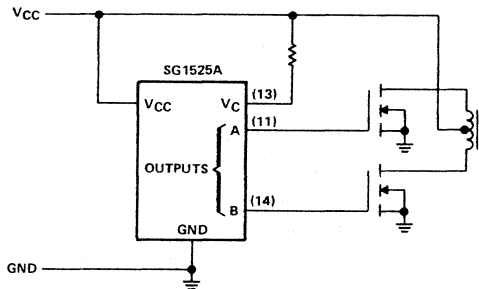
**TYPES SG1525A, SG1527A, SG2525A, SG2527A, SG3525A, SG3527A  
PULSE-WIDTH MODULATION CONTROLLERS**

**TYPICAL APPLICATION DATA**



In conventional push-pull bipolar designs, forward base drive is controlled by  $R_1 - R_3$ . Rapid turn-off times for the power devices are achieved with speed-up capacitors  $C_1$  and  $C_2$ .

**FIGURE 12 — BIPOLAR PUSH-PULL CIRCUIT**

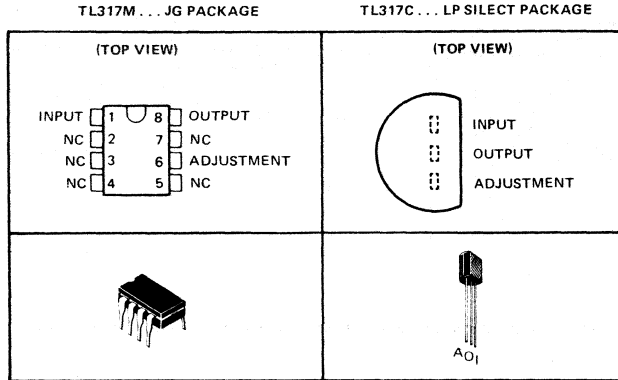


The low source impedance of the output drivers provides rapid charging of power FET input capacitance while minimizing external components.

**FIGURE 13 — LOW-IMPEDANCE BIPOLAR-DRIVE  
PUSH-PULL CIRCUIT**

- Output Voltage Range Adjustable from 1.2 V to 32 V
- Guaranteed Output Current Capability of 100 mA
- Input Regulation Typically 0.01% Per Input-Volt Change
- Output Regulation Typically 0.5%
- Ripple Rejection Typically 80 dB

terminal assignments



NC—No internal connection

description

The TL317 is an adjustable 3-terminal positive-voltage regulator capable of supplying 100 milliamperes over an output-voltage range of 1.2 volts to 32 volts. It is exceptionally easy to use and requires only two external resistors to set the output voltage. Both input and output regulation are better than standard fixed regulators. The device is packaged in standard packages that are easily mounted and handled.

In addition to higher performance than fixed regulators, this regulator offers full overload protection available only in integrated circuits. Included on the chip are current limit and thermal overload protection. All overload protection circuitry remains fully functional even if the adjustment terminal is disconnected. Normally, no capacitors are needed unless the device is situated far from the input filter capacitors in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. The adjustment terminal can be bypassed to achieve very high ripple rejection, which is difficult to achieve with standard 3-terminal regulators.

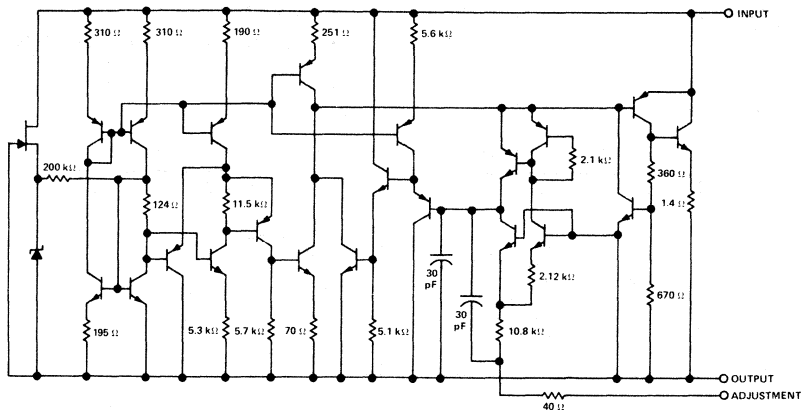
Besides replacing fixed regulators, the regulator is useful in a wide variety of other applications. Since the regulator is floating and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input-to-output differential is not exceeded. Its primary application is that of a programmable output regulator, but by connecting a fixed resistor between the adjustment terminal and the output terminal, this device can be used as a precision current regulator. Supplies with electronic shutdown can be achieved by clamping the adjustment terminal to ground, which programs the output to 1.2 volts where most loads draw little current.

The TL317M is characterized for operation over the full military temperature range from  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The TL317C is characterized for operation from  $0^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .



# TYPE TL317M, TL317C 3-TERMINAL ADJUSTABLE REGULATOR

schematic



## absolute maximum ratings over operation temperature range (unless otherwise noted)

Input-to-output differential voltage, $V_I - V_O$ .....	35 V
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 1): JG package .....	1050 mW
LP package .....	775 mW
Continuous total dissipation at (or below) 25°C case temperature (see Note 1) .....	1600 mW
Operating free-air, case, or virtual junction temperature range: TL317M .....	-55°C to 150°C
TL317C .....	0°C to 150°C
Storage temperature range .....	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds, JG package .....	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds, LP package .....	260°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Dissipation Derating Table.

DISSIPATION DERATING TABLE

PACKAGE	REFERENCE POINT	POWER RATING	DERATING FACTOR	ABOVE ( $T_A$ OR $T_C$ )
JG	Free-air	1050 mW	8.4 mW/°C	25°C
	Case	1600 mW	38.4 mW/°C	108°C
LP	Free-air	775 mW	6.2 mW/°C	25°C
	Case	1600 mW	28.6 mW/°C	94°C

## recommended operating conditions

	TL317M		TL317C		UNIT
	MIN	MAX	MIN	MAX	
Output current, $I_O$	2.5	100	2.5	100	mA
Operating virtual junction temperature, $T_J$	-55	125	0	125	°C

Voltage Regulators

6

# TYPE TL317M, TL317C 3-TERMINAL ADJUSTABLE REGULATOR

electrical characteristics over recommended ranges of operating virtual junction temperature (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	MIN	TYP	MAX	UNIT
Input regulation (see Note 2)	$V_I - V_O = 3 \text{ V to } 35 \text{ V}$ , See Note 3		0.01	0.02	% / V
	$T_J = 25^\circ \text{ C}$ $I_O = 2.5 \text{ mA to } 100 \text{ mA}$		0.02	0.05	
Ripple rejection	$V_O = 10 \text{ V}$ , $f = 120 \text{ Hz}$		65		dB
	$V_O = 10 \text{ V}$ , $f = 120 \text{ Hz}$ , 10- $\mu\text{F}$ capacitor between ADJ and ground		66	80	
Output regulation	$I_O = 2.5 \text{ mA to } 100 \text{ mA}$ , $T_J = 25^\circ \text{ C}$ , See Note 3		25		mV
	$V_O \leq 5 \text{ V}$		0.5		%
	$V_O \geq 5 \text{ V}$		50		mV
	$V_O \geq 5 \text{ V}$		1		%
Output voltage change with temperature	$T_J = 0^\circ \text{ C to } 125^\circ \text{ C}$		1		%
Output voltage long-term drift (see Note 4)	After 1000 h at $T_J = 125^\circ \text{ C}$ and $V_I - V_O = 35 \text{ V}$		0.3	1	%
Output noise voltage	$f = 10 \text{ Hz to } 10 \text{ kHz}$ , $T_J = 25^\circ \text{ C}$		0.003		%
Minimum output current to maintain regulation	$V_I - V_O = 35 \text{ V}$		1.5	2.5	mA
Peak output current	$V_I - V_O \leq 35 \text{ V}$	100	200		mA
Adjustment-terminal current			50	100	$\mu\text{A}$
Change in adjustment-terminal current	$V_I - V_O = 2.5 \text{ V to } 35 \text{ V}$ , $I_O = 2.5 \text{ mA to } 100 \text{ mA}$		0.2	5	$\mu\text{A}$
Reference voltage (output to ADJ)	$V_I - V_O = 3 \text{ V to } 35 \text{ V}$ , $I_O = 2.5 \text{ mA to } 100 \text{ mA}$ , $P < \text{rated dissipation}$	1.2	1.25	1.3	V

† Unless otherwise noted, these specifications apply for the following test conditions:  $V_I - V_O = 5 \text{ V}$  and  $I_O = 2.5 \text{ mA}$ .

- NOTES: 2. Input regulation is expressed here as the percentage change in output voltage per 1-volt change at the input.  
3. Input regulation and output regulation are measured using pulse techniques ( $t_w \leq 10 \mu\text{s}$ , duty cycle  $\leq 5\%$ ) to limit changes in average internal dissipation. Output voltage changes due to large changes in internal dissipation must be taken into account separately.  
4. Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

## TYPICAL APPLICATION DATA

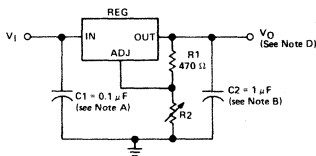


FIGURE 1—ADJUSTABLE VOLTAGE REGULATOR

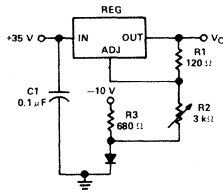
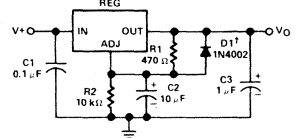


FIGURE 2—0-V to 30-V REGULATOR CIRCUIT



† D1 discharges C2 if output is shorted to ground.

FIGURE 3—ADJUSTABLE REGULATOR CIRCUIT WITH IMPROVED RIPPLE REJECTION

- NOTES: A. Use of an input bypass capacitor is recommended if regulator is far from filter capacitors.  
B. Use of an output capacitor improves transient response but is optional.  
C.  $V_{ref}$  equals the difference between the output and adjustment terminal voltages.  
D. Output voltage is calculated from the equation:  $V_O = V_{ref} \left( 1 + \frac{R_2}{R_1} \right)$

# TYPE TL317M, TL317C 3-TERMINAL ADJUSTABLE REGULATOR

## TYPICAL APPLICATION DATA

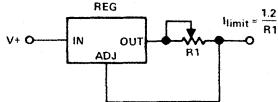


FIGURE 4—PRECISION CURRENT LIMITER CIRCUIT

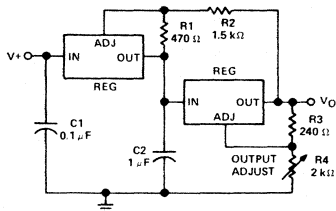


FIGURE 5—TRACKING PREREGULATOR CIRCUIT

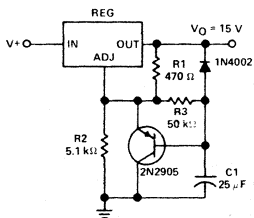


FIGURE 6—SLOW-TURN-ON 15-V REGULATOR CIRCUIT

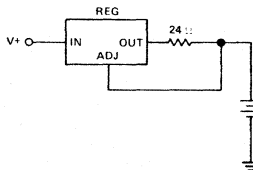
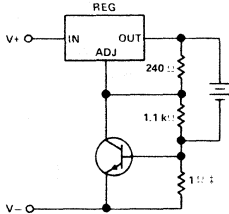
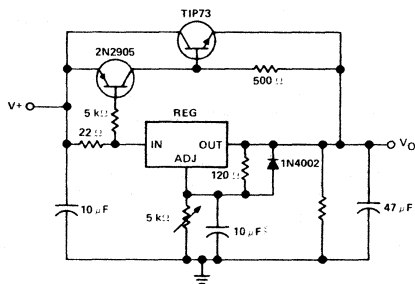


FIGURE 7—50-mA CONSTANT-CURRENT BATTERY CHARGER CIRCUIT



‡ This resistor sets peak current (100 mA for 6 Ω).

FIGURE 8—CURRENT-LIMITED 6-V CHARGER



† Minimum load current is 30 mA.

§ Optional capacitor improves ripple rejection

FIGURE 9—HIGH-CURRENT ADJUSTABLE REGULATOR

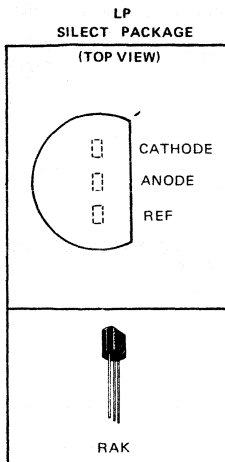


- Temperature Compensated
- Programmable Output Voltage
- Low Output Resistance
- Low Output Noise
- Sink Capability to 100 mA

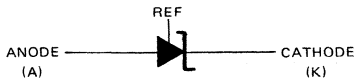
**description**

The TL430 is a three-terminal adjustable shunt regulator featuring excellent temperature stability, wide operating current range, and low output noise. The output voltage may be set by two external resistors to any desired value between 3 volts and 30 volts. The TL430 can replace zener diodes in many applications providing improved performance.

The TL430I is characterized for operation from -25°C to 85°C, and the TL430C is characterized for operating from 0°C to 70°C.



**functional block diagram**



**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Regulator voltage (see Note 1)	30 V
Continuous regulator current	150 mA
Continuous dissipation at (or below) 25°C free-air temperature (see Note 2)	775 mW
Operating free-air temperature range: TL430I	-40°C to 85°C
TL430C	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

**recommended operating conditions**

	MIN	MAX	UNIT
Regulator Voltage, $V_Z$	$V_{ref}$	30	V
Regulator current, $I_Z$	2	100	mA

- NOTES: 1. All voltage values are with respect to the anode terminal.  
2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Figure 5.



# TYPES TL430I, TL430C ADJUSTABLE SHUNT REGULATORS

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER	TEST FIGURE	TEST CONDITIONS	TL430I			TL430C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V <sub>ref</sub> Reference input voltage	1	V <sub>Z</sub> = V <sub>ref</sub> , I <sub>Z</sub> = 10 mA	2.6	2.75	2.9	2.5	2.75	3	V
αV <sub>ref</sub> Temperature coefficient of reference input voltage	1	V <sub>Z</sub> = V <sub>ref</sub> , I <sub>Z</sub> = 10 mA, T <sub>A</sub> = 0°C to 70°C	+120 +200			+120			ppm/°C
I <sub>ref</sub> Reference input current	2	I <sub>Z</sub> = 10 mA, R <sub>1</sub> = 10 kΩ, R <sub>2</sub> = ∞	3 10			3 10			μA
I <sub>ZK</sub> Regulator current near lower knee of regulation range	1	V <sub>Z</sub> = V <sub>ref</sub>	0.5 2			0.5 2			mA
I <sub>ZM</sub> Regulator current at maximum limit of regulation range	1	V <sub>Z</sub> = V <sub>ref</sub>	50			50			mA
	2	V <sub>Z</sub> = 5 V to 30 V, See Note 3	100			100			
r <sub>Z</sub> Differential regulator resistance (see Note 4)	1	V <sub>Z</sub> = V <sub>ref</sub> , ΔI <sub>Z</sub> = (52-2) mA	1.5 3			1.5 3			Ω
V <sub>nZ</sub> Noise voltage	2	f = 0.1 Hz to 10 Hz	V <sub>Z</sub> = 3 V			50			μV
			V <sub>Z</sub> = 12 V			200			
			V <sub>Z</sub> = 30 V			650			

NOTES: 3. The average power dissipation, V<sub>Z</sub> • I<sub>Z</sub> • duty cycle, must not exceed the maximum continuous rating in any 10-ms interval.  
4. The regulator resistance for V<sub>Z</sub> > V<sub>ref</sub>, r<sub>Z</sub>', is given by:

$$r'_Z = r_Z \left( 1 + \frac{R_1}{R_2} \right)$$

## PARAMETER MEASUREMENT INFORMATION

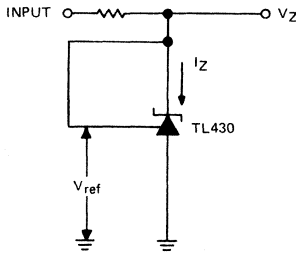
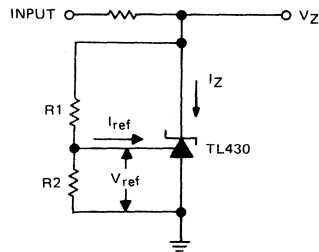


FIGURE 1—TEST CIRCUIT FOR V<sub>Z</sub> = V<sub>ref</sub>



$$V_Z = V_{ref} \left( 1 + \frac{R_1}{R_2} \right) + I_{ref} \cdot R_1$$

FIGURE 2—TEST CIRCUIT FOR V<sub>Z</sub> > V<sub>ref</sub>



TYPICAL CHARACTERISTICS

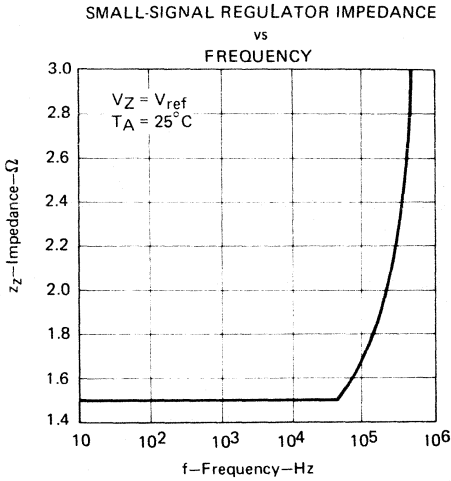


FIGURE 3

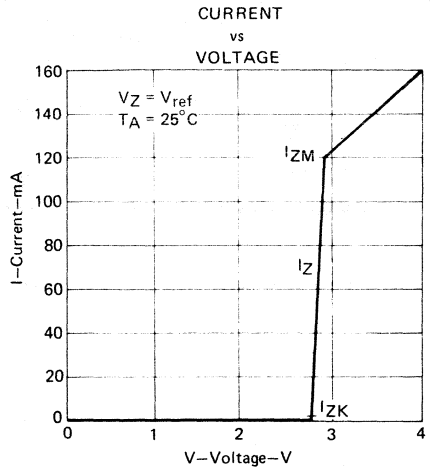


FIGURE 4

THERMAL INFORMATION

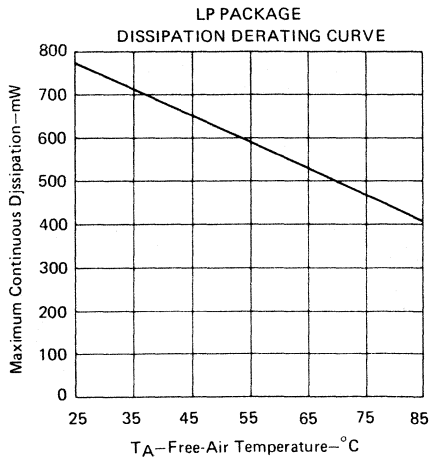


FIGURE 5

# TYPES TL430I, TL430C ADJUSTABLE SHUNT REGULATORS

## TYPICAL APPLICATION DATA

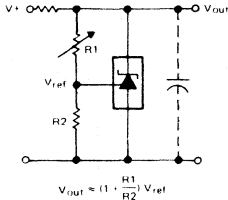


FIGURE 6—SHUNT REGULATOR

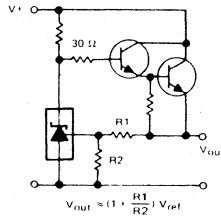


FIGURE 7—SERIES REGULATOR

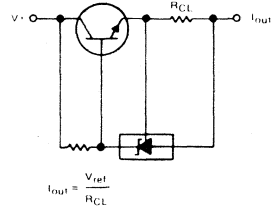


FIGURE 8—CURRENT LIMITER

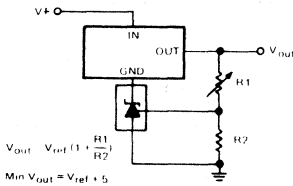


FIGURE 9—OUTPUT CONTROL OF A  
THREE-THERMAL  
FIXED REGULATOR

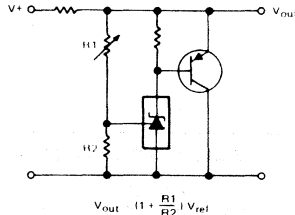


FIGURE 10—HIGHER-CURRENT  
APPLICATIONS

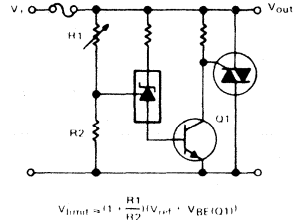


FIGURE 11—CROW BAR

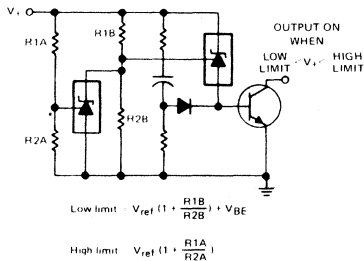


FIGURE 12—OVER-VOLTAGE/UNDER-VOLTAGE  
PROTECTION CIRCUIT

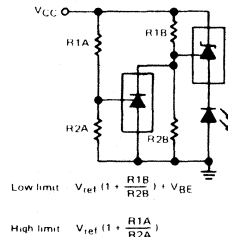


FIGURE 13—VCC MONITOR

# LINEAR INTEGRATED CIRCUITS

# TYPES TL431M, TL431I, TL431C ADJUSTABLE PRECISION SHUNT REGULATORS

D2410, JULY 1978—REVISED DECEMBER 1982

- Equivalent Full-Range Temperature Coefficient . . . 30 ppm/°C Typ
- Temperature Compensated for Operation Over Full Rated Operating Temperature Range
- Adjustable Output Voltage
- Fast Turn-On Response
- Sink Current Capability . . . 1 mA to 100 mA
- Low (0.2-Ω Typ) Dynamic Output Impedance
- Low Output Noise Voltage

## description

The TL431 is a three-terminal adjustable regulator series with guaranteed thermal stability over applicable temperature ranges. The output voltage may be set to any value between  $V_{ref}$  (approximately 2.5 volts) and 36 volts with two external resistors (see Figure 16). These devices have a typical dynamic output impedance of 0.2 Ω. Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacements for zener diodes in many applications.

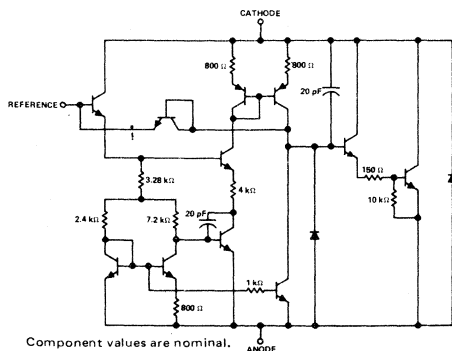
The TL431M is characterized for operation over the full military temperature range of -55°C to 125°C. The TL431I is characterized for operation from -40°C to 85°C, and the TL431C from 0°C to 70°C.

## terminal assignments

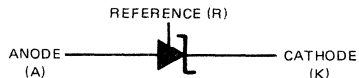
TL431M . . . JG DUAL-IN-LINE PACKAGE	TL431I, TL431C . . . LP SILECT PACKAGE	TL431I, TL431C . . . P DUAL-IN-LINE PACKAGE
(TOP VIEW)	(TOP VIEW)	(TOP VIEW)

NC—No internal connection

## schematic



## functional block diagram



# TYPES TL431M, TL431I, TL431C

## ADJUSTABLE PRECISION SHUNT REGULATORS

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Cathode voltage (see Note 1)	37 V
Continuous cathode current range	-100 mA to 150 mA
Reference input current range	-50 $\mu$ A to 10 mA
Continuous power dissipation at (or below) 25°C free-air temperature (see Note 2):	
JG package	1050 mW
LP package	775 mW
P package	1000 mW
Operating free-air temperature range:	
TL431C	0°C to 70°C
TL431I	-40°C to 85°C
TL431M	-55°C to 125°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: LP or P package	260°C

- NOTES: 1. Voltage values are with respect to the anode terminal unless otherwise noted.  
 2. For operation above 25°C free-air temperature, refer to the Dissipation Derating Table.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE T <sub>A</sub>
JG	1050 mW	8.4 mW/°C	25°C
LP	775 mW	6.2 mW/°C	25°C
P	1000 mW	8.0 mW/°C	25°C

### recommended operating conditions

	MIN	MAX	UNIT
Cathode voltage, V <sub>K</sub> A	V <sub>ref</sub>	36	V
Cathode current, I <sub>K</sub> , (for regulation)	1	100	mA

# TYPES TL431M, TL431I, TL431C ADJUSTABLE PRECISION SHUNT REGULATORS

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER	TEST CIRCUIT	TEST CONDITIONS	TL431M			TL431I			TL431C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V <sub>ref</sub>	Reference input voltage	V <sub>K</sub> A = V <sub>ref</sub> , I <sub>K</sub> = 10 mA	2440	2495	2550	2440	2495	2550	2440	2495	2550	mV
V <sub>ref(dev)</sub>	Deviation of reference input voltage over full temperature range†	V <sub>K</sub> A = V <sub>ref</sub> , I <sub>K</sub> = 10 mA, T <sub>A</sub> = full range‡	22	44	15	30	8	17	8	17	17	mV
ΔV <sub>ref</sub>	Ratio of change in reference input voltage to the change in cathode voltage	ΔV <sub>K</sub> A = 10 V – V <sub>ref</sub> ΔV <sub>K</sub> A = 36 V – 10 V	-1.4	-2.7	-1.4	-2.7	-1.4	-2.7	-1.4	-2.7	-2.7	mV
I <sub>ref</sub>	Reference input current	I <sub>K</sub> = 10 mA, R1 = 10 kΩ, R2 = ∞	-1	-2	-1	-2	-1	-2	-1	-2	-2	μA
I <sub>ref(dev)</sub>	Deviation of reference input current over full temperature range‡	I <sub>K</sub> = 10 mA, R1 = 10 kΩ, R2 = ∞ T <sub>A</sub> = full range‡	2	4	2	4	2	4	2	4	4	μA
I <sub>min</sub>	Minimum cathode current for regulation	I <sub>K</sub> = 10 mA, V <sub>ref</sub> = 0	1	3	0.8	2.5	0.4	1.2	0.4	1.2	1.2	μA
I <sub>off</sub>	Off-state cathode current	V <sub>K</sub> A = V <sub>ref</sub> , I <sub>K</sub> = 1 mA to 100 mA f ≤ 1 kHz	0.4	1	0.4	1	0.4	1	0.4	1	1	μA
z <sub>ka</sub>	Dynamic impedance §	V <sub>K</sub> A = V <sub>ref</sub> , I <sub>K</sub> = 1 mA to 100 mA f ≤ 1 kHz	0.1	1	0.1	1	0.1	1	0.1	1	1	μA
			0.2	0.5	0.2	0.5	0.2	0.5	0.2	0.5	0.5	Ω

† Full temperature range is -55°C to 125°C for the TL431M, -40°C to 85°C for the TL431I, and 0°C to 70°C for the TL431C.

‡ The deviation parameters V<sub>ref(dev)</sub> and I<sub>ref(dev)</sub> are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The equivalent full-range temperature coefficient of the reference input voltage, αV<sub>ref</sub>, is defined as:

$$\left| \alpha V_{ref} \left( \frac{\text{ppm}}{^{\circ}\text{C}} \right) \right| = \frac{\left( \frac{V_{ref}(\text{dev})}{V_{ref} @ 25^{\circ}\text{C}} \right) \times 10^6}{\Delta T_A}$$

where ΔT<sub>A</sub> is the rated operating free-air temperature range of the device.

αV<sub>ref</sub> can be positive or negative depending on whether minimum V<sub>ref</sub> or maximum V<sub>ref</sub> occurs at the lower temperature (see Figure 8).

Example: Max V<sub>ref</sub> = 2500 mV @ 30°C, Min V<sub>ref</sub> = 2492 mV @ 0°C, V<sub>ref</sub> = 2495 mV @ 25°C, ΔT<sub>A</sub> = 70°C for TL431C

$$\left| \alpha V_{ref} \right| = \frac{\left( \frac{8 \text{ mV}}{2495 \text{ mV}} \right) \times 10^6}{70^{\circ}\text{C}} = 46 \text{ ppm}/^{\circ}\text{C}$$

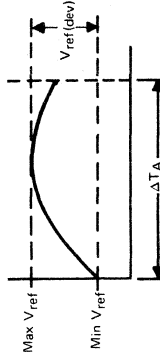
Because minimum V<sub>ref</sub> occurs at the lower temperature, the coefficient is positive.

§ The dynamic impedance is defined as:

$$z_{ka} = \frac{\Delta V_{KA}}{\Delta I_K}$$

When the device is operated with two external resistors (see Figure 2), the total dynamic impedance of the circuit is given by:

$$\left| z \right| = \frac{\Delta V}{\Delta I} \approx z_{ka} \left( 1 + \frac{R1}{R2} \right)$$



# TYPES TL431M, TL431I, TL431C ADJUSTABLE PRECISION SHUNT REGULATORS

## PARAMETER MEASUREMENT INFORMATION

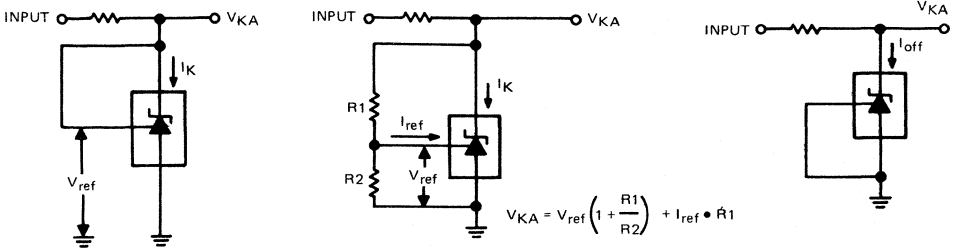


FIGURE 1—TEST CIRCUIT FOR  $V_{KA} = V_{ref}$     FIGURE 2—TEST CIRCUIT FOR  $V_{KA} > V_{ref}$     FIGURE 3—TEST CIRCUIT FOR  $I_{off}$

## TYPICAL CHARACTERISTICS

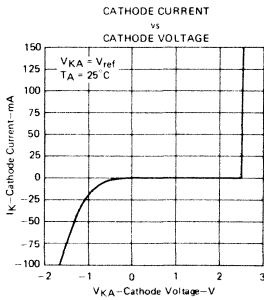


FIGURE 4

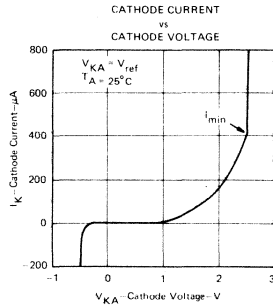


FIGURE 5

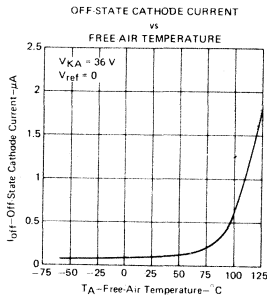


FIGURE 6

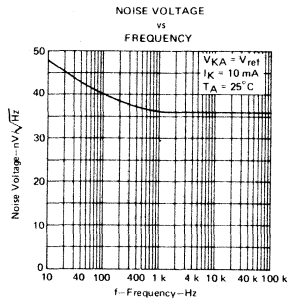


FIGURE 7





# TYPES TL431M, TL431I, TL431C ADJUSTABLE PRECISION SHUNT REGULATORS

## TYPICAL CHARACTERISTICS

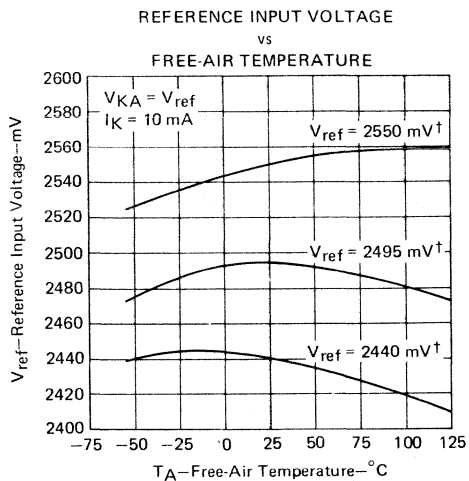


FIGURE 8

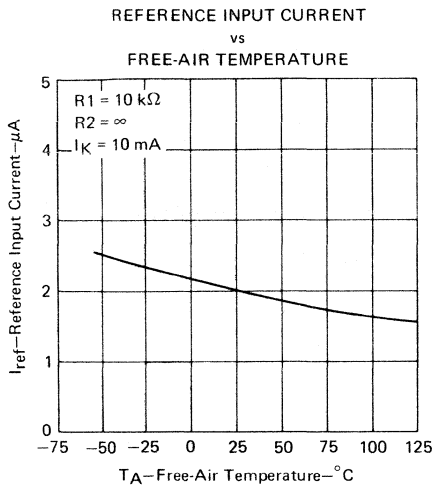


FIGURE 9

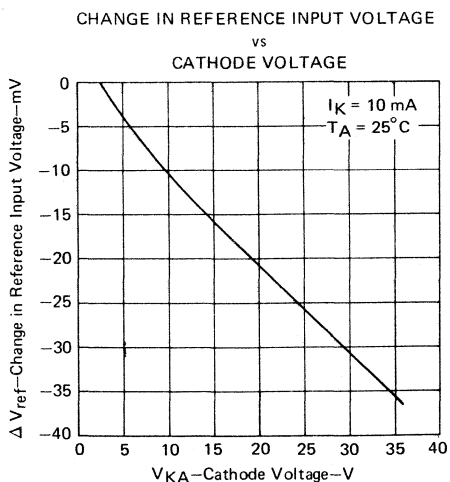


FIGURE 10

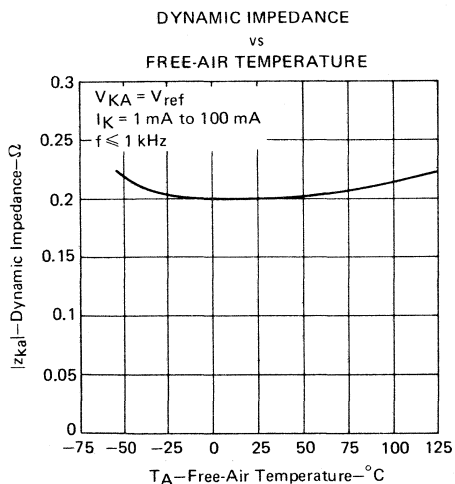


FIGURE 11

$^\dagger$ Data is for devices having the indicated value of  $V_{ref}$  at  $I_K = 10 \text{ mA}$ ,  $T_A = 25^\circ\text{C}$ .

# TYPES TL431M, TL431I, TL431C ADJUSTABLE PRECISION SHUNT REGULATORS

## TYPICAL CHARACTERISTICS

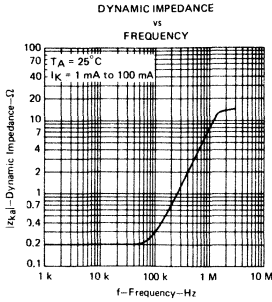
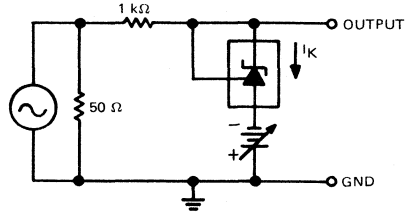


FIGURE 12



TEST CIRCUIT FOR DYNAMIC IMPEDANCE

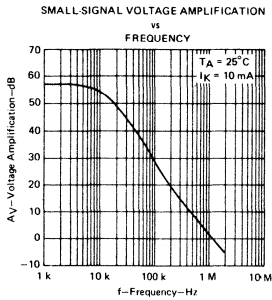
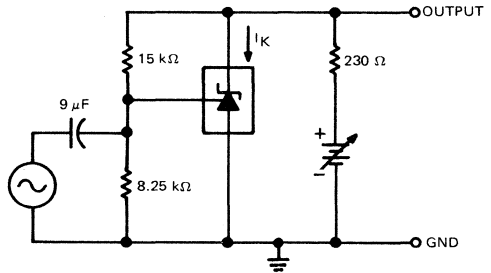


FIGURE 13



TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

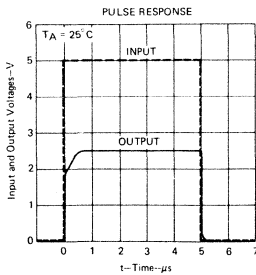
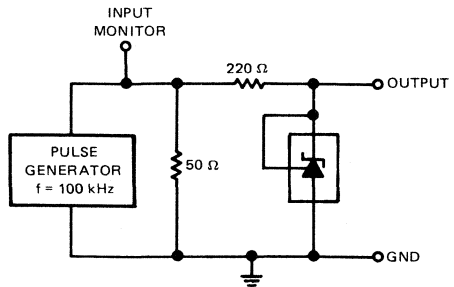


FIGURE 14

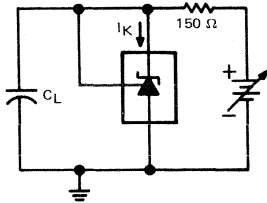


TEST CIRCUIT FOR PULSE RESPONSE

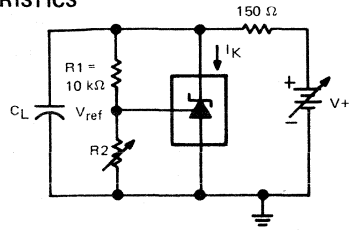


# TYPES TL431M, TL431I, TL431C ADJUSTABLE PRECISION SHUNT REGULATORS

## TYPICAL CHARACTERISTICS



TEST CIRCUIT FOR CURVE A BELOW



TEST CIRCUIT FOR CURVES B, C, AND D BELOW

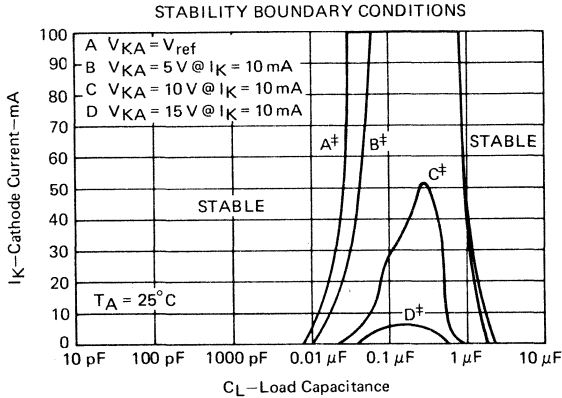


FIGURE 15

†The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ were adjusted to establish the initial V<sub>KA</sub> and I<sub>K</sub> conditions with C<sub>L</sub> = 0. V+ and C<sub>L</sub> were then adjusted to determine the ranges of stability.

## TYPICAL APPLICATIONS

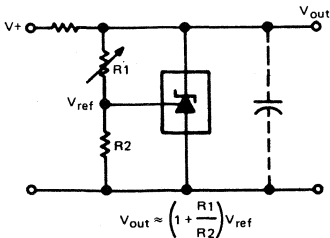


FIGURE 16—SHUNT REGULATOR

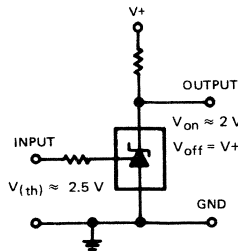


FIGURE 17—SINGLE-SUPPLY COMPARATOR WITH TEMPERATURE-COMPENSATED THRESHOLD

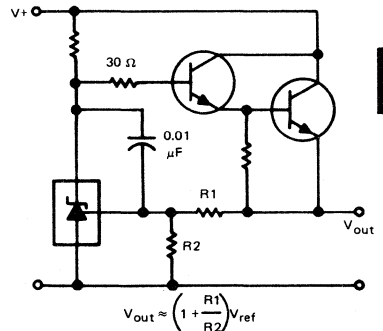


FIGURE 18—SERIES REGULATOR

# TYPES TL431M, TL431I, TL431C ADJUSTABLE PRECISION SHUNT REGULATORS

## TYPICAL APPLICATIONS

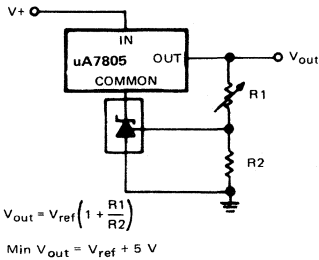


FIGURE 19—OUTPUT CONTROL OF A THREE-TERMINAL FIXED REGULATOR

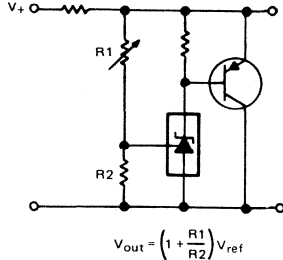


FIGURE 20—HIGHER-CURRENT SHUNT REGULATOR

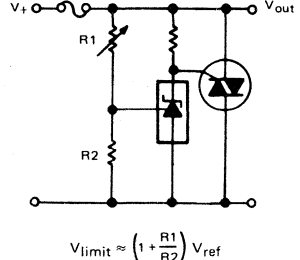


FIGURE 21—CROW BAR

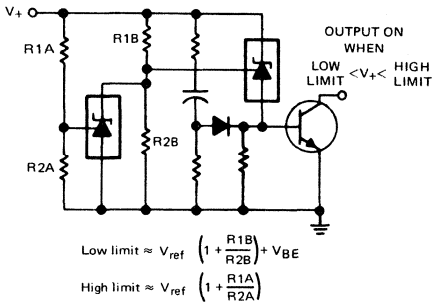


FIGURE 22—OVER-VOLTAGE/UNDER-VOLTAGE PROTECTION CIRCUIT

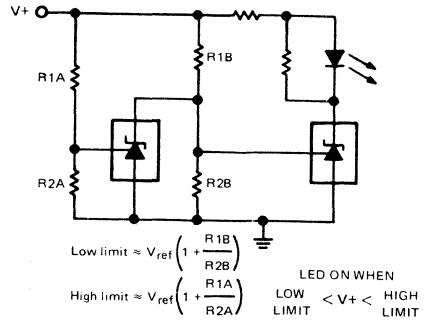


FIGURE 23—VOLTAGE MONITOR

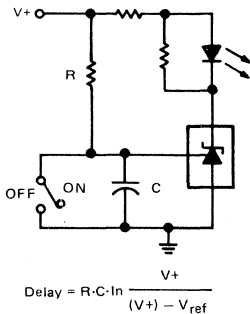


FIGURE 24—DELAY TIMER

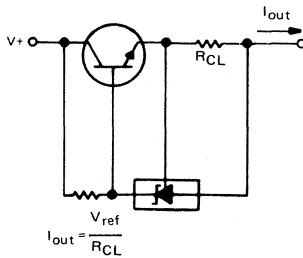


FIGURE 25—CURRENT LIMITER OR CURRENT SOURCE

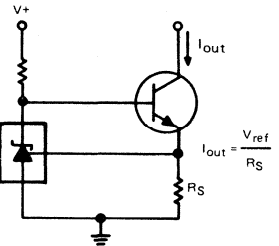


FIGURE 26—CONSTANT-CURRENT SINK

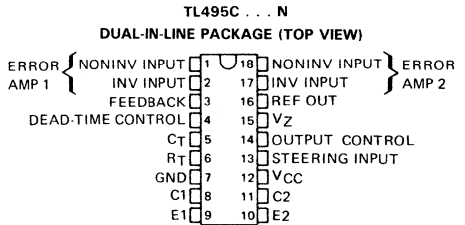
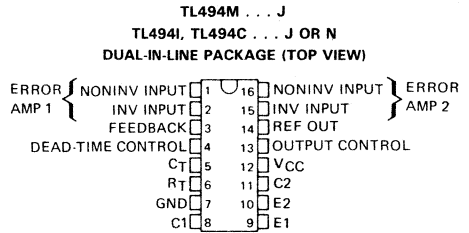
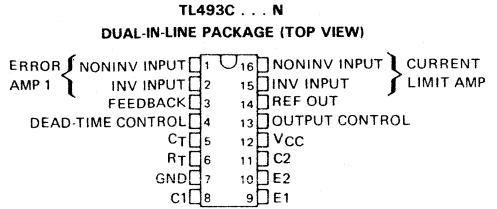
- Complete PWM Power Control Circuitry
- Uncommitted Outputs for 200-mA Sink or Source Current
- Output Control Selects Single-Ended or Push-Pull Operation
- Internal Circuitry Prohibits Double Pulse at Either Output
- Variable Dead-Time Provides Control Over Total Range
- Internal Regulator Provides a Stable 5-V Reference Supply Trimmed to 1%
- Circuit Architecture Allows Easy Synchronization
- TL493 Has Output Current-Limit Sensing
- TL495 Has On-Chip 39-V Zener and External Control of Output Steering

**description**

The TL493, TL494, and TL495 each incorporate on a single monolithic chip all the functions required in the construction of a pulse-width-modulation control circuit. Designed primarily for power supply control, these devices offer the systems engineer the flexibility to tailor the power supply control circuitry to his application.

The TL493 contains an error amplifier, current-limiting amplifier, an on-chip adjustable oscillator, a dead-time control comparator, pulse-steering control flip-flop, a 5-volt, 1%-precision regulator, and output-control circuits.

The error amplifier exhibits a common-mode voltage range from  $-0.3$  volts to  $V_{CC} - 2$  volts. The current-limit amplifier exhibits a common-mode voltage range from  $-0.3$  volts to 3 volts with an offset voltage of approximately 80 millivolts in series with the inverting input to ease circuit design requirements. The dead-time control comparator has a fixed offset that provides approximately 5% dead time when externally altered. The on-chip oscillator may be bypassed by terminating  $R_T$  (pin 6) to the reference output and providing a sawtooth input to  $C_T$  (pin 5), or it may be used to drive the common circuits in synchronous multiple-rail power supplies.



**DEVICE TYPES, SUFFIX VERSIONS, AND PACKAGES**

	TL493	TL494	TL495
TL49-M	*	J	*
TL49-I	*	J,N	*
TL49-C	N	J,N	N

\*These combinations are not defined by this data sheet.

**FUNCTION TABLE**

INPUTS		OUTPUT FUNCTION
OUTPUT CONTROL	STEERING INPUT (TL495 only)	
$V_I \leq 0.4$ V	Open	Single-ended or parallel output
$V_I \geq 2.4$ V	Open	Normal push-pull operation
$V_I \geq 2.4$ V	$V_I \leq 0.4$ V	PWM Output at Q1
$V_I \geq 2.4$ V	$V_I \geq 2.4$ V	PWM Output at Q2

# TYPES TL493, TL494, TL495 PULSE-WIDTH-MODULATION CONTROL CIRCUITS

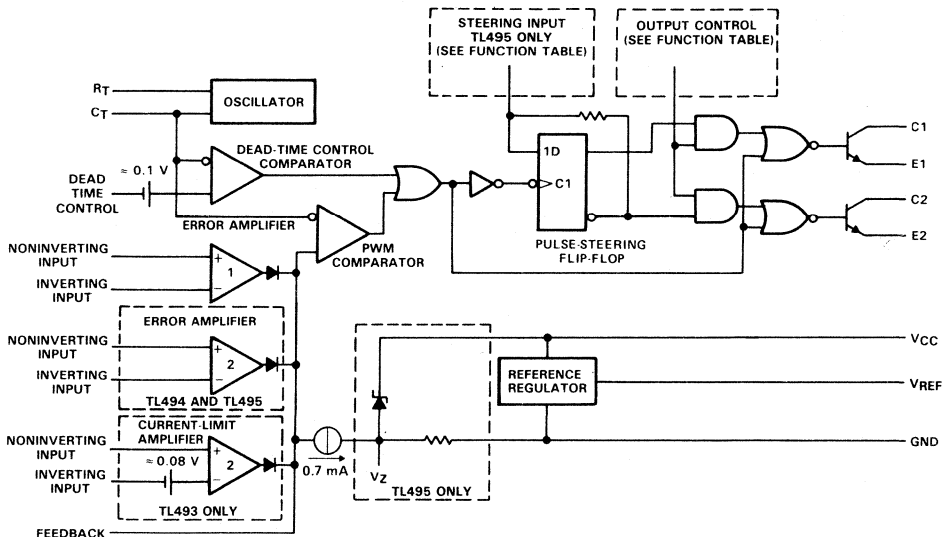
## description (continued)

The uncommitted output transistors provide either common-emitter or emitter-follower output capability. Each device provides for push-pull or single-ended output operation, which may be selected through the output-control function. The architecture of these devices prohibits the possibility of either output being pulsed twice during push-pull operation.

The TL493 and TL494 are similar except that an additional error amplifier is included in the TL494 instead of a current-limiting amplifier. The TL495 provides the identical functions found in the TL494. In addition, it contains an on-chip 39-volt zener diode for high-voltage applications where  $V_{CC}$  is greater than 40 volts, and an output-steering control that overrides the internal control of the pulse-steering flip-flop.

The TL494M is characterized for operation over the full military temperature range from  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The TL494I is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The TL493C, TL494C, and TL495C are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

## functional block diagram



Voltage Regulators



## TYPES TL493, TL494, TL495 PULSE-WIDTH-MODULATION CONTROL CIRCUITS

absolute maximum ratings over operating free-air temperature range  
(unless otherwise noted)

	TL494M	TL494I	TL493C TL494C TL495C	UNIT
Supply voltage, $V_{CC}$ (see Note 1)	41	41	41	V
Amplifier input voltages	$V_{CC} + 0.3$	$V_{CC} + 0.3$	$V_{CC} + 0.3$	V
Collector output voltage	41	41	41	V
Collector output current	250	250	250	mA
Continuous total dissipation at (or below) 25 °C free-air temperature (see Note 2)	1000	1000	1000	mW
Operating free-air temperature range	-55 to 125	-25 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N package		260	260	°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
2. For operation above 25 °C free-air temperature, refer to Dissipation Derating Table. In the J package, TL494M chips are alloy-mounted; TL494I and TL494C chips are glass mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	1000 mW	11.0 mW/°C	59 °C
J (Glass-Mounted Chip)	1000 mW	8.2 mW/°C	28 °C
N	1000 mW	9.2 mW/°C	41 °C

recommended operating conditions

	TL494M		TL494I		TL493C TL494C TL495C		UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	
Supply voltage, $V_{CC}$	7	40	7	40	7	40	V
Amplifier input voltages, $V_I$	-0.3	$V_{CC} - 2$	-0.3	$V_{CC} - 2$	-0.3	$V_{CC} - 2$	V
Collector output voltage, $V_O$		40		40		40	V
Collector output current (each transistor)		200		200		200	mA
Current into feedback terminal		0.3		0.3		0.3	mA
Timing capacitor, $C_T$	0.47	10 000	0.47	10 000	0.47	10 000	nF
Timing resistor, $R_T$	1.8	500	1.8	500	1.8	500	kΩ
Oscillator frequency	1	300	1	300	1	300	kHz
Operating free-air temperature, $T_A$	-55	125	-25	85	0	70	°C

# TYPES TL493, TL494, TL495

## PULSE-WIDTH-MODULATION CONTROL CIRCUITS

electrical characteristics over recommended operating free-air temperature range,  $V_{CC} = 15\text{ V}$ ,  $f = 10\text{ kHz}$  (unless otherwise noted)

### reference section

PARAMETER	TEST CONDITIONS†	TL494M			TL493C TL494I, TL494C TL495C			UNIT
		MIN	TYP‡	MAX	MIN	TYP‡	MAX	
Output voltage ( $V_{ref}$ )	$I_O = 1\text{ mA}$	4.75	5	5.25	4.75	5	5.25	V
Input regulation	$V_{CC} = 7\text{ V to }40\text{ V}$	2 25			2 25			mV
Output regulation	$I_O = 1\text{ to }10\text{ mA}$	1 15			1 15			mV
Output voltage change with temperature	$\Delta T_A = \text{MIN to MAX}$	0.2 1			0.2 1			%
Short-circuit output current‡	$V_{ref} = 0$	10	35	50	35			mA

### oscillator section (see Figure 1)

PARAMETER	TEST CONDITIONS†	TL494M			TL493C TL494I, TL494C TL495C			UNIT
		MIN	TYP‡	MAX	MIN	TYP‡	MAX	
Frequency	$C_T = 0.01\ \mu\text{F}$ , $R_T = 12\text{ k}\Omega$	10			10			kHz
Standard deviation of frequency¶	All values of $V_{CC}$ , $C_T$ , $R_T$ , $T_A$ constant	10			10			%
Frequency change with voltage	$V_{CC} = 7\text{ V to }40\text{ V}$ , $T_A = 25^\circ\text{C}$	0.1			0.1			%
Frequency change with temperature	$C_T = 0.01\ \mu\text{F}$ , $R_T = 12\text{ k}\Omega$ , $\Delta T_A = \text{MIN to MAX}$	12			12			%

### amplifier sections (see Figure 2)

PARAMETER		TEST CONDITIONS		MIN	TYP‡	MAX	UNIT
Input offset voltage	Error	$V_O(\text{pin } 3) = 2.5\text{ V}$		2 10			mV
	current-limit (TL493 only)			80			
Input offset current		$V_O(\text{pin } 3) = 2.5\text{ V}$		25	250		nA
Input bias current		$V_O(\text{pin } 3) = 2.5\text{ V}$		0.2	1		$\mu\text{A}$
Common-mode input voltage range	Error	$V_{CC} = 7\text{ V to }40\text{ V}$		-0.3 to $V_{CC} - 2$			V
	Current-limit (TL493 only)			-0.3 to 3			
Open-loop voltage amplification	Error	$\Delta V_O = 3\text{ V}$ , $V_O = 0.5\text{ V to }3.5\text{ V}$		70	95		dB
	Current-limit (TL493 only)			90			
Unity-gain bandwidth				800			kHz
Common-mode rejection ratio	Error	$V_{CC} = 40\text{ V}$ , $T_A = 25^\circ\text{C}$		65	80		dB
	Current-limit (TL493 only)			70			
Output sink current (pin 3)		$V_{ID} = -15\text{ mV to }-5\text{ V}$ , $V_{I(\text{pin } 3)} = 0.5\text{ V}$		0.3	0.7		mA
Output source current (pin 3)		$V_{ID} = 15\text{ mV to }5\text{ V}$ , $V_{I(\text{pin } 3)} = 3.5\text{ V}$		-2			mA

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ All typical values except for parameter changes with temperature are at  $T_A = 25^\circ\text{C}$ .

§ Duration of the short-circuit should not exceed one second.

¶ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula  $\sigma = \sqrt{\frac{\sum_{n=1}^N (x_n - \bar{x})^2}{N - 1}}$



# TYPES TL493, TL494, TL495 PULSE-WIDTH-MODULATION CONTROL CIRCUITS

electrical characteristics over recommended operating free-air temperature range,  $V_{CC} = 15\text{ V}$ ,  $f = 10\text{ kHz}$  (unless otherwise noted)

### output section

PARAMETER	TEST CONDITIONS	TL494M			TL493C TL494I, TL494C TL495C			UNIT
		MIN	TYP <sup>†</sup>	MAX	MIN	TYP <sup>†</sup>	MAX	
Collector off-state current	$V_{CE} = 40\text{ V}$ , $V_{CC} = 40\text{ V}$		2	100		2	100	$\mu\text{A}$
Emitter off-state current	$V_{CC} = V_C = 40\text{ V}$ , $V_E = 0$			-150			-100	$\mu\text{A}$
Collector-emitter saturation voltage	Common-emitter $V_E = 0$ , $I_C = 200\text{ mA}$		1.1	1.5		1.1	1.3	V
	Emitter-follower $V_C = 15\text{ V}$ , $I_E = -200\text{ mA}$		1.5	2.5		1.5	2.5	
Output control input current	$V_I = V_{ref}$			3.5			3.5	$\text{mA}$

### dead-time control-section (see Figure 1)

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
Input bias current (pin 4)	$V_I = 0$ to $5.25\text{ V}$		-2	-10	$\mu\text{A}$
Maximum duty cycle, each output	$V_I$ (pin 4) = 0		45		%
Input threshold voltage (pin 4)	Zero duty cycle		3	3.3	V
	Maximum duty cycle		0		

### pwm comparator section (see Figure 1)

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
Input threshold voltage (pin 3)	Zero duty cycle		4	4.5	V
Input sink current (pin 3)	$V$ (pin 3) = $0.7\text{ V}$	0.3	0.7		$\text{mA}$

### steering control (TL495 only)

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
Input current	$V_I = 0.4\text{ V}$		-200	$\mu\text{A}$
	$V_I = 2.4\text{ V}$		200	

### zener-diode circuit (TL495 only)

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
Breakdown voltage	$V_{CC} = 41\text{ V}$ , $I_Z = 2\text{ mA}$		39		V
Sink current	$V$ (pin 15) = $1\text{ V}$		0.3		$\text{mA}$

### total device (see Figure 1)

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT	
Standby supply current	Pin 6 at $V_{ref}$ , All other inputs and outputs open	$V_{CC} = 15\text{ V}$		6	10	$\text{mA}$
		$V_{CC} = 40\text{ V}$		9	15	
Average supply current	$V$ (pin 4) = $2\text{ V}$		7.5		$\text{mA}$	

### switching characteristics, $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
Output voltage rise time	Common-emitter configuration, See Figure 3		100	200	ns
Output voltage fall time			25	100	ns
Output voltage rise time	Emitter-follower configuration, See Figure 4		100	200	ns
Output voltage fall time			40	100	ns

<sup>†</sup>All typical values except for temperature coefficient are at  $T_A = 25^\circ\text{C}$ .



PARAMETER MEASUREMENT INFORMATION

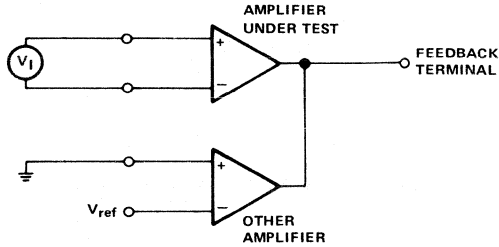


FIGURE 2 – AMPLIFIER CHARACTERISTICS

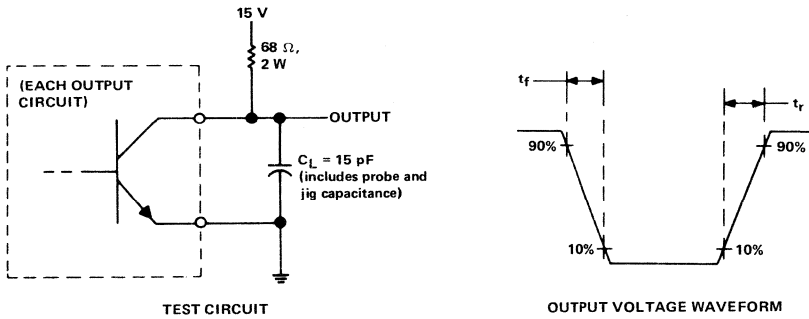


FIGURE 3 – COMMON-EMITTER CONFIGURATION

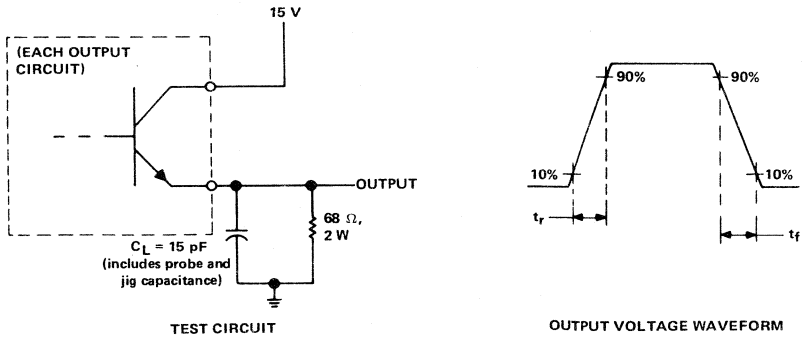


FIGURE 4 – EMITTER-FOLLOWER CONFIGURATION

**TYPES TL493, TL494, TL495**  
**PULSE-WIDTH-MODULATION CONTROL CIRCUITS**

**TYPICAL CHARACTERISTICS**

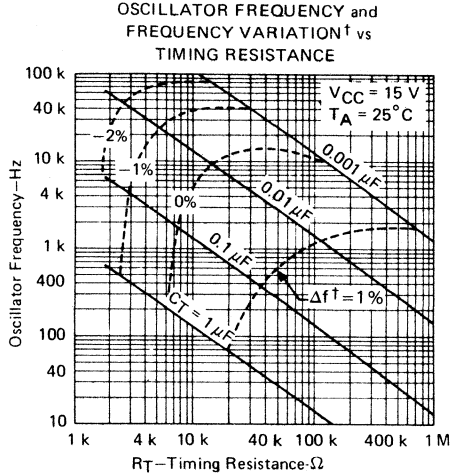


FIGURE 5

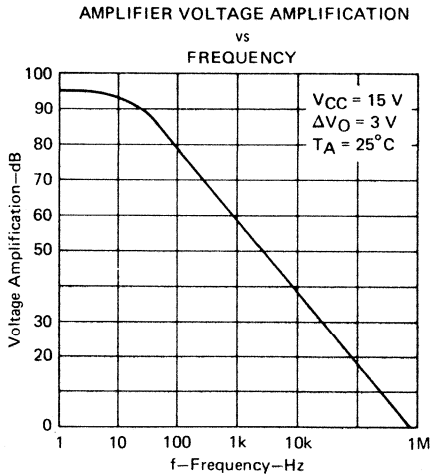


FIGURE 6

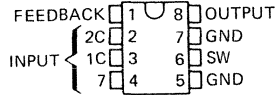
<sup>†</sup>Frequency variation ( $\Delta f$ ) is the change in oscillator frequency that occurs over the full temperature range.

Voltage Regulators



- Internal Step-Up Switching Regulator
- Fixed 9-Volt Output
- Charges Battery Source During Transformer-Coupled-Input Operation
- Minimum External Components Required (1 Inductor, 1 Capacitor, 1 Diode)
- 1- or 2-Cell-Input Operation

**P DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



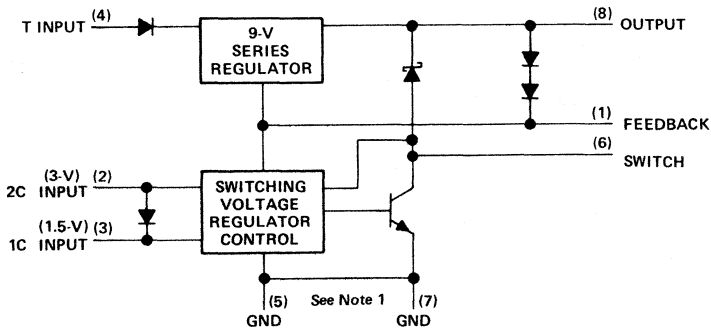
Pins 5 and 7 are connected together internally.

**description**

The TL496 power supply control circuit is designed to provide a 9-volt regulated supply from a variety of input sources. Operable from a 1- or 2-cell-battery input, the TL496 performs as a switching regulator with the addition of a single inductor and filter capacitor. When ac coupled with a step-down transformer, the TL496 operates as a series regulator to maintain the regulated output voltage and, with the addition of a single catch diode, time shares to recharge the input batteries.

The design of the TL496 allows minimal supply current drain during stand-by operation (125  $\mu$ A typical). With most battery sources this allows a constant bias to be maintained on the power supply. This makes power instantly available to the system thus eliminating power-up sequencing problems.

**functional block diagram**



NOTE 1: Pins 5 and 7, though connected together internally, must both be terminated to ground to ensure proper circuit operation.

# TYPE TL496C

## 9-VOLT POWER-SUPPLY CONTROLLER

### absolute maximum ratings

Input voltage:	
Pin 2	3.5 V
Pin 3	2.5 V
Pin 4	20 V
Output voltage (Pin 6)	12 V
Diode reverse voltage (Pin 8)	12 V
Switch current (Pin 6)	1.2 A
Diode current (Pin 8)	1.2 A
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

### electrical characteristics at 25°C free-air temperature

#### series regulator section (input is pin 4)

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Dropout voltage	$V_I = 5 \text{ V}$ ,	$I_O = -50 \text{ mA}$	1.5	2		V
Regulated output voltage	$V_I = 20 \text{ V}$	$I_O = -50 \mu\text{A}$	9.5	10.1	11.2	V
		$I_O = -80 \text{ mA}$	9.0	10.0	11.0	
	$V_I = 20 \text{ V}$ , Pin 1 shorted to pin 8	$I_O = -50 \mu\text{A}$	8.5	9.0	9.7	
		$I_O = -80 \text{ mA}$	6.7	8.6	9.5	
Standby current (pin 4)	$V_I = 20 \text{ V}$ ,	Pin 8 at 12 V			400	$\mu\text{A}$
Reverse current thru pin 4	$V_I = -1.5 \text{ V}$ ,	1 mA into Pin 8			-25	$\mu\text{A}$

#### output switch

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{CE(sat)}$ Collector-emitter saturation voltage	800 mA into Pin 6,	Pin 2 at 2.25 V	0.35	0.6		V

#### diode (pin 6 to pin 8)

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_F$ Forward voltage	$I_F = 1.5 \text{ A}$		1.6	2.5		V
$I_R$ Reverse current thru pin 6	Pin 6 at 0 V,	1 mA into Pin 8			-20	$\mu\text{A}$

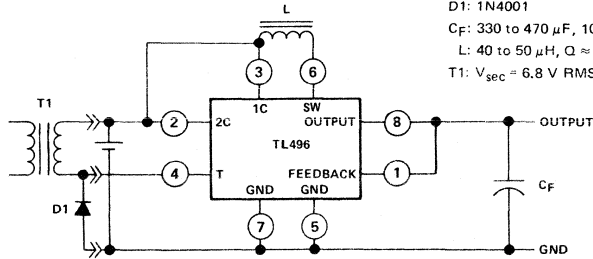
#### control section

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
On-state current (pin 2)	Pins 1 and 8 at 0 V,	Pin 2 at 3 V	60	100		mA
Standby current (pin 1)	Pin 1 at 8.65 V,	Pins 2 and 6 at 3 V		40		$\mu\text{A}$
Standby current (pin 2 and 6)	Pin 1 at 8.65 V,	Pins 2 and 6 at 3 V		400		$\mu\text{A}$
Start-up current (current into pin 6 to initiate cycle)	Pins 1, 2, 6 and 8 at 2.25 V		16			mA



# TYPE TL496C 9-VOLT POWER-SUPPLY CONTROLLER

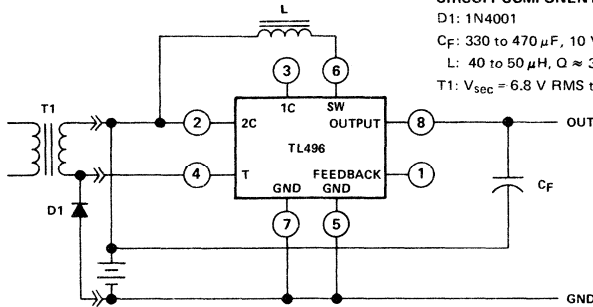
## TYPICAL APPLICATION DATA



### CIRCUIT COMPONENT INFORMATION

D1: 1N4001  
 $C_F$ : 330 to 470  $\mu$ F, 10 V, electrolytic  
 L: 40 to 50  $\mu$ H,  $Q \approx 3$ ,  $R < 0.15 \Omega$   
 T1:  $V_{sec} = 6.8$  V RMS typ.,  $R_{sec} = 11 \Omega$  typ.

FIGURE 1—ONE-CELL OPERATION



### CIRCUIT COMPONENT INFORMATION

D1: 1N4001  
 $C_F$ : 330 to 470  $\mu$ F, 10 V electrolytic  
 L: 40 to 50  $\mu$ H,  $Q \approx 3$ ,  $R < 0.15 \Omega$   
 T1:  $V_{sec} = 6.8$  V RMS typ.,  $R_{sec} = 11 \Omega$  typ.

FIGURE 2—TWO-CELL OPERATION

### recommended operating conditions

	MIN	MAX	UNIT
Input voltage, one-cell operation (pins 2 and 3 to ground)	1.1	1.5	V
Input voltage, two-cell operation (pin 2 to ground)	2.3	3	V
Input voltage, one-cell or two-cell operation (pin 4 to ground)	$V_O + 2$	20	V

### typical electrical characteristics for circuits above

PARAMETER		ONE-CELL OPERATION (FIGURE 1)	TWO-CELL OPERATION (FIGURE 2)
Input current	No load	125 $\mu$ A	125 $\mu$ A
	$R_L = 120 \Omega$	525 mA	405 mA
	Without T1	7.2 V	8.6 V
Output voltage	With T1	8.6 V	10 V
	Output current capability	40 mA	80 mA
Efficiency		66%	66%
Battery life (AA NiCad) no load		60 days	166 days

## TYPE TL496C 9-VOLT POWER-SUPPLY CONTROLLER

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### functional description

The TL496 is designed to operate from either a single-cell or two-cell source. To operate the device from a single cell (1.1 V to 1.5 V) the source must be connected to both inputs 1C and 2C as shown in Figure 1. For two-cell operation (2.3 V to 3.0 V), the input is applied to the 2C input only and the 1C input is left open (see Figure 2).

### battery operation

The TL496 operates as a switching regulator from a battery input. The cycle is initiated when a low voltage condition is sensed by the internal feedback (the thresholds at pin 1 and pin 8 are approximately 7.2 and 8.6 volts respectively). An internal latch is set and the output transistor is turned "on." This causes the current in the external inductor (L) to increase linearly until it reaches a peak value of approximately 1 ampere. When the peak current is sensed the internal latch is reset and the output transistor is turned "off." The energy developed in the inductor is then delivered to the output storage capacitor through the blocking diode. The latch remains in the off state until the feedback signal indicates the output voltage is again deficient.

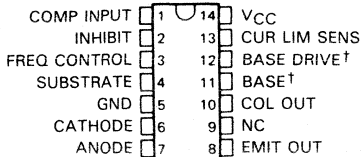
### transformer-coupled operation

The TL496 operates on alternate half cycles of the ac input during transformer-coupled operation to, first, sustain the output voltage and, second, recharge the batteries. The TL496 performs like a series regulator to supply charge to the output filter/storage capacitor during the first half cycle. The output voltage of the series regulator is slightly higher voltage than that created by the switching circuit; this maintains the feedback voltage above the switching regulator control circuit threshold. This effectively inhibits the switching control circuitry. During the second half cycle an external diode (1N4001) is used to clamp the negative going end of the transformer secondary to ground thus allowing the positive-going end (end connected to V+ side of battery) to pump charge into the stand-by batteries.



- All Monolithic
- High Efficiency . . . 60% or Greater
- Output Current . . . 500 mA
- Input Current Limit Protection
- TTL Compatible Inhibit
- Adjustable Output Voltage
- Input Regulation . . . 0.2% Typ
- Output Regulation . . . 0.4% Typ
- Soft Start-up Capability

TL497AM . . . J  
TL497AI, TL497AC . . . J OR N  
DUAL-IN-LINE PACKAGE  
(TOP VIEW)



NC—No internal connection

† The Base pin (# 11) and Base Drive pin (# 12) are used for device testing only. They are not normally used in circuit applications of the device.

**description**

The TLC497A incorporates on a single monolithic chip all the active functions required in the construction of a switching voltage regulator. It can also be used as the control element to drive external components for high-power-output applications. The TL497A was designed for ease of use in step-up, step-down, or voltage inversion applications requiring high efficiency.

The TL497A is a fixed-on-time variable-frequency switching voltage regulator control circuit. The on-time is programmed by a single external capacitor connected between the frequency control pin and ground. This capacitor,  $C_T$ , is charged by an internal constant-current generator to a predetermined threshold. The charging current and the threshold vary proportionally with  $V_{CC}$ , thus the on-time remains constant over the specified range of input voltage (5 to 12 volts). Typical on-times for various values of  $C_T$  are as follows:

TIMING CAPACITOR, $C_T$ (pF)	200	250	350	400	500	750	1000	1500	2000
ON-TIME ( $\mu$ s)	19	22	26	32	44	56	80	120	180

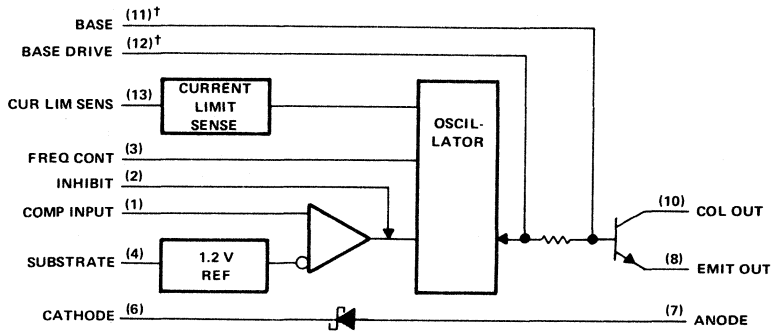
The output voltage is controlled by an external resistor ladder network ( $R_1$  and  $R_2$  in Figures 1, 2, and 3) that provides a feedback voltage to the comparator input. This feedback voltage is compared to the reference voltage of 1.2 volts (relative to the substrate pin) by the high-gain comparator. When the output voltage decays below the value required to maintain 1.2 V at the comparator input, the comparator enables the oscillator circuit, which charges and discharges  $C_T$  as described above. The internal pass transistor is driven on during the charging of  $C_T$ . The internal transistor may be used directly for switching currents up to 500 milliamperes. Its collector and emitter are uncommitted and it is current driven to allow operation from the positive supply voltage or ground. An internal Schottky diode matched to the current characteristics of the internal transistor is also available for blocking or commutating purposes. The TL497A also has on-chip current-limit circuitry that senses the peak currents in the switching regulator and protects the inductor against saturation and the pass transistor against overstress. The current limit is adjustable and is programmed by a single sense resistor,  $R_{CL}$ , connected between pin 14 and pin 13. The current-limit circuitry is activated when 0.7 volt is developed across  $R_{CL}$ . External gating is provided by the inhibit input. When the inhibit input is high, the output is turned off.

Simplicity of design is a primary feature of the TL497A. With only six external components (three resistors, two capacitors, and one inductor), the TL497A will operate in numerous voltage conversion applications (step-up, step-down, invert) with as much as 85% of the source power delivered to the load. The TL497A replaces the TL497 in all applications.

The TL497AM is characterized for operation over the full military temperature range of  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ , the TL497AI is characterized for operation from  $-25^\circ\text{C}$  to  $85^\circ\text{C}$ , and the TL497AC from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

# TYPES TL497AM, TL497AI, TL497AC SWITCHING VOLTAGE REGULATORS

## functional block diagram



† The Base pin (#11 and Base Drive pin (#12) are used for device testing only. They are not normally used in circuit applications of the device.

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Input voltage, $V_{CC}$ (see Note 1)	15 V
Output voltage	35 V
Comparator input voltage	5 V
Inhibit input voltage	5 V
Diode reverse voltage	35 V
Power switch current	750 mA
Diode forward current	750 mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	1000 mW
Operating free-air temperature range: TL497AM	-55°C to 125°C
TL497AI	-25°C to 85°C
TL497AC	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N package	260°C

NOTES: 1. All voltage values except diode voltages are with respect to network ground terminal.  
2. Above 28°C free-air temperature, derate the N package at the rate of 9.2 mW/°C. Above 41°C free-air temperature, derate the J glass-mounted package at the rate of 8.2 mW/°C. Above 59°C free-air temperature, derate the J alloy-mounted package at the rate of 11.0 mW/°C. In the J package, TL4974AM chips are alloy mounted, TL4974AC chips are glass mounted.

## recommended operating conditions

	MIN	MAX	UNIT
Input voltage, $V_I$	4.5	12	V
Output voltage: step-up configuration (see Figure 1)	$V_I + 2$	30	V
step-down configuration (see Figure 2)	$V_{ref}$	$V_I - 1$	V
inverting regulator (see Figure 3)	$-V_{ref}$	-25	V
Power switch current		500	mA
Diode forward current		500	mA

# TYPES TL497AM, TL497AI, TL497AC SWITCHING VOLTAGE REGULATORS

electrical characteristics at specified free-air temperature,  $V_I = 6\text{ V}$  (unless otherwise noted)

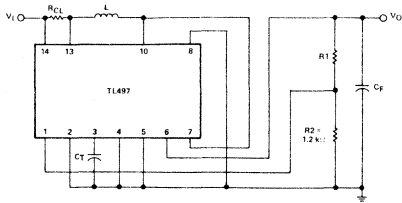
PARAMETER	TEST CONDITIONS†		TL497AM, TL497AI			TL497AC			UNIT	
			MIN	TYP‡	MAX	MIN	TYP‡	MAX		
High-level inhibit input voltage		25°C	2.5			2.5			V	
Low-level inhibit input voltage		25°C			0.8			0.8	V	
High-level inhibit input current	$V_{I(I)} = 5\text{ V}$	Full range		0.8	1.5		0.8	1.5	mA	
Low-level inhibit input current	$V_{I(I)} = 0\text{ V}$	Full range		5	20		5	10	μA	
Comparator reference voltage	$V_I = 4.5\text{ V}$ to $6\text{ V}$	Full range	1.14	1.20	1.26	1.08	1.20	1.32	V	
Comparator input bias current	$V_I = 6\text{ V}$	Full range		40	100		40	100	μA	
Switch on-state voltage	$V_I = 4.5\text{ V}$	$I_O = 100\text{ mA}$	25°C		0.13	0.2		0.13	0.2	V
		$I_O = 500\text{ mA}$	Full range			1			0.85	V
Switch off-state current	$V_I = 4.5\text{ V}$ , $V_O = 30\text{ V}$	25°C		10	50		10	50	μA	
		Full range			500			200	μA	
Current-limit sense voltage	$V_I = 6\text{ V}$	25°C	0.45		1	0.45		1	V	
Diode forward voltage	$I_O = 10\text{ mA}$	Full range		0.75	0.95		0.75	0.85	V	
	$I_O = 100\text{ mA}$	Full range		0.9	1.1		0.9	1	V	
	$I_O = 500\text{ mA}$	Full range		1.33	1.75		1.33	1.55	V	
Diode reverse voltage	$I_O = 500\text{ μA}$	Full range	30						V	
	$I_O = 200\text{ μA}$	Full range				30			V	
On-state supply current		25°C		11	14		11	14	mA	
		Full range			16			15	mA	
Off-state supply current		25°C		6	9		6	9	mA	
		Full range			11			10	mA	

† Full range for TL497AM is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ , for TL497AI is  $-25^\circ\text{C}$  to  $85^\circ\text{C}$ , and for TL497AC is  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

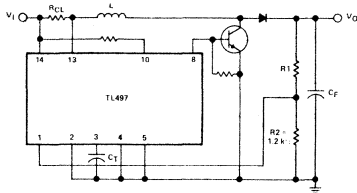
‡ All typical values are at  $T_A = 25^\circ\text{C}$ .

# TYPES TL497AM, TL497AI, TL497AC, SWITCHING VOLTAGE REGULATORS

## TYPICAL APPLICATION DATA



**BASIC CONFIGURATION**  
( $I_{PK} < 500 \text{ mA}$ )

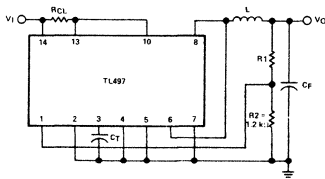


**EXTENDED POWER CONFIGURATION**  
(USING EXTERNAL TRANSISTOR)

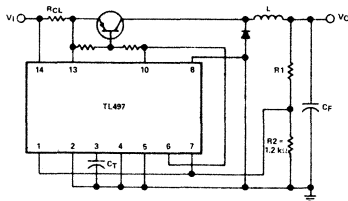
### DESIGN EQUATIONS

- $I_{PK} = 2 I_O \max \left[ \frac{V_O}{V_I} \right]$
  - $L (\mu\text{H}) = \frac{V_I}{I_{PK}} t_{on} (\mu\text{s})$
- Choose L (50 to 500  $\mu\text{H}$ ), calculate  $t_{on}$  (25 to 150  $\mu\text{s}$ )
- $C_T (\text{pF}) \approx 12 t_{on} (\mu\text{s})$
  - $R_1 = (V_O - 1.2) \text{ k}\Omega$
  - $R_{CL} = \frac{0.5 \text{ V}}{I_{PK}}$
  - $C_F (\mu\text{F}) \approx t_{on} (\mu\text{s}) \left[ \frac{V_I}{V_O} I_{PK} + I_O \right]$   
Vripple (PK)

FIGURE 1—POSITIVE REGULATOR, STEP-UP CONFIGURATIONS



**BASIC CONFIGURATION**  
( $I_{PK} < 500 \text{ mA}$ )



**EXTENDED POWER CONFIGURATION**  
(USING EXTERNAL TRANSISTOR)

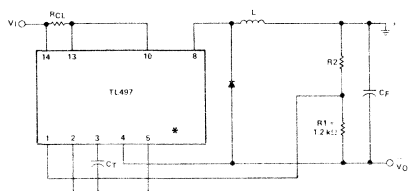
### DESIGN EQUATIONS

- $I_{PK} = 2 I_O \max$
  - $L (\mu\text{H}) = \frac{V_I - V_O}{I_{PK}} t_{on} (\mu\text{s})$
- Choose L (50 to 500  $\mu\text{H}$ ), calculate  $t_{on}$  (10 to 150  $\mu\text{s}$ )
- $C_T (\text{pF}) \approx 12 t_{on} (\mu\text{s})$
  - $R_1 = (V_O - 1.2) \text{ k}\Omega$
  - $R_{CL} = \frac{0.5 \text{ V}}{I_{PK}}$
  - $C_F (\mu\text{F}) \approx t_{on} (\mu\text{s}) \left[ \frac{V_I}{V_O} I_{PK} + I_O \right]$   
Vripple (PK)

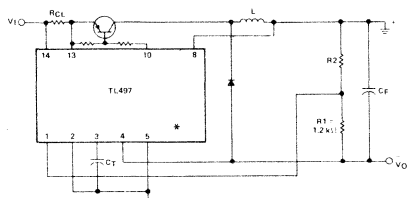
FIGURE 2—POSITIVE REGULATOR, STEP-DOWN CONFIGURATIONS

# TYPES TL497AM, TL497AI, TL497AC SWITCHING VOLTAGE REGULATORS

## TYPICAL APPLICATION DATA



**BASIC CONFIGURATION**  
( $I_{PK} < 500 \text{ mA}$ )



**EXTENDED POWER CONFIGURATION**  
(USING EXTERNAL TRANSISTOR)

$$I_{PK} = 2 I_O \max \left[ 1 + \frac{|V_O|}{V_I} \right]$$

$$L (\mu\text{H}) = \frac{V_I}{I_{PK}} t_{on} (\mu\text{s})$$

Choose L (50 to 500  $\mu\text{H}$ ), calculate  $t_{on}$  (25 to 150  $\mu\text{s}$ )

$$C_T (\text{pF}) \approx 12 t_{on} (\mu\text{s})$$

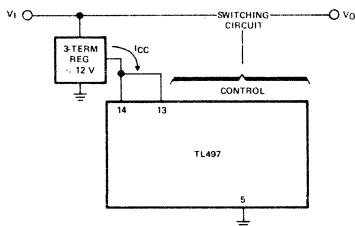
$$R_2 = (V_O - 1.2) \text{ k}\Omega$$

$$R_{CL} = \frac{0.5 \text{ V}}{I_{PK}}$$

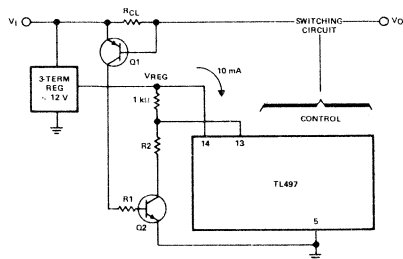
$$C_F (\mu\text{F}) \approx t_{on} (\mu\text{s}) \frac{\left[ \frac{V_I}{V_O} I_{PK} + I_O \right]}{\text{Vripple (PK)}}$$

\*Use external catch-diode, e.g., 1N4001, when building an inverting supply with the TL497A.

**FIGURE 3—INVERTING APPLICATIONS**



**EXTENDED INPUT CONFIGURATION WITHOUT CURRENT LIMIT**



**CURRENT LIMIT FOR EXTENDED INPUT CONFIGURATION**

**FIGURE 4—EXTENDED INPUT VOLTAGE RANGE ( $V_I > 15 \text{ V}$ )**

### DESIGN EQUATIONS

$$R_{CL} = \frac{V_{BE}(Q1)}{I_{limit} (\text{PK})}$$

$$R_1 = \frac{V_I}{I_B(Q2)}$$

$$R_2 = (V_{reg} - 1) 10 \text{ k}\Omega$$



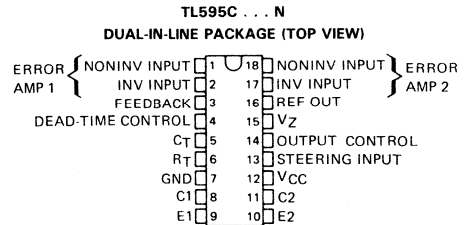
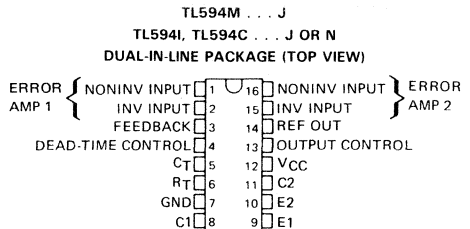
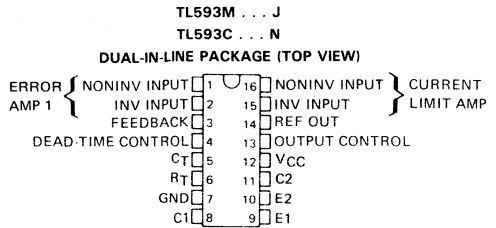
- Complete PWM Power Control Circuitry
- Uncommitted Outputs for 200-mA Sink or Source Current
- Output Control Selects Single-Ended or Push-Pull Operation
- Internal Circuitry Prohibits Double Pulse at Either Output
- Variable Dead-Time Provides Control Over Total Range
- Internal Regulator Provides a Stable 5-V Reference Supply Trimmed to 1%
- Circuit Architecture Allows Easy Synchronization
- Under-Voltage Lockout for Low  $V_{CC}$  Conditions
- TL593 has Output Current-Limit Sensing
- TL595 has On-Chip 39-V Zener and External Control of Output Steering
- Improved Direct Replacements for TL493, TL494, and TL495

**description**

The TL593, TL594, and TL595 devices, each incorporate on a single monolithic chip all the functions required in the construction of a pulse-width-modulation control circuit. Designed primarily for power supply control, these devices offer the systems engineer the flexibility to tailor the power supply control circuitry to his application. The TL593, TL594, and TL595 are improved direct replacements for the TL493, TL494, and TL495.

The TL593 contains an error amplifier, current-limiting amplifier, an on-chip adjustable oscillator, a dead-time control comparator, pulse-steering control flip-flop, 5-volt regulator with a precision of 1%, an under-voltage lockout control circuit, and output control circuitry.

The error amplifier exhibits a common-mode voltage range from  $-0.3$  volts to  $V_{CC} - 2$  volts. The current-limit amplifier exhibits a common-mode voltage range from  $-0.3$  volts to  $V_{CC} - 6$  volts with an offset voltage of approximately 80 millivolts in series with the inverting input to ease circuit design requirements. The dead-time control comparator has a fixed offset that provides approximately 5% dead time when externally altered. The on-chip oscillator may be bypassed by terminating  $R_T$  (pin 6) to the reference output and providing a sawtooth input to  $C_T$  (pin 5), or it may be used to drive the common circuitry in synchronous multiple-rail power supplies.



**DEVICE TYPES, SUFFIX VERSIONS, AND PACKAGES**

	TL593	TL594	TL595
TL59-M	J	J	*
TL59-I	*	J,N	*
TL59-C	N	J,N	N

\*These combinations are not defined by this data sheet.

**FUNCTION TABLE**

INPUTS		OUTPUT FUNCTION
OUTPUT CONTROL	STEERING INPUT (TL595 only)	
$V_I < 0.4$ V	Open	Single ended or parallel output
$V_I > 2.4$ V	Open	Normal push-pull operation
$V_I > 2.4$ V	$V_I < 0.4$ V	PWM Output at Q1
$V_I > 2.4$ V	$V_I > 2.4$ V	PWM Output at Q2

# TYPES TL593, TL594, TL595

## PULSE-WIDTH-MODULATION CONTROL CIRCUITS

### description (continued)

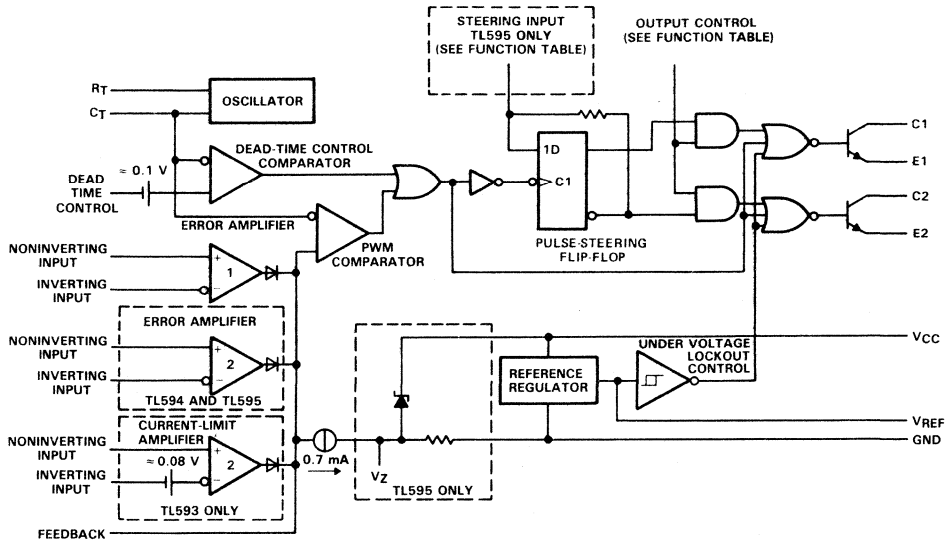
The uncommitted output transistors provide either common-emitter or emitter-follower output capability. Each device provides for push-pull or single-ended output operation with selection by means of the output-control function. The architecture of these devices prohibits the possibility of either output being pulsed twice during push-pull operation. The under-voltage lockout control circuit locks the outputs off until the internal circuitry is operational.

The TL593 and TL594 are similar except that an additional error amplifier is included in the TL594 instead of a current-limiting amplifier. The TL595 provides the identical functions found in the TL594. In addition, the TL595 also contains an on-chip 39-volt zener diode for high-voltage applications where  $V_{CC}$  is greater than 40 volts, and an output steering control that overrides the internal control of the pulse-steering flip-flop.

The TL593M and TL594M are characterized for operation over the full military temperature range from  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The TL594I is characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The TL593C, TL594C, and TL595C are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

### functional block diagram

Voltage Regulators





# TYPES TL593, TL594, TL595 PULSE-WIDTH-MODULATION CONTROL CIRCUITS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TL593M TL594M	TL594I	TL593C TL594C TL595C	UNIT
Supply voltage, $V_{CC}$ (see Note 1)	41	41	41	V
Amplifier input voltages	$V_{CC} + 0.3$	$V_{CC} + 0.3$	$V_{CC} + 0.3$	V
Collector output voltage	41	41	41	V
Collector output current	250	250	250	mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	1000	1000	1000	mW
Operating free-air temperature range	-55 to 125	-25 to 85	0 to 70	°C
Storage temperature range	-65 to 150	-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N package		260	260	°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.

2. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J package, the TL593M and TL594M chips are alloy mounted; TL594I and TL594C chips are glass mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	1000 mW	11.0 mW/°C	59°C
J (Glass-Mounted Chip)	1000 mW	8.2 mW/°C	28°C
N	1000 mW	9.2 mW	41°C

recommended operating conditions

	TL593M TL594M		TL594I		TL593C TL594C TL595C		UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	
Supply voltage, $V_{CC}$	7	40	7	40	7	40	V
Amplifier input voltages, $V_I$	-0.3	$V_{CC} - 2$	-0.3	$V_{CC} - 2$	-0.3	$V_{CC} - 2$	V
Collector output voltage, $V_O$		40		40		40	V
Collector output current (each transistor)		200		200		200	mA
Current into feedback terminal		0.3		0.3		0.3	mA
Timing capacitor, $C_T$	0.47	10 000	0.47	10 000	0.47	10 000	nF
Timing resistor, $R_T$	1.8	500	1.8	500	1.8	500	kΩ
Oscillator frequency	1	300	1	300	1	300	kHz
Operating free-air temperature, $T_A$	-55	125	-25	85	0	70	°C

Voltage Regulators



# TYPES TL593, TL594, TL595

## PULSE-WIDTH-MODULATION CONTROL CIRCUITS

electrical characteristics over recommended operating free-air temperature range,  $V_{CC} = 15\text{ V}$ ,  $f = 10\text{ kHz}$  (unless otherwise noted)

### reference section

PARAMETER	TEST CONDITIONS <sup>†</sup>	TL593M TL594M			TL593C TL594I, TL594C TL595C			UNIT
		MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	
Output voltage ( $V_{ref}$ )	$I_O = 1\text{ mA}$ , $T_A = 25^\circ\text{C}$	4.95	5	5.05	4.95	5	5.05	V
Input regulation	$V_{CC} = 7\text{ V to }40\text{ V}$ , $T_A = 25^\circ\text{C}$		2	25		2	25	mV
Output regulation	$I_O = 1\text{ to }10\text{ mA}$ , $T_A = 25^\circ\text{C}$		14	35		14	35	mV
Output voltage change with temperature	$\Delta T_A = \text{MIN to MAX}$		0.2	1		0.2	1	%
Short-circuit output current <sup>§</sup>	$V_{ref} = 0$	10	35	60	10	35	50	mA

### oscillator section (see Figure 2)

PARAMETER	TEST CONDITIONS <sup>†</sup>	TL593M TL594M			TL593C TL594I, TL594C TL595C			UNIT
		MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	
Frequency			10			10		kHz
Standard deviation of frequency <sup>¶</sup>	All values of $V_{CC}$ , $C_T$ , $R_T$ , $T_A$ constant		10			10		%
Frequency change with voltage	$V_{CC} = 7\text{ V to }40\text{ V}$ , $T_A = 25^\circ\text{C}$		0.1			0.1		%
Frequency change with temperature	$\Delta T_A = \text{MIN to MAX}$			12			12	%

### amplifier sections (see Figure 1)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>‡</sup>	MAX	UNIT
Input offset voltage	Error		Feedback pin at 2.5 V		2	
	current-limit (TL593 only)			80		
Input offset current		Feedback control at 2.5 V		25	250	nA
Input bias current		Feedback control at 2.5 V		0.2	1	$\mu\text{A}$
Common-mode input voltage range	Error	$V_{CC} = 7\text{ V to }40\text{ V}$		-0.3 to $V_{CC} - 2$		V
	Current-limit (TL593 only)			-0.3 to $V_{CC} - 6$		
Open-loop voltage amplification	Error	$\Delta V_O = 3\text{ V}$ , $V_O = 0.5\text{ V to }3.5\text{ V}$		70	95	dB
	Current-limit (TL593 only)				90	
Unity-gain bandwidth				800		kHz
Common-mode rejection ratio	Error	$V_{CC} = 40\text{ V}$ , $T_A = 25^\circ\text{C}$		65	80	dB
	Current-limit (TL593 only)				70	
Output sink current (pin 3)		$V_{ID} = -15\text{ mV to }-5\text{ V}$ , Feedback control at 0.5 V	0.3	0.7		mA
Output source current (pin 3)		$V_{ID} = 15\text{ mV to }5\text{ V}$ , Feedback at 3.5 V	-2			mA

<sup>†</sup>For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

<sup>‡</sup>All typical values except for parameter changes with temperature are at  $T_A = 25^\circ\text{C}$ .

<sup>§</sup>Duration of the short-circuit should not exceed one second.

<sup>¶</sup>Standard deviation is a measure of the statistical distribution about the mean as derived from the formula

$$\sigma = \sqrt{\frac{\sum_{n=1}^N (x_n - \bar{X})^2}{N - 1}}$$

# TYPES TL593, TL594, TL595 PULSE-WIDTH-MODULATION CONTROL CIRCUITS

electrical characteristics over recommended operating free-air temperature range,  $V_{CC} = 15\text{ V}$ ,  $f = 10\text{ kHz}$  (unless otherwise noted)

dead-time control section (see Figure 2)

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>‡</sup>	MAX	UNIT
Input bias current (pin 4)	$V_I = 0$ to $5.25\text{ V}$		-2	-10	$\mu\text{A}$
Maximum duty cycle, each output	Dead-time control at $0\text{ V}$	45			%
Input threshold voltage (pin 4)	Zero duty cycle		3	3.3	V
	Maximum duty cycle	0			

output section

PARAMETER	TEST CONDITIONS	TL593M TL594M			TL593C TL594I, TL594C TL595C			UNIT
		MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	
Collector off-state current	$V_{CE} = 40\text{ V}$ , $V_{CC} = 40\text{ V}$	2		100	2		100	$\mu\text{A}$
	$V_C = 15\text{ V}$ , $V_E = 0\text{ V}$ , $V_{CC} = 1$ to $3\text{ V}$ , Dead-time and output control pins at $0\text{ V}$	4		200	4		200	
	Emitter off-state current	$V_{CC} = V_C = 40\text{ V}$ , $V_E = 0$			-150			
Collector-emitter saturation voltage	Common-emitter $V_E = 0$ , $I_C = 200\text{ mA}$	1.1		1.5	1.1		1.3	V
Emitter-follower saturation voltage	Emitter-follower $V_C = 15\text{ V}$ , $I_E = -200\text{ mA}$	1.5		2.5	1.5		2.5	
Output control input current	$V_I = V_{ref}$			3.5			3.5	mA

pwm comparator section (see Figure 2)

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>‡</sup>	MAX	UNIT
Input threshold voltage (pin 3)	Zero duty cycle		4	4.5	V
Input sink current (pin 3)	$V(\text{pin } 3) = 0.5\text{ V}$	0.3		0.7	mA

under-voltage lockout section (see Figure 2)

PARAMETER	TEST CONDITIONS <sup>†</sup>	TL593M TL594M			TL593C TL594I, TL594C TL595C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Threshold voltage	$T_A = 25^\circ\text{C}$			6			6	V
	$\Delta T_A = \text{MIN to MAX}$	3		6.9	3.5		6.9	
Hysteresis <sup>‡</sup>		30			100			mV

total device (see Figure 2)

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>‡</sup>	MAX	UNIT	
Standby supply current	Pin 6 at $V_{ref}$ . All other inputs and outputs open	$V_{CC} = 15\text{ V}$		9	15	mA
		$V_{CC} = 40\text{ V}$		11	18	
Average supply current	Dead-time Control at $2\text{ V}$ , See Figure 2		12.4		mA	

<sup>†</sup>For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

<sup>‡</sup>All typical values except for parameter changes with temperature are at  $T_A = 25^\circ\text{C}$ .

[Hysteresis is the difference between the positive-going input threshold voltage and the negative-going input threshold voltage.

# TYPES TL593, TL594, TL595

## PULSE-WIDTH-MODULATION CONTROL CIRCUITS

switching characteristics,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
Output voltage rise time	Common-emitter configuration, See Figure 3		100	200	ns
Output voltage fall time			30	100	
Output voltage rise time	Emitter-follower configuration, See Figure 4		200	400	ns
Output voltage fall time			45	100	

<sup>†</sup>All typical values are at  $T_A = 25^\circ\text{C}$ .

### PARAMETER MEASUREMENT INFORMATION

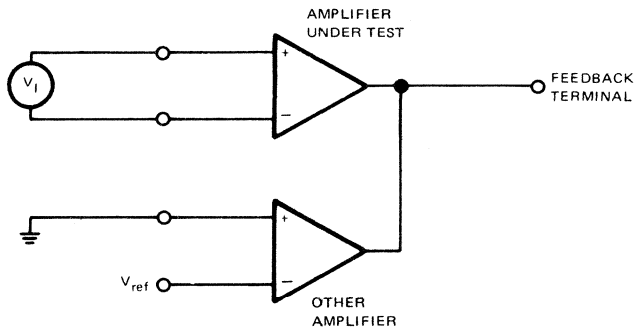


FIGURE 1 — AMPLIFIER CHARACTERISTICS

# TYPES TL593, TL594, TL595 PULSE-WIDTH-MODULATION CONTROL CIRCUITS

## PARAMETER MEASUREMENT INFORMATION

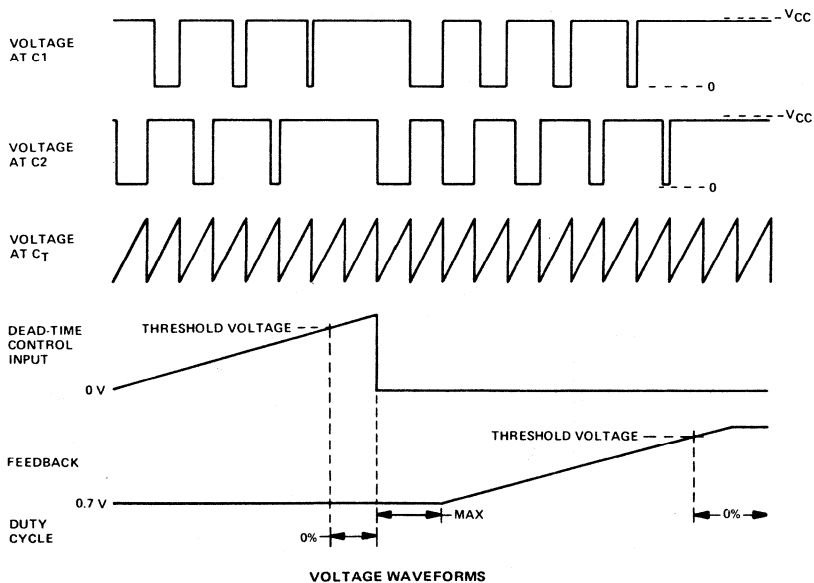
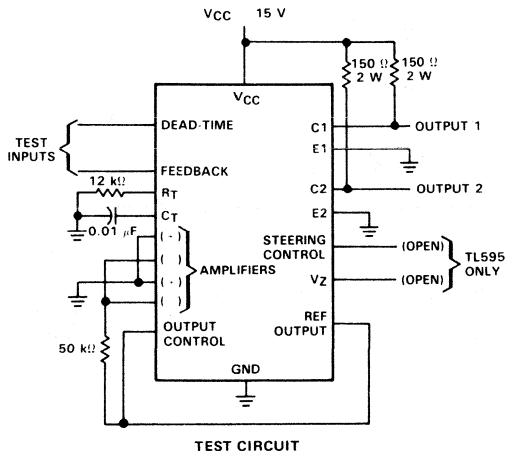
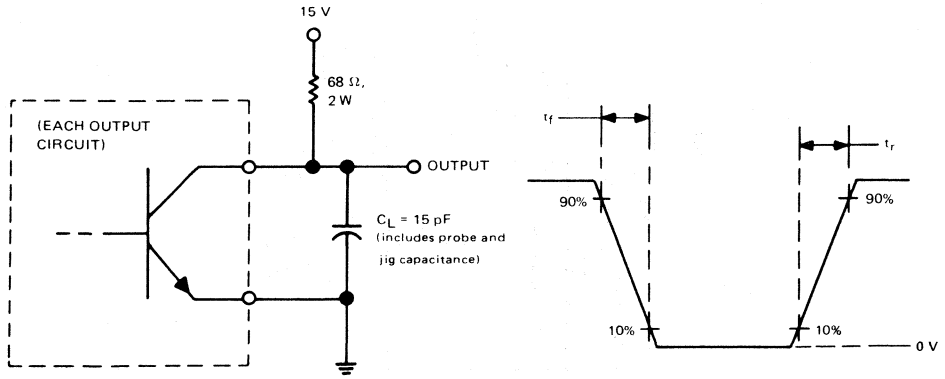


FIGURE 2—OPERATIONAL TEST CIRCUIT AND WAVEFORMS

**TYPES TL593, TL594, TL595**  
**PULSE-WIDTH-MODULATION CONTROL CIRCUITS**

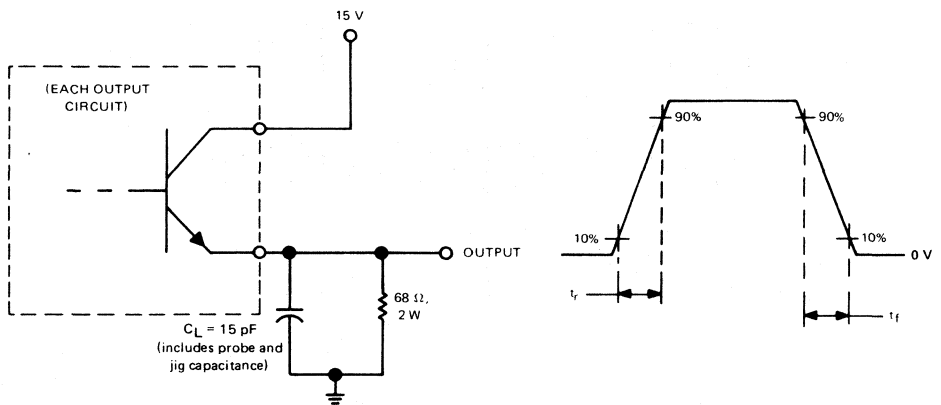
**PARAMETER MEASUREMENT INFORMATION**



TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 3—COMMON-EMITTER CONFIGURATION



TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 4—EMITTER-FOLLOWER CONFIGURATION

TYPICAL CHARACTERISTICS

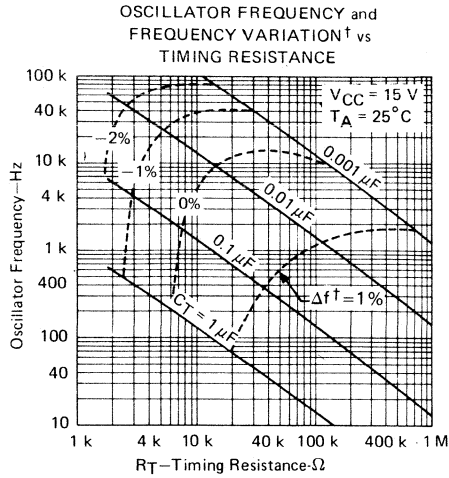


FIGURE 5

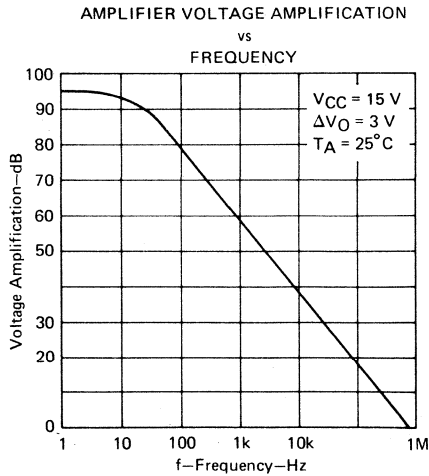


FIGURE 6

<sup>†</sup>Frequency variation ( $\Delta f$ ) is the change in oscillator frequency that occurs over the full temperature range.

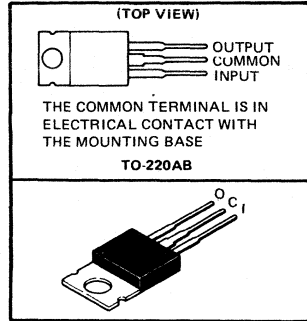




- $\pm 1\%$  Output tolerance at  $25^\circ\text{C}$
- $\pm 2\%$  Output Tolerance Over Full Operating Range
- Thermal Shutdown
- Internal Short-Circuit Current Limiting
- Pinout Identical to  $\mu\text{A}7800$  Series
- Improved Version of  $\mu\text{A}7800$  Series

NOMINAL OUTPUT VOLTAGE	REGULATOR
5 V	TL780-05C
12 V	TL780-12C
15 V	TL780-15C

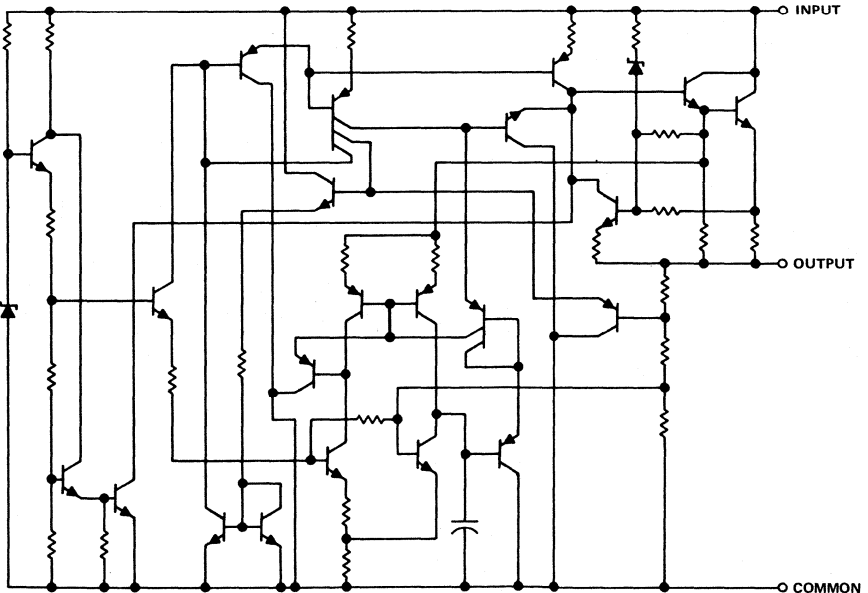
**KC PACKAGE**



**description**

Each fixed-voltage precision regulator in this series is capable of supplying 1.5 amperes of load current. A unique temperature-compensation technique coupled with an internally trimmed bandgap reference has resulted in improved accuracy when compared to other three-terminal regulators. Advanced layout techniques provide excellent line, load, and thermal regulation. The internal current limiting and thermal shutdown features make the devices essentially immune to overload.

**schematic**



# SERIES TL780 POSITIVE VOLTAGE REGULATORS

## absolute maximum ratings over operating temperature range (unless otherwise noted)

Input voltage	35 V
Continuous total dissipation at 25°C free-air temperature (see Note 1)	2 W
Continuous total dissipation at (or below) 25°C case temperature (see Note 1)	15 W
Operating free-air, case, or virtual junction temperature range	0 to 150°C
Storage temperature range	-65 to 150°C
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds	260°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

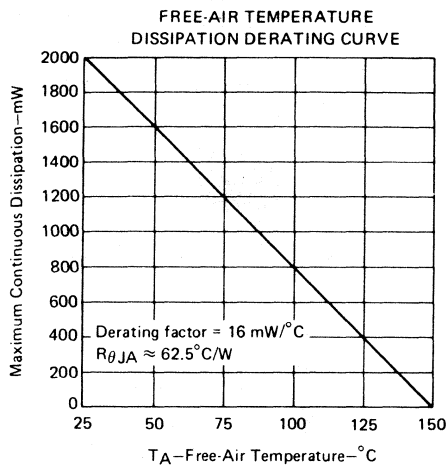


FIGURE 1

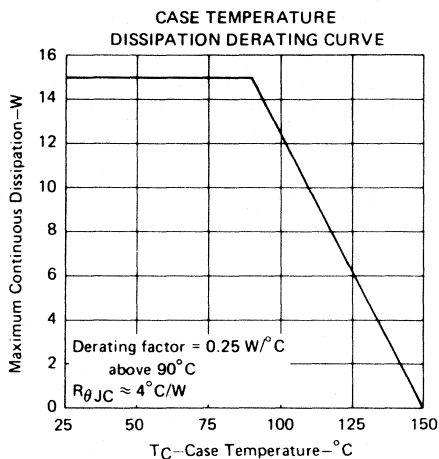


FIGURE 2

## recommended operating conditions

		MIN	MAX	UNIT
Input voltage, $V_I$	TL780-05C	7	25	V
	TL780-12C	14.5	30	
	TL780-15C	17.5	30	
Output current, $I_O$			1.5	A
Operating virtual junction temperature, $T_J$		0	125	°C



## SERIES TL780 POSITIVE VOLTAGE REGULATORS

TL780-05C electrical characteristics at specified virtual junction temperature,  
 $V_I = 10\text{ V}$ ,  $I_O = 500\text{ mA}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	MIN	TYP	MAX	UNIT	
Output voltage	$I_O = 5\text{ mA to }1\text{ A}$ , $P \leq 15\text{ W}$ $V_I = 7\text{ V to }20\text{ V}$	25°C	4.95	5	5.05	V
		0°C to 125°C	4.9		5.1	
Input regulation	$V_I = 7\text{ V to }25\text{ V}$	25°C		0.5	5	mV
	$V_I = 8\text{ V to }12\text{ V}$			0.5	5	
Ripple rejection	$V_I = 8\text{ V to }18\text{ V}$ , $f = 120\text{ Hz}$	0°C to 125°C	70	85		dB
Output regulation	$I_O = 5\text{ mA to }1.5\text{ A}$	25°C		4	25	mV
	$I_O = 250\text{ mA to }750\text{ mA}$			1.5	15	
Output resistance	$f = 1\text{ kHz}$	0°C to 125°C	0.0035			Ω
Temperature coefficient of output voltage	$I_O = 5\text{ mA}$	0°C to 125°C		0.25		mV/°C
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$	25°C		75		μV
Dropout voltage	$I_O = 1\text{ A}$	25°C		2		V
Bias current		25°C		5	8	mA
Bias current change	$V_I = 7\text{ V to }25\text{ V}$	0°C to 125°C		0.7	1.3	mA
	$I_O = 5\text{ mA to }1\text{ A}$			0.03	0.5	
Short-circuit output current	$V_I = 35\text{ V}$	25°C		750		mA
Peak output current		25°C		2.2		A

TL780-12C electrical characteristics at specified virtual junction temperature,  
 $V_I = 19\text{ V}$ ,  $I_O = 500\text{ mA}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	MIN	TYP	MAX	UNIT	
Output voltage	$I_O = 5\text{ mA to }1\text{ A}$ , $P \leq 15\text{ W}$ $V_I = 14.5\text{ V to }27\text{ V}$	25°C	11.88	12	12.12	V
		0°C to 125°C	11.76		12.24	
Input regulation	$V_I = 14.5\text{ V to }30\text{ V}$	25°C		1.2	12	mV
	$V_I = 16\text{ V to }22\text{ V}$			1.2	12	
Ripple rejection	$V_I = 15\text{ V to }25\text{ V}$ , $f = 120\text{ Hz}$	0°C to 125°C	65	80		dB
Output regulation	$I_O = 5\text{ mA to }1.5\text{ A}$	25°C		6.5	60	mV
	$I_O = 250\text{ mA to }750\text{ mA}$			2.5	36	
Output resistance	$f = 1\text{ kHz}$	0°C to 125°C	0.0035			Ω
Temperature coefficient of output voltage	$I_O = 5\text{ mA}$	0°C to 125°C		0.6		mV/°C
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$	25°C		180		μV
Dropout voltage	$I_O = 1\text{ A}$	25°C		2		V
Bias current		25°C		5.5	8	mA
Bias current change	$V_I = 14.5\text{ V to }30\text{ V}$	0°C to 125°C		0.4	1.3	mA
	$I_O = 5\text{ mA to }1\text{ A}$			0.03	0.5	
Short-circuit output current	$V_I = 35\text{ V}$	25°C		350		mA
Peak output current		25°C		2.2		A

† All characteristics are measured with a capacitor across the input of 0.33 μF and a capacitor across the output of 0.22 μF. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10\text{ ms}$ , duty cycles  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# SERIES TL780

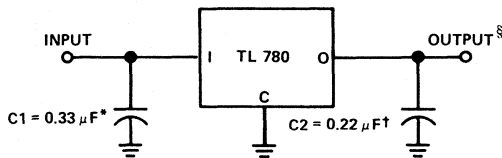
## POSITIVE VOLTAGE REGULATORS

TL780-15C electrical characteristics at specified virtual junction temperature,  
 $V_I = 23\text{ V}$ ,  $I_O = 500\text{ mA}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	MIN TYP MAX			UNIT	
Output voltage	$I_O = 5\text{ mA to }1\text{ A}$ , $P \leq 15\text{ W}$ $V_I = 17.5\text{ V to }30\text{ V}$	$25^\circ\text{C}$	14.85	15	15.15	V
		$0^\circ\text{C to }125^\circ\text{C}$	14.7		15.3	
Input regulation	$V_I = 17.5\text{ V to }30\text{ V}$	$25^\circ\text{C}$		1.5	15	mV
	$V_I = 20\text{ V to }26\text{ V}$			1.5	15	
Ripple rejection	$V_I = 18.5\text{ V to }28.5\text{ V}$ $f = 120\text{ Hz}$	$0^\circ\text{C to }125^\circ\text{C}$	60	75		dB
Output regulation	$I_O = 5\text{ mA to }1.5\text{ A}$	$25^\circ\text{C}$		7	75	mV
	$I_O = 250\text{ mA to }750\text{ mA}$			2.5	45	
Output resistance	$f = 1\text{ kHz}$	$0^\circ\text{C to }125^\circ\text{C}$	0.0035			$\Omega$
Temperature coefficient of output voltage	$I_O = 5\text{ mA}$	$0^\circ\text{C to }125^\circ\text{C}$	0.62			$\text{mV}/^\circ\text{C}$
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$	$25^\circ\text{C}$	225			$\mu\text{V}$
Dropout voltage	$I_O = 1\text{ A}$	$25^\circ\text{C}$	2			V
Bias current		$25^\circ\text{C}$	5.5	8		mA
Bias current change	$V_I = 17.5\text{ V to }30\text{ V}$	$0^\circ\text{C to }125^\circ\text{C}$	0.4	1.3		mA
	$I_O = 5\text{ mA to }1\text{ A}$		0.02	0.5		
Short-circuit output current	$V_I = 35\text{ V}$	$25^\circ\text{C}$	230			mA
Peak output current		$25^\circ\text{C}$	2.2			A

† All characteristics are measured with a capacitor across the input of  $0.33\ \mu\text{F}$  and a capacitor across the output of  $0.22\ \mu\text{F}$ . All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

### TYPICAL APPLICATION DATA



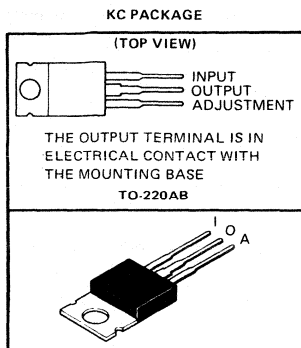
\*C1 required if regulator is far from power supply filter.

†C2 not required for stability, however transient response is improved

§ Permanent damage can occur if output is pulled below ground.



- Output Adjustable From 1.25 V To 125-Volt
- 700 mA Output Current
- Full Short-Circuit, Safe-Operating-Area, and Thermal Shutdown Protection
- 0.001 %/V Typical Input Regulation
- 0.15% Typical Output Regulation
- 76 dB Typical Ripple Rejection
- Standard TO-220AB Package



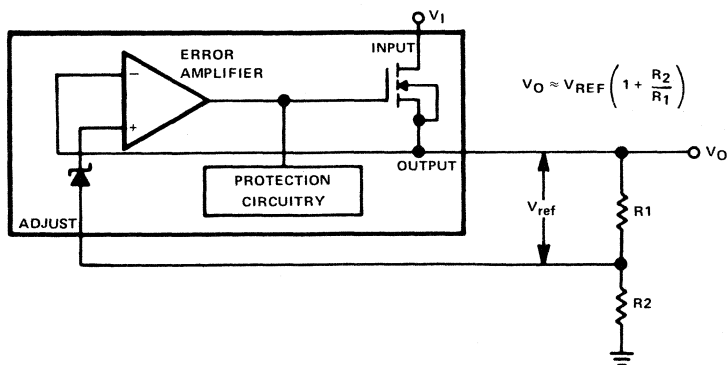
**description**

The TL783 is an adjustable 3-terminal positive-voltage regulator with an output range of 1.25 volts to 125 volts and a DMOS output transistor capable of sourcing more than 700 milliamperes. It is designed for use in high-voltage applications where standard bipolar regulators cannot be used. Excellent performance specifications . . . superior to those of most bipolar regulators . . . are achieved through circuit design and advanced layout techniques.

As a state-of-the-art regulator, the TL783 combines standard bipolar circuitry with high-voltage double-diffused MOS transistors on one chip to yield a device capable of withstanding voltages far higher than standard bipolar integrated circuits. Because of its lack of secondary breakdown and thermal runaway characteristics usually associated with bipolar outputs, the TL783 maintains full overload protection while operating at up to 125 volts from input to output. Other features of the device include current limiting, safe-operating-area (SOA) protection, and thermal shutdown. Even if the adjustment pin is inadvertently disconnected, the protection circuitry remains functional.

Only two external resistors are required to program the output voltage. An input bypass capacitor is necessary only when the regulator is situated far from the input filter. An output capacitor, although not required, will improve transient response and protection from instantaneous output short-circuits. Excellent ripple rejection can be achieved without a bypass capacitor at the adjustment terminal.

**functional block diagram**



# TYPE TL783C HIGH-VOLTAGE ADJUSTABLE REGULATOR

## absolute maximum ratings over operating temperature range (unless otherwise noted)

Input-to-output differential voltage, $V_I - V_O$ .....	125 V
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 1) .....	2 W
Continuous total dissipation at (or below) 25°C case temperature (see Note 1) .....	20 W
Operating free-air, case, or virtual junction temperature range .....	0°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds .....	260°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

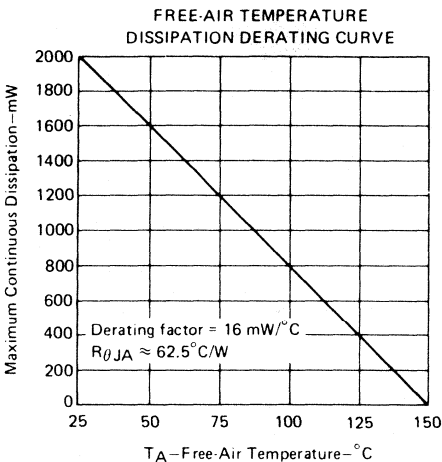


FIGURE 1

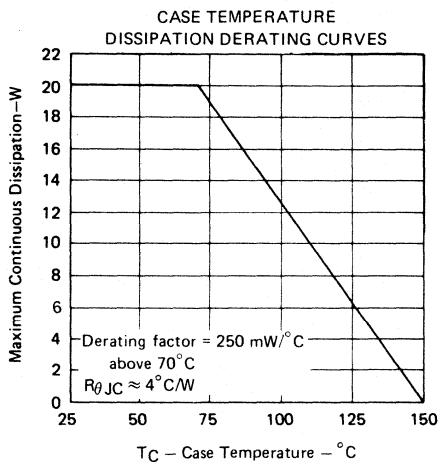


FIGURE 2

## recommended operating conditions

	MIN	MAX	UNIT
Input-to-output voltage differential, $V_I - V_O$ .....		125	V
Output current, $I_O$ .....	15	700	mA
Operating virtual junction temperature, $T_J$ .....	0	125	°C



# TYPE TL783C HIGH-VOLTAGE ADJUSTABLE REGULATOR

electrical characteristics at  $V_I - V_O = 25\text{ V}$ ,  $I_O = 0.5\text{ A}$ ,  $T_J = 0^\circ\text{C}$  to  $125^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MIN	TYP	MAX	UNIT
Input regulation‡	$V_I - V_O = 20\text{ V}$ to $125\text{ V}$		$T_J = 25^\circ\text{C}$	0.001	0.01	%V
			$T_J = 0^\circ\text{C}$ to $125^\circ\text{C}$	0.004	0.02	
Ripple rejection	$\Delta V_{I(p-p)} = 10\text{ V}$ ,	$V_O = 10\text{ V}$ ,	$f = 120\text{ Hz}$	66	76	dB
Output regulation	$I_O = 15\text{ mA}$ to $700\text{ mA}$ ,	$T_J = 25^\circ\text{C}$	$V_O \leq 5\text{ V}$	7.5	25	mV
			$V_O \geq 5\text{ V}$	0.15	0.5	%
	$I_O = 15\text{ mA}$ to $700\text{ mA}$	$V_O \leq 5\text{ V}$	20	70	mV	
		$V_O \geq 5\text{ V}$	0.3	1.5	%	
Output voltage change with temperature			0.4		%	
Output voltage long-term drift	1000 h at $T_J = 125^\circ\text{C}$ , See Note 2	$V_I - V_O = 125\text{ V}$ ,	0.2		%	
Output noise voltage	$f = 10\text{ Hz}$ to $10\text{ kHz}$ ,	$T_J = 25^\circ\text{C}$	0.003		%	
Minimum output current to maintain regulation	$V_I - V_O = 125\text{ V}$		15		mA	
Peak output current	$V_I - V_O = 25\text{ V}$ ,		1100		mA	
	$t = 1\text{ ms}$					
	$V_I - V_O = 15\text{ V}$ ,		715			
	$t = 30\text{ ms}$					
Adjustment-terminal current	$V_I - V_O = 25\text{ V}$ ,		700	900		
	$t = 30\text{ ms}$					
Change in adjustment-terminal current	$V_I - V_O = 15\text{ V}$ to $125\text{ V}$ ,		83		$\mu\text{A}$	
	$I_O = 15\text{ mA}$ to $700\text{ mA}$ , $P \leq$ rated dissipation		110			
Reference voltage (output to ADJ)	$V_I - V_O = 10\text{ V}$ to $125\text{ V}$ ,	$I_O = 15\text{ mA}$ to $700\text{ mA}$ , $P \leq$ rated dissipation	1.2	1.27	1.3	V

† All characteristics except noise voltage and ripple rejection are measured using pulse techniques ( $t_w \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ) to limit changes in average internal dissipation. Output voltage changes due to large changes in internal dissipation must be taken into account separately.

‡ Input regulation is expressed here as the percentage change in output voltage per 1-volt change at the input.

NOTE 2: Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

# TYPE TL783C HIGH-VOLTAGE ADJUSTABLE REGULATOR

## TYPICAL CHARACTERISTICS

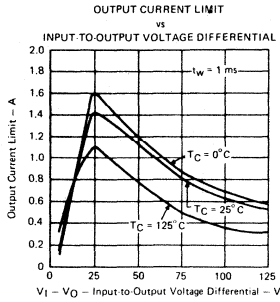


FIGURE 3

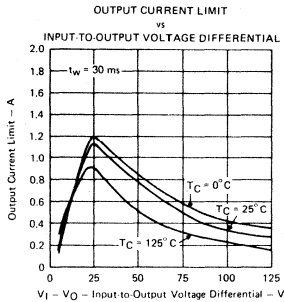


FIGURE 4

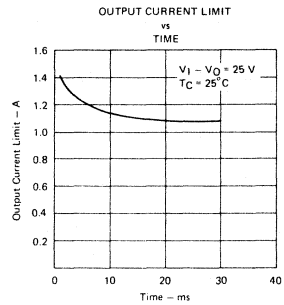


FIGURE 5

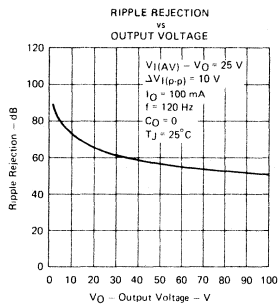


FIGURE 6

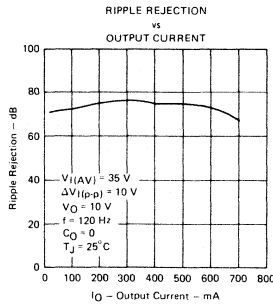


FIGURE 7

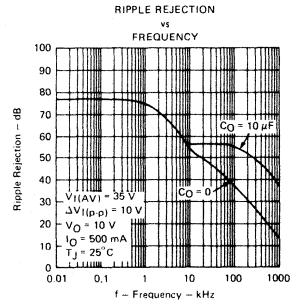


FIGURE 8

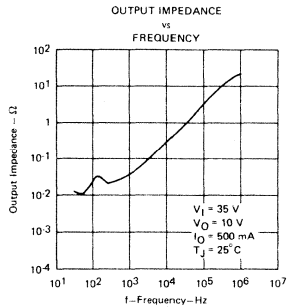


FIGURE 9





# TYPE TL783C HIGH-VOLTAGE ADJUSTABLE REGULATOR

## TYPICAL CHARACTERISTICS

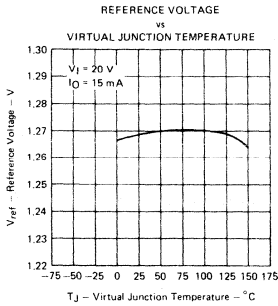


FIGURE 10

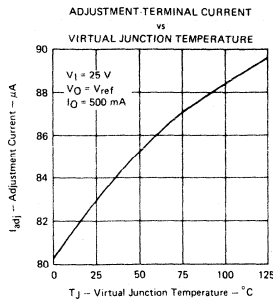


FIGURE 11

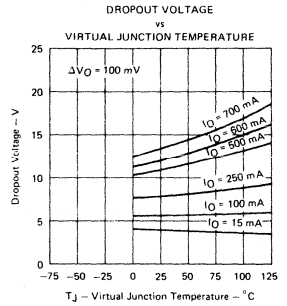


FIGURE 12

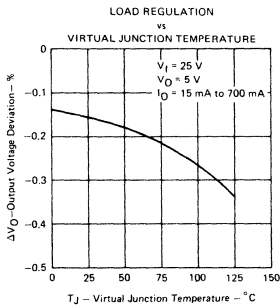


FIGURE 13

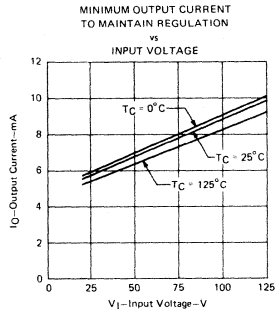


FIGURE 14

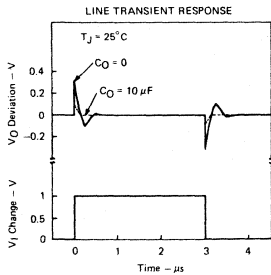


FIGURE 15

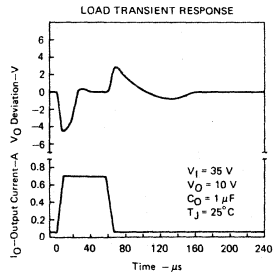


FIGURE 16



# TYPE TL783C

## HIGH-VOLTAGE ADJUSTABLE REGULATOR

### DESIGN CONSIDERATIONS

The internal reference (see functional block diagram) is used to generate 1.25 volts nominal ( $V_{ref}$ ) between the output and adjustment terminals. This voltage is developed across R1 and causes a constant current to flow through R1 and the programming resistor R2, giving an output voltage of:

$$V_O = V_{ref} (1 + R2/R1) + I_{adj} (R2)$$

or

$$V_O \approx V_{ref} (1 + R2/R1).$$

The TL783 was designed to minimize  $I_{adj}$  and maintain consistency over line and load variations, thereby minimizing the  $I_{adj}$  (R2) error term.

To maintain  $I_{adj}$  at a low level, all quiescent operating current is returned to the output terminal. This quiescent current must be sunk by the external load and is the minimum load current necessary to prevent the output from rising. The recommended R1 value of 82 ohms will provide a minimum load current of 15 milliamperes. Larger values may be used if the input-to-output differential voltage is less than 125 volts (see minimum operating current curve) or if the load will sink some portion of the minimum current.

#### Bypass capacitors

The TL783 regulator is stable without bypass capacitors; however, any regulator will become unstable with certain values of output capacitance if an input capacitor is not used. Therefore, the use of input bypassing is recommended whenever the regulator is located more than four inches from the power-supply filter capacitor. A 1-microfarad tantalum or electrolytic capacitor is usually sufficient.

Adjustment-terminal capacitors are not recommended for use on the TL783 because they can seriously degrade load transient response as well as create a need for extra protection circuitry. Excellent ripple rejection is presently achieved without this added capacitor.

Due to the relatively low gain of the MOS output stage, output voltage drop-out may occur under large load transient conditions. Addition of an output bypass capacitor will greatly enhance load transient response as well as prevent drop-out. For most applications it is recommended that an output bypass capacitor be used with a minimum value of:

$$C_O (\mu f) = 15/V_O$$

Larger values will provide proportionally better transient response characteristics.

#### Protection circuitry

The TL783 regulator includes built-in protection circuitry capable of guarding the device against most overload conditions encountered in normal operation. These protective features are current limiting, safe-operating-area protection, and thermal shutdown. These circuits are meant to protect the device under occasional fault conditions only. Continuous operation in the current limit or thermal shutdown mode is not recommended.

The internal protection circuits of the TL783 will protect the device up to maximum rated  $V_I$  as long as certain precautions are taken. If  $V_I$  is instantaneously switched on, transients exceeding maximum input ratings may occur, which can destroy the regulator. These are usually caused by lead inductance and bypass capacitors causing a ringing voltage on the input. In addition, if rise times in excess of 10 V/ns are applied to the input, a parasitic n-p-n transistor in parallel with the DMOS output can be turned on causing the device to fail. If the device is operated over 50 volts and the input is switched on rather than ramped on, a low-Q capacitor, such as a tantalum or electrolytic should be used rather than ceramic, paper, or plastic bypass capacitors. A dissipation factor of 0.015 or greater will usually provide adequate damping to suppress ringing. Normally, no problems will occur if the input voltage is allowed to ramp upward through the action of an ac line rectifier and filter network.

## TYPE TL783C HIGH-VOLTAGE ADJUSTABLE REGULATOR

Similarly, if an instantaneous short circuit is applied to the outputs, both ringing and excessive fall times can result. A tantalum or electrolytic bypass capacitor is recommended to eliminate this problem. However, if a large output capacitor is used and the input is shorted, addition of a protection diode may be necessary to prevent capacitor discharge through the regulator. The amount of discharge current delivered is dependent on output voltage, size of capacitor, and fall time of  $V_I$ . A protective diode (see Figure 17) is required only for capacitance values greater than

$$C_O (\mu\text{f}) = 3 \times 10^4 / (V_O)^2.$$

Care should always be taken to prevent insertion of regulators into a socket with power on. Power should be turned off before removing or inserting regulators.

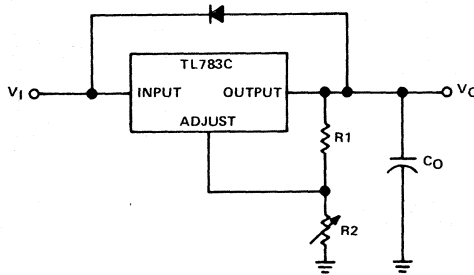


FIGURE 17—REGULATOR WITH PROTECTIVE DIODE

### Load regulation

The current set resistor (R1) should be located close to the regulator output terminal rather than near the load. This eliminates long line drops from being amplified through the action of R1 and R2 to degrade load regulation. To provide remote ground sensing, R2 should be near the load ground.

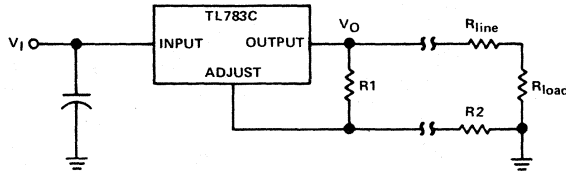
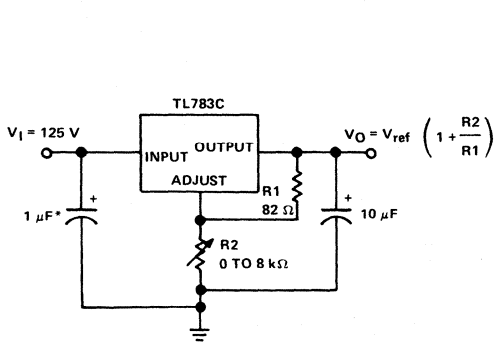


FIGURE 18—REGULATOR WITH CURRENT-SET RESISTOR

# TYPE TL783C HIGH-VOLTAGE ADJUSTABLE REGULATOR

## TYPICAL APPLICATION DATA



\*NEEDED IF DEVICE IS MORE THAN 4 INCHES FROM FILTER CAPACITOR

FIGURE 19—1.25-V TO 115-V ADJUSTABLE REGULATOR

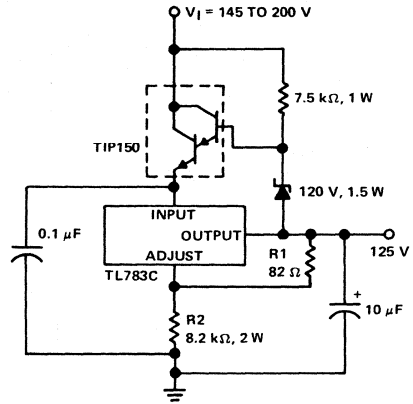


FIGURE 20—125 V SHORT-CIRCUIT-PROTECTED OFF-LINE REGULATOR

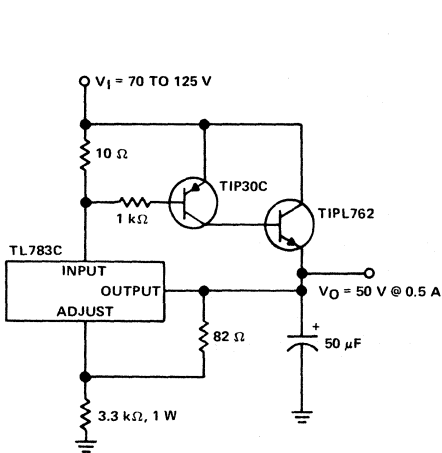


FIGURE 21—50-V REGULATOR WITH CURRENT BOOST

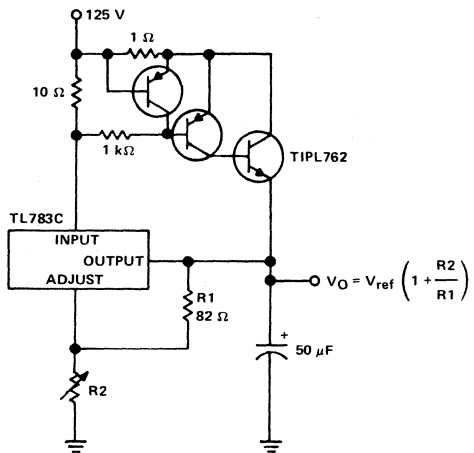


FIGURE 22—ADJUSTABLE REGULATOR WITH CURRENT BOOST AND CURRENT LIMIT

TYPICAL APPLICATION DATA

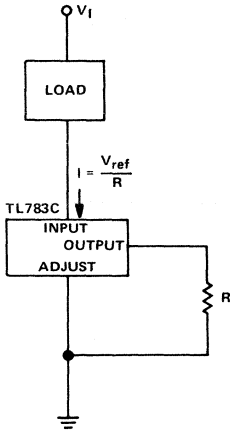


FIGURE 23—CURRENT-SINKING REGULATOR

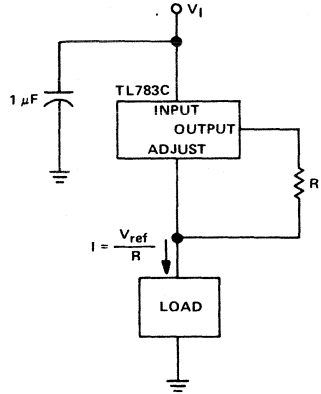


FIGURE 24—CURRENT-SOURCING REGULATOR

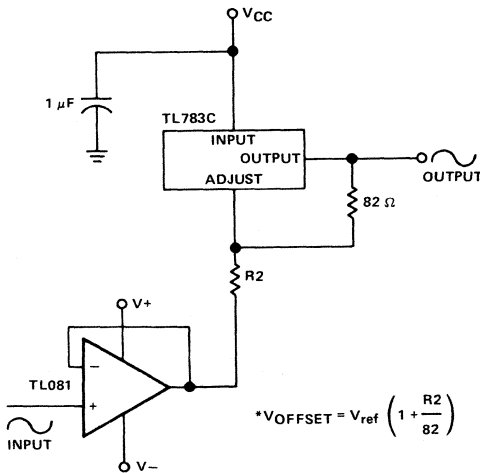


FIGURE 25—HIGH-VOLTAGE UNITY-GAIN OFFSET AMPLIFIER

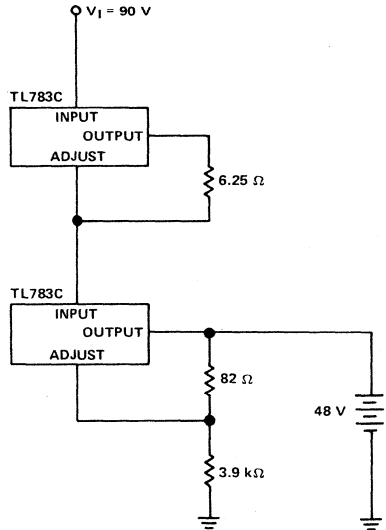


FIGURE 26—48-V, 200-mA FLOAT CHARGER

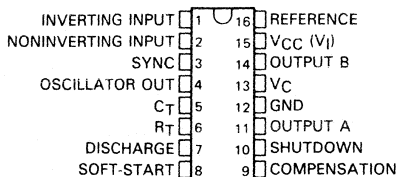


- Complete PWM Power Control Circuitry
- 8-Volt to 35-Volt Operation
- 5.1-Volt Reference Trimmed to  $\pm 1\%$
- Frequency Range . . . 100 Hz to 500 Hz
- Adjustable Deadtime Control
- Under-Voltage Lockout for Low  $V_{CC}$  Conditions
- Latched PWM Prevents Multiple Pulses
- Dual Sink or Source Output Drivers
- Improved Direct Replacements for Silicon General SG1525A/SG1527A Series

TL1525A, TL1527A . . . J  
TL2525A, TL2527A . . . J OR N  
TL3525A, TL3527A . . . J OR N

DUAL-IN-LINE PACKAGE

(TOP VIEW)



**output logic**

TL1525A, TL2525A, TL3525A . . . OR  
TL1527A, TL2527A, TL3527A . . . NOR

**description**

The TL1525A/TL1527A series of pulse-width modulation integrated circuits are designed to offer improved performance and lower external parts count when used to implement various types of switching power supplies. Each device includes an on-chip 5.1-volt reference, error amplifier, programmable oscillator, pulse-steering flip-flop, a latched comparator under-voltage lockout, shutdown circuitry, and complementary source or sink outputs. The on-chip 5.1-volt reference is trimmed to  $\pm 1\%$  initial accuracy, serves as a reference output, and supplies the internal regulator control circuitry. The input common-mode range of the error amplifier includes the reference voltage, which eliminates the need for external divider resistors.

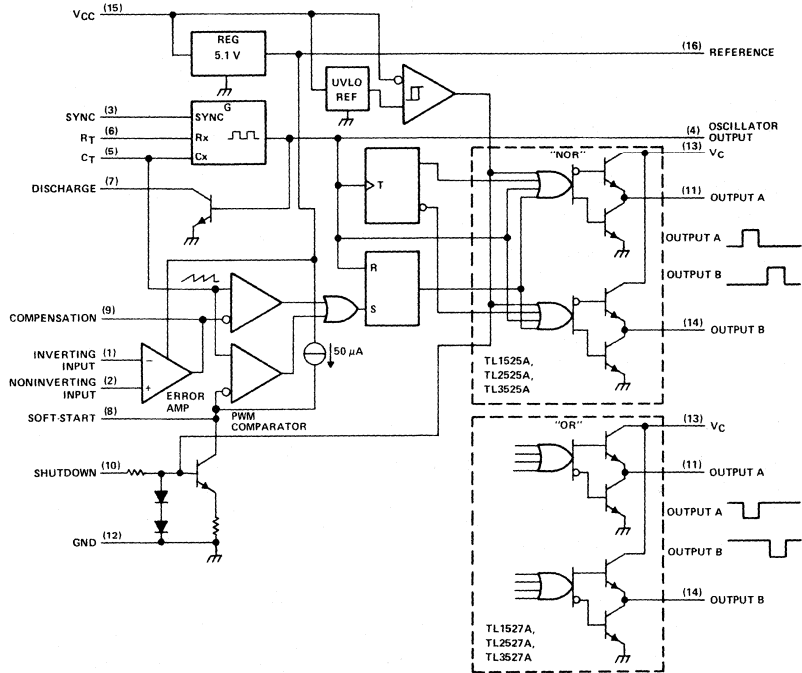
The oscillator operates at a fixed frequency determined by one timing resistor  $R_T$  and one timing capacitor  $C_T$ . The timing resistor establishes the constant charging current for  $C_T$ , resulting in a linear voltage ramp at  $C_T$ , which is fed to the PWM comparator providing linear control of the output pulse duration by the error amplifier. A Sync input to the oscillator allows for external synchronization or for multiple units to be slaved together. A single external resistor between the  $C_T$  pin and the Discharge pin provides a wide range of dead-time adjustment. These devices also feature built-in soft-start circuitry that requires only an external timing capacitor. The Shutdown pin controls both the soft-start and the output drivers, and provides instantaneous turn-off with soft-start recycle for slow turn-on. The soft-start and output driver circuitry are also controlled by the under-voltage lockout circuit, which, during low-input supply voltage of less than that required for normal operation, keeps the soft-start capacitor discharged and the output drivers off.

Another unique feature is the S-R latch following the PWM comparator. This feature enables the output drivers to be turned off any time the PWM pulse is terminated. The latch is reset with each clock pulse. However, the PWM outputs will remain turned off for the duration of the period if the PWM comparator output is in a low-level state. The TL1525A, TL2525A, and TL3525A output stages feature NOR logic resulting in a low output for an off-state. The TL1527A, TL2527A, and TL3527A output stages feature OR logic resulting in a high-level output for an off-state. The output stages are totem-pole designs capable of sourcing or sinking 200 milliamperes of output current.

The TL1525A and TL1527A are characterized for operation over the full military temperature range of  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ . The TL2525A and TL2527A are characterized for operation from  $-25^\circ\text{C}$  to  $85^\circ\text{C}$ . The TL3525A and TL3527A are characterized for operation for  $0^\circ\text{C}$  to  $70^\circ\text{C}$ .

# TYPES TL1525A, TL1527A, TL2525A, TL2527A, TL3525A, TL3527A PULSE-WIDTH MODULATION CONTROLLERS

functional block diagram (positive logic)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V <sub>CC</sub> (see Note 1)	40 V
Collector voltage, V <sub>C</sub>	40 V
Logic input voltage range sync and shutdown	-0.3 V to 5.5 V
Analog input voltage range error amplifier inputs	-0.3 V to V <sub>CC</sub>
Output current, I <sub>O</sub>	500 mA
Reference output current, I <sub>REF</sub>	50 mA
Current through C <sub>T</sub> terminal	-5 mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	1000 mW
Operating free-air temperature range: TL1525A, TL1527A	-55°C to 125°C
TL2525A, TL2527A	-25°C to 85°C
TL3525A, TL3527A	0°C to 70°C
Operating virtual junction temperature range	0°C to 150°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J Package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N Package	260°C

NOTES: 1. All voltage values are with respect to network ground terminal.  
 2. For operating above 25°C free-air temperature, see Dissipation Derating Curves, Figures 1 and 2. In the J package, TL1525A and TL1527A chips are alloy-mounted; TL2525A, TL2527A, TL3525A, and TL3527A chips are epoxy mounted.



# TL2525A, TL2527A, TL3525A, TL3527A PULSE-WIDTH MODULATION CONTROLLERS

$\approx 20\text{ V}$

TL3525A, TL3527A			UNIT
MIN	TYP	MAX	
5	5.1	5.2	V
4.95		5.25	mV
	14	20	mV
	5	50	mV
	24	50	mV
	25	50	mV
	40	200	$\mu\text{V}$
	80	100	mA

TL3525A, TL3527A			UNIT
27A	MIN	TYP	MAX
MAX	400		100
100		$\pm 2\%$	$\pm 6\%$
$\pm 6\%$		$\pm 1\%$	$\pm 2\%$
$\pm 1\%$		$\pm 3\%$	$\pm 6\%$
$\pm 6\%$		3	3.5
			V
1	0.3	0.6	1
			$\mu\text{s}$
2.8	1.2	2	2.8
			V
2.5		1.6	2.5
			mA
2.2	1.7	2	2.2
			mA

Information is not intended to be a guarantee or warranty.

N PACKAGE FREE-AIR TEMPERATURE  
DISSIPATION DERATING CURVE

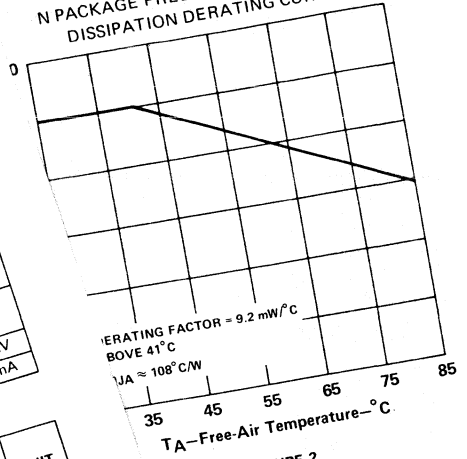


FIGURE 2

TL3525A, TL3527A			UNIT
TL2527A	MIN	MAX	
MAX			
35	8	35	V
35	4.5	35	V
$\pm 100$	0	$\pm 100$	mA
$\pm 400$	0	$\pm 400$	mA
20	0	20	mA
500	100	500	kHz
150	2	150	k $\Omega$
0.1	0.001	0.1	$\mu\text{F}$
500	0	500	$\Omega$
85	0	70	$^\circ\text{C}$

# TYPES TL1525A, TL1527A, TL2525A, TL2527A, TL3525A, T PULSE-WIDTH MODULATION CONTROLLERS

electrical characteristics over recommended operating free-air temperature  
(unless otherwise noted)  
reference section

PARAMETER	TEST CONDITIONS	TL1525A, TL2525A, TL	
		MIN	TYP
Output voltage	$T_J = 25^\circ\text{C}$ $V_{CC} = 8\text{ V to }35\text{ V}$ $I_Q = 0\text{ to }20\text{ mA}$	5.05	5.1
Input regulation	$V_{CC} = 8\text{ V to }35\text{ V}$ $I_Q = 0\text{ to }20\text{ mA}$		5
Output regulation	$V_{CC} = 8\text{ V to }35\text{ V}$ $I_Q = 0\text{ to }20\text{ mA}$		14
Output voltage change with temperature			5
Output voltage long-term drift (see Note 3)	After 1000 h at $T_J = 125^\circ\text{C}$		24
Output noise voltage (RMS)	$f = 10\text{ Hz to }10\text{ kHz}$ , $T_J = 25^\circ\text{C}$		25
Short-circuit output current	$V_Q = 0\text{ V}$ , $T_J = 25^\circ\text{C}$		40
			80

## oscillator section

PARAMETER	TEST CONDITIONS	TL1525A, TL152525A, TL25	
		MIN	TYP
Maximum frequency	$R_T = 2\text{ k}\Omega$ , $C_T = 1\text{ nF}$		
Minimum frequency	$R_T = 150\text{ k}\Omega$ , $C_T = 0.1\text{ }\mu\text{F}$	400	
Initial frequency error	$R_T = 3.6\text{ k}\Omega$ , $R_D = 0\text{ }\Omega$ , $C_T = 0.1\text{ }\mu\text{F}$ , $f = 40\text{ kHz}$ , $T_A = 25^\circ\text{C}$		$\pm 2\%$
Frequency change with supply voltage	$V_{CC} = 8\text{ V to }35\text{ V}$		$\pm 0.3\%$
Frequency change with temperature	$T_A = \text{MIN to MAX}$		$\pm 0.3\%$
Output amplitude at Pin 4	$R_T = 3.6\text{ k}\Omega$ , $R_D = 0\text{ }\Omega$ , $C_T = 0.1\text{ }\mu\text{F}$ , $f = 40\text{ kHz}$		$\pm 3\%$
Output pulse duration at Pin 4	$R_T = 3.5\text{ k}\Omega$ , $R_D = 0\text{ }\Omega$ , $C_T = 0.1\text{ }\mu\text{F}$ , $f = 40\text{ kHz}$ , $T_J = 25^\circ\text{C}$	3	3.5
Input threshold voltage at Pin 3		0.3	0.5
Input current at Pin 3	$V_I(\text{Pin}3) = 3.5\text{ V}$		1.2
Current through Pin 5 due to internal current mirror	Current through Pin 6 = 6 mA		1.7

NOTE 3: Since long-term drift cannot be measured on the individual devices prior to shipment, this specific value is an engineering estimate of the average drift to be expected from lot to lot.

# TYPES TL1525A, TL1527A, TL2525A, TL2527A, TL3525A, TL3527A PULSE-WIDTH MODULATION CONTROLLERS

electrical characteristics over recommended operating free-air temperature range,  $V_{CC} = 20\text{ V}$   
(unless otherwise noted)

## error amplifier section

PARAMETER	TEST CONDITIONS	TL1525A, TL1527A TL2525A, TL2527A			TL3525A, TL3527A			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
High-level output voltage		3.8	5.6		3.8	5.6		V
Low-level output voltage			0.2	0.5		0.2	0.5	V
Input offset voltage			0.5	5		2	10	mV
Input bias current			1	10		1	10	$\mu\text{A}$
Input offset current				1			1	$\mu\text{A}$
Open-loop voltage amplification	$R_L \geq 10\text{ M}$	60	75		60	75		dB
Common-mode rejection ratio	$V_{IC} = 1.5\text{ V to } 5.2\text{ V}$	60	75		60	75		dB
Supply voltage rejection ratio	$V_{CC} = 8\text{ V to } 35\text{ V}$	50	60		50	60		dB
Gain-bandwidth product	$A_V = 0\text{ dB}, T_J = 25^\circ\text{C}$	1	2		1	2		MHz

## comparator section

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
Input threshold voltage	$R_T = 3.6\text{ k}\Omega,$ $R_D = 0\ \Omega,$ $C_T = 10\text{ nF}, f = 40\text{ kHz}$	Duty cycle = 0%		0.6	0.9	V
		Duty cycle = MAX		3.3	3.6	
Input bias current			0.5	1	$\mu\text{A}$	

## soft-start section

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Soft-start voltage	$V_I$ at Pin 10 = 2 V		0.4	0.6	V
Soft-start current	$V_I$ at Pin 10 = 0 V	25	50	80	$\mu\text{A}$
Input current, Shutdown	$V_I$ at Pin 10 = 2.5 V		0.4	1	mA

## output section

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
High-level output voltage	$I_{OH} = -20\text{ mA}$	18	19		V
	$I_{OH} = -100\text{ mA}$	17	18		
Low-level output voltage	$I_{OL} = 20\text{ mA}$		0.2	0.4	V
	$I_{OL} = 100\text{ mA}$		1	2	
Under-voltage lockout voltage	$V_I$ at Pins 8 and 9 = high	6	7	8	V
Collector cutoff current (see Note 4)	$V_C = 35\text{ V}, I_O = 100\text{ mA}$			200	$\mu\text{A}$
Output pulse rise time	$C_L = 1\text{ nF}, T_J = 25^\circ\text{C}$		100	600	ns
Output pulse fall time	$C_L = 1\text{ nF}, T_J = 25^\circ\text{C}$		50	300	ns
Shutdown delay time	$V_I$ at Pin 10 = 3 V, capacitance at pin 8 = 0, $T_J = 25^\circ\text{C}$		0.2	0.5	$\mu\text{s}$

NOTE 4: Collector cutoff current specifications apply only for the TL1525A, TL2525A, and TL3525A devices.

## total device

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Minimum duty cycle				0%	
Maximum duty cycle		45%	49%		
Standby current	$V_{CC} = 35\text{ V}$		14	20	mA

**TYPES TL1525A, TL1527A, TL2525A, TL2527A, TL3525A, TL3527A  
PULSE-WIDTH MODULATION CONTROLLERS**

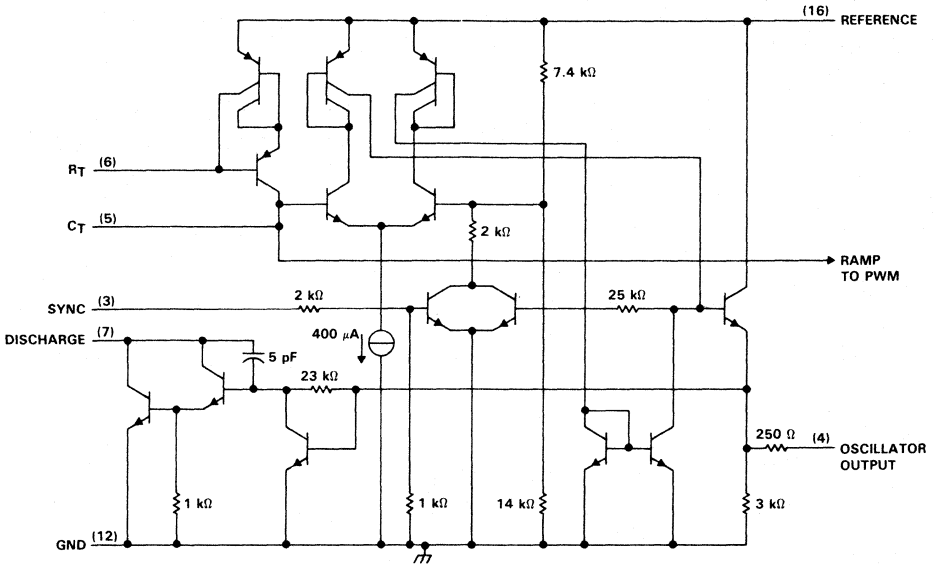


FIGURE 3 -- OSCILLATOR SCHEMATIC DIAGRAM

**TYPICAL CHARACTERISTICS**

CHARGING TIME  
vs  
TIMING RESISTOR

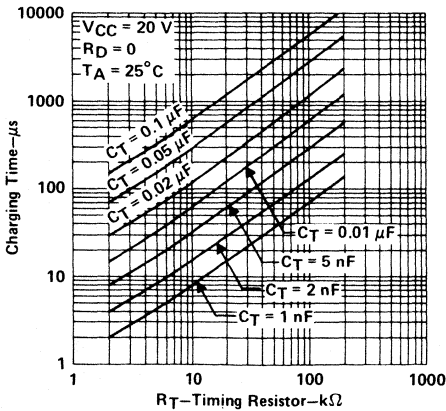


FIGURE 4

DISCHARGE TIME  
vs  
DEAD TIME RESISTOR

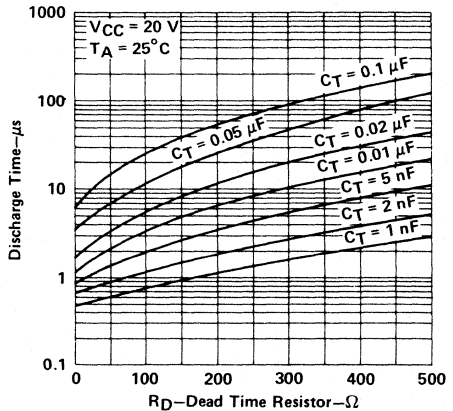


FIGURE 5

TYPES TL1525A, TL1527A, TL2525A, TL2527A, TL3525A, TL3527A  
PULSE-WIDTH MODULATION CONTROLLERS

TYPICAL CHARACTERISTICS

ERROR AMPLIFIER OPEN-LOOP  
FREQUENCY RESPONSE

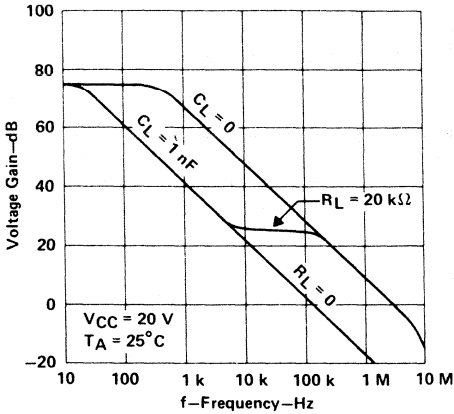


FIGURE 6

TL1525A OUTPUT SATURATION VOLTAGE  
vs  
OUTPUT CURRENT

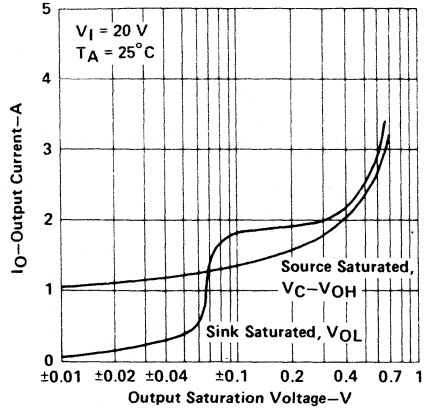


FIGURE 7

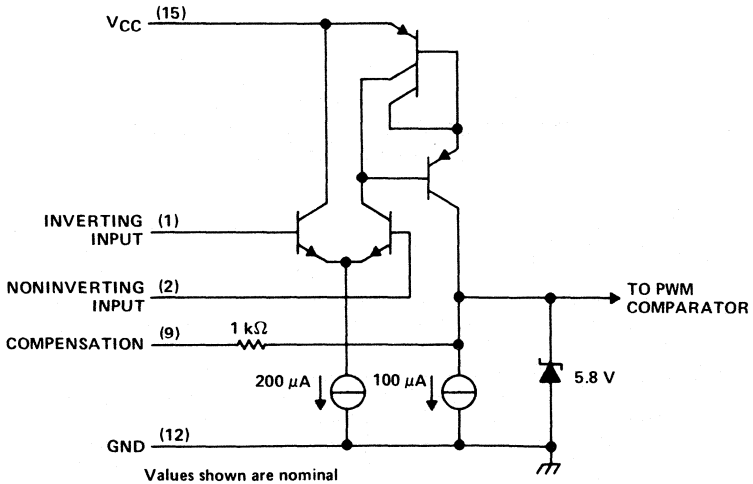


FIGURE 8 - ERROR AMPLIFIER SCHEMATIC DIAGRAM

**TYPES TL1525A, TL1527A, TL2525A, TL2527A, TL3525A, TL3527A  
PULSE-WIDTH MODULATION CONTROLLERS**

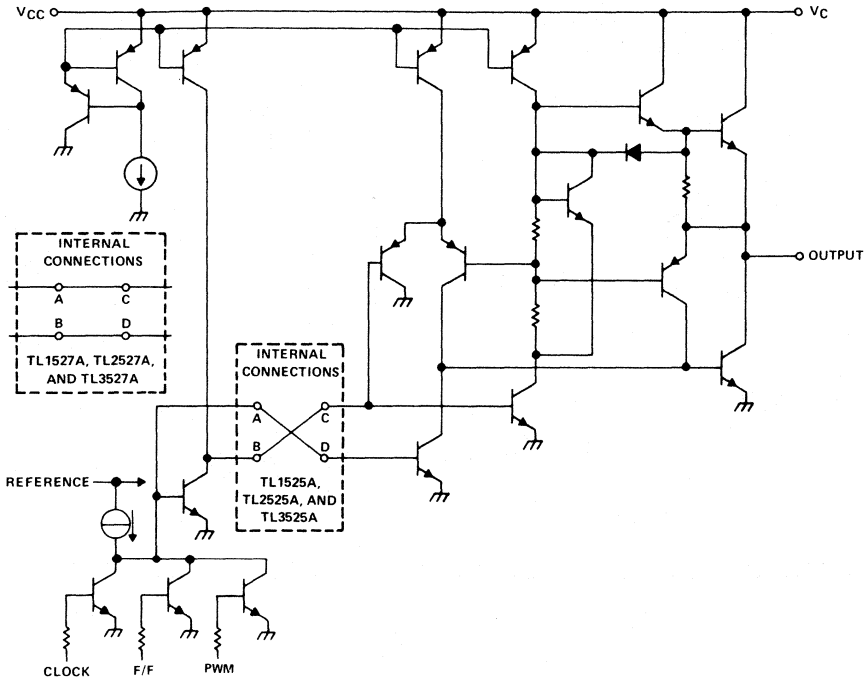


FIGURE 9 — OUTPUT CIRCUIT SCHEMATIC DIAGRAM

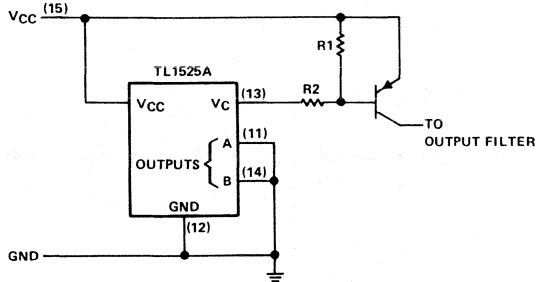
**TYPICAL APPLICATION DATA**

**shutdown options**

1. Use an external transistor or open-collector comparator to pull down on the Compensation terminal (Pin 9). This will set the PWM latch and turn off both driver outputs. If the shutdown signal is momentary, pulse-by-pulse protection will be accomplished as the PWM latch is reset with each clock pulse.
2. The same results may be accomplished by pulling down on the Soft-Start terminal (Pin 8) with the only difference being that on this pin shutdown will not affect the amplifier compensation network, but must discharge any soft-start capacitance.
3. Application of a positive-going signal to the Shutdown terminal (Pin 10) will provide the most rapid shutdown of the driver outputs but will not immediately set the PWM latch if there is a capacitor at the Soft-Start terminal. The capacitor will discharge but at a current twice the charging current. The PWM latch can be set on a pulse-by-pulse basis by the shutdown terminal if there is no external capacitance on the Soft-start terminal (Pin 8). Slow turn-on may still be accomplished by connecting an external capacitor, blocking diode, and charging resistor to the Compensation terminal (Pin 9).

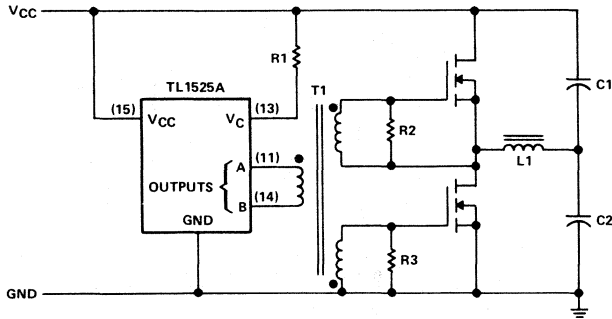
# TYPES TL1525A, TL1527A, TL2525A, TL2527A, TL3525A, TL3527A PULSE-WIDTH MODULATION CONTROLLERS

## TYPICAL APPLICATION DATA



For single-ended supplies, the driver outputs are grounded. The  $V_C$  terminal is switched to ground by the totem-pole source transistors on the alternate oscillator cycles.

FIGURE 10 — SINGLE-ENDED CIRCUIT

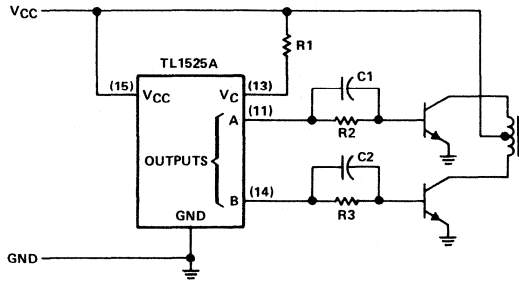


Low-power transformers can be directly driven by the TL1525A. Automatic reset occurs during deadtime when both ends of the primary winding are switched to ground.

FIGURE 11 — TRANSFORMER-COUPLED CIRCUIT

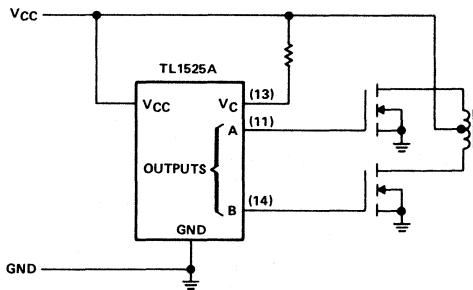
**TYPES TL1525A, TL1527A, TL2525A, TL2527A, TL3525A, TL3527A  
PULSE-WIDTH MODULATION CONTROLLERS**

**TYPICAL APPLICATION DATA**



In conventional push-pull bipolar designs, forward base drive is controlled by  $R_1 - R_3$ . Rapid turn-off times for the power devices are achieved with speed-up capacitors  $C_1$  and  $C_2$ .

**FIGURE 12 — BIPOLAR PUSH-PULL CIRCUIT**



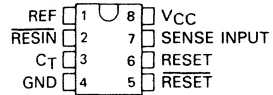
The low source impedance of the output drivers provides rapid charging of power FET input capacitance while minimizing external components.

**FIGURE 13 — LOW-IMPEDANCE BIPOLAR-DRIVE  
PUSH-PULL CIRCUIT**



- Power-On Reset Generator
- Automatic Reset Generation After Voltage Drop
- Wide Supply Voltage Range . . . 3 V to 18 V
- Precision Voltage Sensor
- Temperature-Compensated Voltage Reference
- True and Complement Reset Outputs
- Externally Adjustable Pulse Width

D OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**description**

The TL7702A series are monolithic integrated circuit supply voltage supervisors specifically designed for use as reset controllers in microcomputer and microprocessor systems. During power-up the device tests the supply voltage and keeps the RESET and RESET outputs active (high and low, respectively) as long as the supply voltage has not reached its nominal voltage value. Taking RESIN low has the same effect. To ensure that the microcomputer system has reset, the TL7702A then initiates an internal time delay that delays the return of the reset outputs to their inactive states. Since the time delay for most microcomputers and microprocessors is in the order of several machine cycles, the device internal time delay is determined by an external capacitor connected to the C<sub>T</sub> input (pin 3).

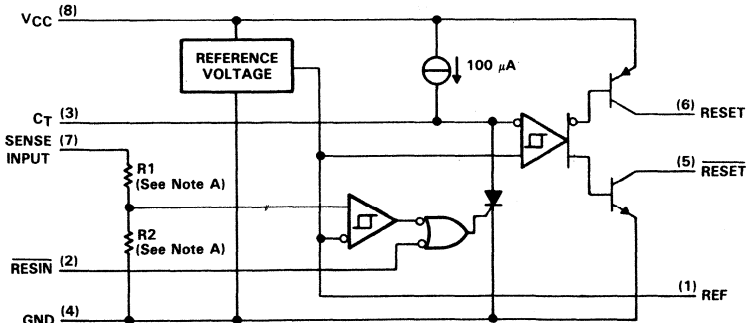
$$t_d = 1.3 \times 10^4 \times C_T$$

Where: C<sub>T</sub> is in farads (F) and t<sub>d</sub> is in seconds(s)

In addition, when the supply voltage drops below the nominal value, the outputs will be active until the supply voltage returns to the nominal value. An external capacitor (typically 0.1 μF) must be connected to the REF output (pin 1) to reduce the influence of fast transients in the supply voltage.

The TL7702A series is characterized for operation from -25°C to 85°C; the TL7702AC series is characterized from 0°C to 70°C.

**functional block diagram**



NOTE A: TL7702A: R1 = 0 Ω, R2 = open  
 TL7705A: R1 = 7.8 kΩ, R2 = 10 kΩ  
 TL7709A: R1 = 19.7 kΩ, R2 = 10 kΩ  
 TL7712A: R1 = 32.7 kΩ, R2 = 10 kΩ  
 TL7715A: R1 = 43.4 kΩ, R2 = 10 kΩ

# TYPES TL7702A, TL7705A, TL7709A, TL7712A, TL7715A SUPPLY VOLTAGE SUPERVISORS

## absolute maximum ratings over operating free-air temperature (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	20 V
Input voltage range at $\overline{RESIN}$	-0.3 V to 20 V
Input voltage at SENSE:	
TL7702A (see Note 2)	-0.3 V to 6 V
TL7705A	-0.3 V to 10 V
TL7709A	-0.3 V to 15 V
TL7712A	-0.3 V to 20 V
TL7715A	-0.3 V to 20 V
High-level output current at $\overline{RESET}$	-30 mA
Low-level output current at $\overline{RESET}$	30 mA
Operating free-air temperature range:	
TL77 - AI	-40° to 85°C
TL77 - AC	0°C to 70°C
Storage temperature range	-65°C to 150°C

- NOTES: 1. All voltage values are with respect to the network ground terminal.  
2. For the TL7702A, the voltage applied to the SENSE terminal must never exceed  $V_{CC}$ .

## recommended operating conditions

		MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$		3.6		18	V
High-level input voltage at $\overline{RESIN}$ , $V_{IH}$		2			V
Low-level input voltage at $\overline{RESIN}$ , $V_{IL}$				0.6	V
Voltage at sense input, $V_I$ :	TL7702A	0	See Note 3		V
	TL7705A	0	10		
	TL7709A	0	15		
	TL7712A	0	20		
	TL7715A	0	20		
High-level output current at $\overline{RESET}$ , $I_{OH}$				-16	mA
Low-level output current at $\overline{RESET}$ , $I_{OL}$				16	mA
Operating free-air temperature range, $T_A$ :	TL77 - AI	-40	85		°C
	TL77 - AC	0	70		

NOTE 3: For proper operation of the TL7702A, the voltage applied to the SENSE terminal should not exceed  $V_{CC} - 1$  V or 6 V, whichever is less.

# TYPES TL7702A, TL7705A, TL7709A, TL7712A, TL7715A SUPPLY VOLTAGE SUPERVISORS

electrical characteristics over recommended ranges of supply voltage, input voltage, output current, and free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS <sup>†</sup>	MIN	TYP	MAX	UNIT	
V <sub>OH</sub>	High-level output voltage at RESET	I <sub>OH</sub> = -16 mA	V <sub>CC</sub> - 1.5			V	
V <sub>OL</sub>	Low-level output voltage at RESET	I <sub>OL</sub> = 16 mA	0.4			V	
V <sub>ref</sub>	Reference voltage	T <sub>A</sub> = 25°C	2.48	2.53	2.58	V	
V <sub>T</sub>	Threshold voltage at SENSE input	V <sub>CC</sub> = 3.6 V to 18 V T <sub>A</sub> = 25°C	TL7702A	2.48	2.53	2.58	V
			TL7705A	4.5	4.55	4.6	
			TL7709A	7.5	7.6	7.7	
			TL7712A	10.6	10.8	11	
			TL7715A	13.2	13.5	13.8	
V <sub>T</sub>	Threshold voltage at SENSE input	V <sub>CC</sub> = 3.6 V to 18 V	TL7702A	2.45	2.53	2.58	V
			TL7705A	4.45	4.55	4.6	V
			TL7709A	7.4	7.6	7.7	V
			TL7712A	10.4	10.8	11.0	V
			TL7715A	13.0	13.5	13.8	V
V <sub>T+</sub> - V <sub>T-</sub>	Hysteresis <sup>‡</sup> at SENSE input	V <sub>CC</sub> = 3.6 V to 18 V, T <sub>A</sub> = 25°C	TL7702A	10		mV	
			TL7705A	15			
			TL7709A	20			
			TL7712A	35			
			TL7715A	45			
I <sub>I</sub>	Input current at $\overline{\text{RESIN}}$ input	V <sub>I</sub> = 2.4 V to V <sub>CC</sub>	20			μA	
		V <sub>I</sub> = 0.4 V	-100				
I <sub>I</sub>	Input current at SENSE input	TL7702A V <sub>ref</sub> < V <sub>I</sub> < V <sub>CC</sub> - 1.5 V	0.5	2		μA	
I <sub>OH</sub>	High-level output current at RESET	V <sub>O</sub> = 18 V	50			μA	
I <sub>OL</sub>	Low-level output current at RESET	V <sub>O</sub> = 0	-50			μA	
I <sub>CC</sub>	Supply current	All inputs and outputs open	1.8	3		mA	

<sup>†</sup>All characteristics are measured with C = 0.1 μF from Pin 1 to GND, and with C = 0.1 μF from Pin 3 to GND.

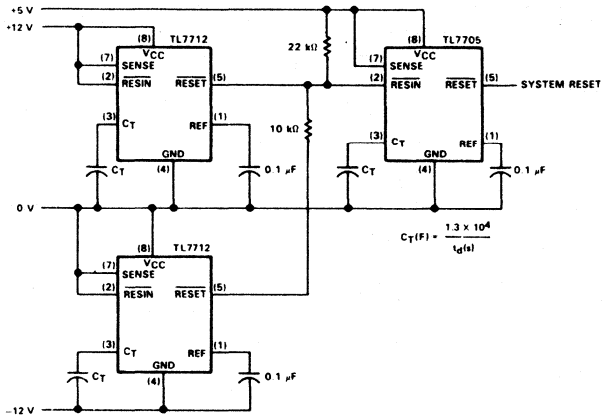
<sup>‡</sup>Hysteresis is the difference between the positive-going input threshold voltage, V<sub>T+</sub>, and the negative-going input threshold voltage, V<sub>T-</sub>.

## SWITCHING CHARACTERISTICS OVER FULL RANGE OF RECOMMENDED OPERATING CONDITIONS

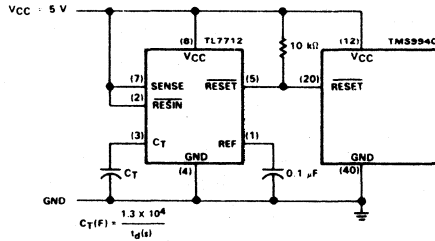
Parameter	Test conditions	min	typ	max	Unit	
t <sub>pi</sub>	Pulse width at SENSE input	V <sub>ih</sub> = V <sub>styp</sub> + 0.04 × V <sub>s</sub> V <sub>il</sub> = V <sub>styp</sub> - 0.04 × V <sub>s</sub>	.9			μs
t <sub>pi</sub>	Pulse width at RESIN input		.4			μs
t <sub>po</sub>	Pulse width at output	C <sub>t</sub> = .1 μF	.65	1.3	2.6	ms
t <sub>pdHL</sub>	Propagation delay time from $\overline{\text{RESIN}}$ to RESET	C <sub>L</sub> = 100pF; V <sub>CC</sub> = 5V R <sub>L</sub> = 4.7 kOhm			1	μs
t <sub>r/f</sub>	Rise/Falltime at RESET and RESET	C <sub>L</sub> = 100pF; V <sub>CC</sub> = 5V R <sub>L</sub> = 4.7 kOhm			1	μs

**TYPES TL7702A, TL7705A, TL7709A, TL7712A, TL7715A  
SUPPLY VOLTAGE SUPERVISORS**

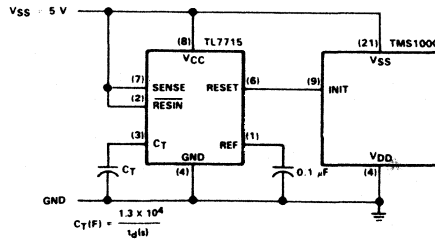
**TYPICAL APPLICATION DATA**



**FIGURE 3 – MULTIPLE POWER SUPPLY SYSTEM RESET GENERATION**



**FIGURE 4 – RESET CONTROLLER FOR TMS9940 SYSTEM**



**FIGURE 5 – RESET CONTROLLER FOR TMS1000**

Voltage Regulators



- 150-mA Load Current Without External Power Transistor
- Typically 0.02% Input Regulation and 0.03% Load Regulation ( $\mu$ A723M)
- Adjustable Current Limiting Capability
- Input Voltages to 40 Volts
- Output Adjustable from 2 to 37 Volts
- Direct Replacement for Fairchild  $\mu$ A723M and  $\mu$ A723C

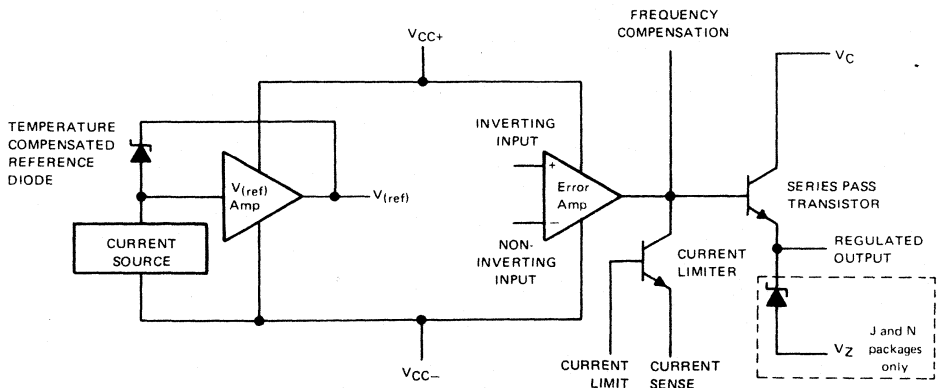
**description**

The  $\mu$ A723M and  $\mu$ A723C are monolithic integrated circuit voltage regulators featuring high ripple rejection, excellent input and load regulation, excellent temperature stability, and low standby current. The circuit consists of a temperature-compensated reference voltage amplifier, an error amplifier, a 150-milliamper output transistor, and an adjustable output current limiter.

The  $\mu$ A723M and  $\mu$ A723C are designed for use in positive or negative power supplies as a series, shunt, switching, or floating regulator. For output currents exceeding 150 mA, additional pass elements may be connected as shown in Figure 4 and 5.

The  $\mu$ A723M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The  $\mu$ A723C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

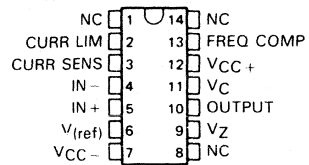
**functional block diagram**



$\mu$ A723M . . . J PACKAGE

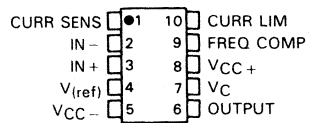
$\mu$ A723C . . . J OR N PACKAGE

(TOP VIEW)



$\mu$ A723M . . . U PACKAGE

(TOP VIEW)

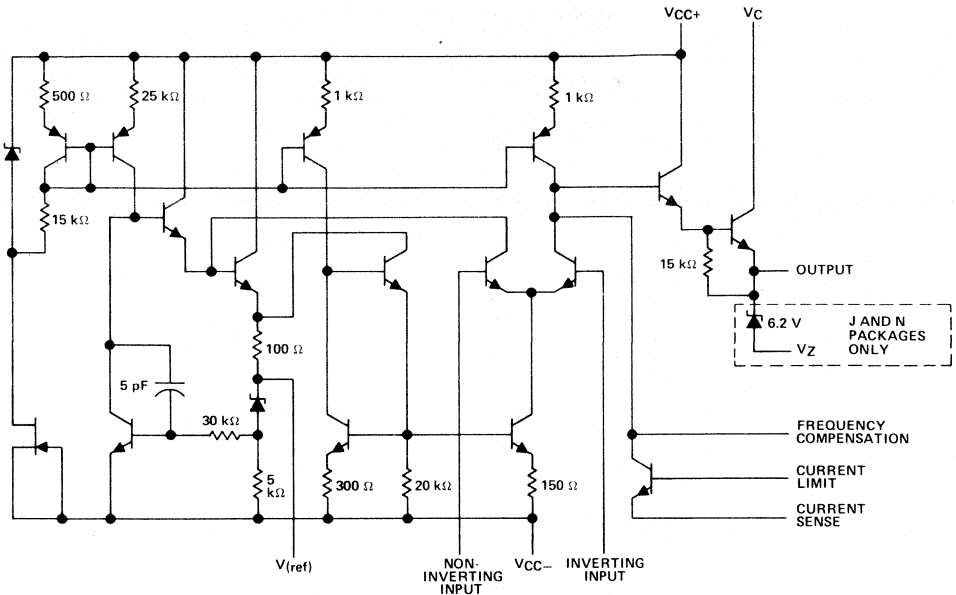


NC - No internal connection



# TYPES $\mu$ A723M, $\mu$ A723C PRECISION VOLTAGE REGULATORS

schematic



RESISTOR AND CAPACITOR VALUES SHOWN ARE NOMINAL.

DISSIPATION DERATING TABLE

POWER	POWER RATING	DERATING FACTOR	ABOVE $T_A$
J (Alloy-Mounted Chip)	1000 mW	11.0 mW/°C	59°C
J (Glass-Mounted Chip)	1000 mW	8.2 mW/°C	28°C
N	1000 mW	9.2 mW/°C	41°C
U	675 mW	5.4 mW/°C	25°C

Voltage Regulators

6

# TYPES $\mu$ A723M, $\mu$ A723C PRECISION VOLTAGE REGULATORS

## TYPICAL APPLICATION DATA

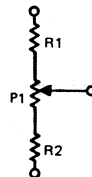
TABLE I  
RESISTOR VALUES (k $\Omega$ ) FOR STANDARD OUTPUT VOLTAGES

OUTPUT VOLTAGE (V)	APPLICABLE FIGURES (SEE NOTE 3)	FIXED OUTPUT $\pm 5\%$		OUTPUT ADJUSTABLE $\pm 10\%$ (SEE NOTE 4)			OUTPUT VOLTAGE (V)	APPLICABLE FIGURES (SEE NOTE 3)	FIXED OUTPUT $\pm 5\%$		OUTPUT ADJUSTABLE $\pm 10\%$ (SEE NOTE 4)		
		R1 (k $\Omega$ )	R2 (k $\Omega$ )	R1 (k $\Omega$ )	P1 (k $\Omega$ )	R2 (k $\Omega$ )			R1 (k $\Omega$ )	R2 (k $\Omega$ )	R1 (k $\Omega$ )	P1 (k $\Omega$ )	R2 (k $\Omega$ )
+3.0	1, 5, 6, 9, 11, 12 (4)	4.12	3.01	1.8	0.5	1.2	+100	7	3.57	105	2.2	10	91
+3.6	1, 5, 6, 9, 11, 12 (4)	3.57	3.65	1.5	0.5	1.5	+250	7	3.57	255	2.2	10	240
+5.0	1, 5, 6, 9, 11, 12 (4)	2.15	4.99	0.75	0.5	2.2	-6 (Note 5)	3, (10)	3.57	2.43	1.2	0.5	0.75
+6.0	1, 5, 6, 9, 11, 12 (4)	1.15	6.04	0.5	0.5	2.7	-9	3, 10	3.48	5.36	1.2	0.5	2.0
+9.0	2, 4, (5, 6, 9, 12)	1.87	7.15	0.75	1.0	2.7	-12	3, 10	3.57	8.45	1.2	0.5	3.3
+12	2, 4, (5, 6, 9, 12)	4.87	7.15	2.0	1.0	3.0	-15	3, 10	3.57	11.5	1.2	0.5	4.3
+15	2, 4, (5, 6, 9, 12)	7.87	7.15	3.3	1.0	3.0	-28	3, 10	3.57	24.3	1.2	0.5	10
+28	2, 4, (5, 6, 9, 12)	21.0	7.15	5.6	1.0	2.0	-45	8	3.57	41.2	2.2	10	33
+45	7	3.57	48.7	2.2	10	39	-100	8	3.57	95.3	2.2	10	91
+75	7	3.57	78.7	2.2	10	68	-250	8	3.57	249	2.2	10	240

TABLE II  
FORMULAS FOR INTERMEDIATE OUTPUT VOLTAGES

<p>Outputs from +2 to +7 volts [Figures 1, 5, 6, 9, 11, 12, (4)]</p> $V_O = V_{(ref)} \times \frac{R_2}{R_1 + R_2}$	<p>Outputs from +4 to +250 volts [Figure 7]</p> $V_O = \frac{V_{(ref)}}{2} \times \frac{R_2 - R_1}{R_1};$ <p>R3 = R4</p>	<p>Current Limiting</p> $I_{(limit)} \approx \frac{0.65 V}{R_{sc}}$
<p>Outputs from +7 to +37 volts [Figures 2, 4, (5, 6, 9, 11, 12)]</p> $V_O = V_{(ref)} \times \frac{R_1 + R_2}{R_2}$	<p>Outputs from -6 to -250 volts [Figures 3, 8, 10]</p> $V_O = -\frac{V_{(ref)}}{2} \times \frac{R_1 + R_2}{R_1};$ <p>R3 = R4</p>	<p>Foldback Current Limiting [Figure 6]</p> $I_{(knee)} \approx \frac{V_O R_3 + (R_3 + R_4) 0.65 V}{R_{sc} R_4}$ $I_{OS} \approx \frac{0.65 V}{R_{sc}} \times \frac{R_3 + R_4}{R_4}$

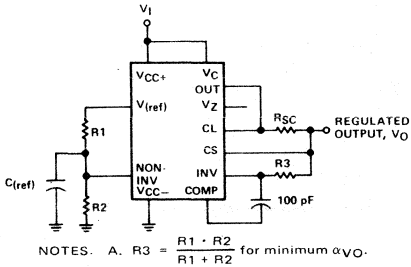
- NOTES: 3. The R1/R2 divider may be across either  $V_O$  or  $V_{(ref)}$ . If the divider is across  $V_{(ref)}$  and uses figures without parentheses, use figures with parentheses when the divider is across  $V_O$ .
4. To make the voltage adjustable, the R1/R2 divider shown in the figures must be replaced by the divider shown at the right.
5. The device requires a minimum of 9 V between  $V_{CC+}$  and  $V_{CC-}$  when  $V_O$  is equal to or more positive than -9 V.



ADJUSTABLE OUTPUT CIRCUITS

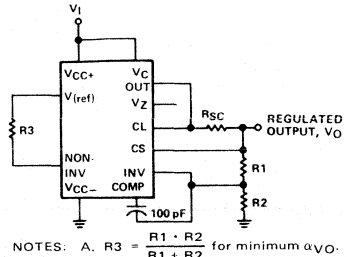


TYPICAL APPLICATION DATA



- NOTES: A.  $R_3 = \frac{R_1 \cdot R_2}{R_1 + R_2}$  for minimum  $\alpha V_O$ .  
B.  $R_3$  may be eliminated for minimum component count. Use direct connection (i.e.,  $R_3 = 0$ ).

FIGURE 1—BASIC LOW-VOLTAGE REGULATOR ( $V_O = 2$  TO 7 VOLTS)



- NOTES: A.  $R_3 = \frac{R_1 \cdot R_2}{R_1 + R_2}$  for minimum  $\alpha V_O$ .  
B.  $R_3$  may be eliminated for minimum component count. Use direct connection (i.e.,  $R_3 = 0$ ).

FIGURE 2—BASIC HIGH-VOLTAGE REGULATOR ( $V_O = 7$  TO 37 VOLTS)

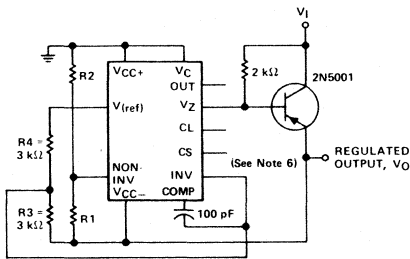


FIGURE 3—NEGATIVE-VOLTAGE REGULATOR

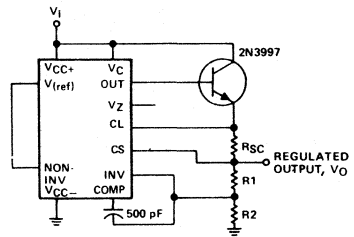


FIGURE 4—POSITIVE-VOLTAGE REGULATOR (EXTERNAL N-P-N PASS TRANSISTOR)

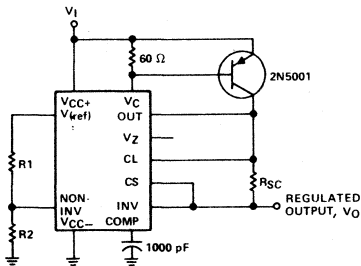


FIGURE 5—POSITIVE-VOLTAGE REGULATOR (EXTERNAL P-N-P PASS TRANSISTOR)

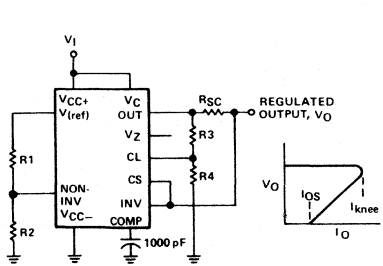


FIGURE 6—FOLDBACK CURRENT LIMITING

# TYPES $\mu$ A723M, $\mu$ A723C PRECISION VOLTAGE REGULATORS

## TYPICAL APPLICATION DATA

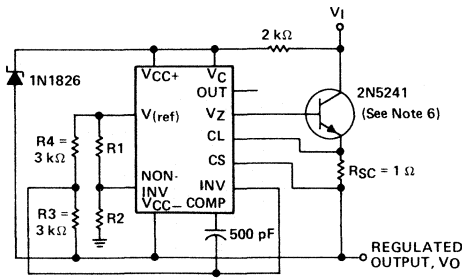


FIGURE 7—POSITIVE FLOATING REGULATOR

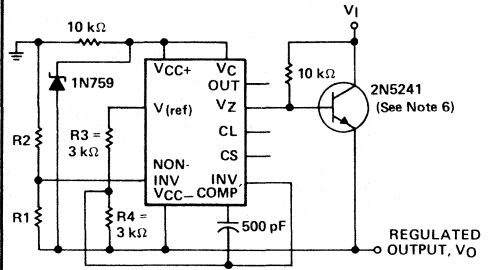


FIGURE 8—NEGATIVE FLOATING REGULATOR

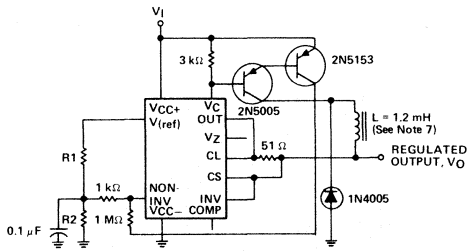


FIGURE 9—POSITIVE SWITCHING REGULATOR

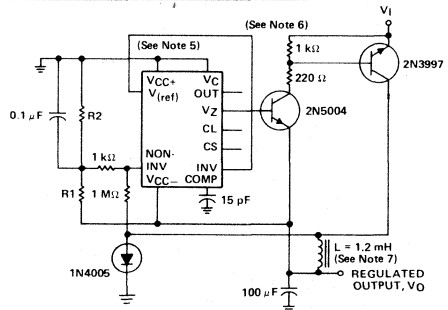
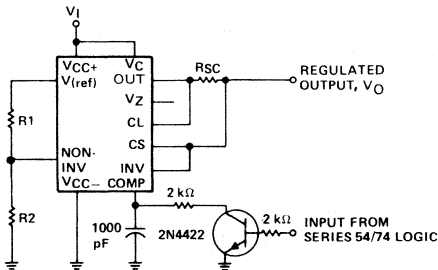


FIGURE 10—NEGATIVE SWITCHING REGULATOR



NOTE A: Current limit transistor may be used for shutdown if current limiting is not required.

FIGURE 11—REMOTE SHUTDOWN REGULATOR WITH CURRENT LIMITING

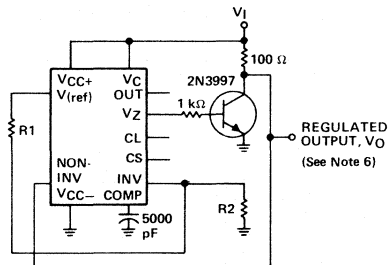


FIGURE 12—SHUNT REGULATOR

- NOTES: 5. The device requires a minimum of 9 V between  $V_{CC+}$  and  $V_{CC-}$  when  $V_O$  is equal to or more positive than  $-9$  V.  
6. When 10-lead  $\mu$ A723 devices are used in applications requiring  $V_Z$ , an external 6.2-V regulator diode must be connected in series with the  $V_O$  terminal.  
7. L is 40 turns of No. 20 enameled copper wire wound on Ferroxcube P36/22-3B7 potted core, or equivalent, with 0.009-inch air gap.

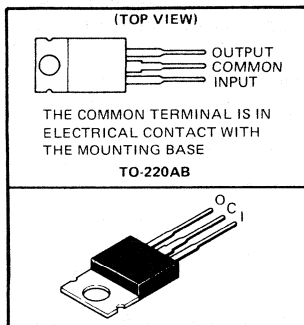
- 3-Terminal Regulators
- Output Current up to 1.5 A
- No External Components
- Internal Thermal Overload Protection
- High Power Dissipation Capability
- Internal Short-Circuit Current Limiting
- Output Transistor Safe-Area Compensation
- Direct replacements for Fairchild  $\mu$ A7800 Series

NOMINAL OUTPUT VOLTAGE	REGULATOR
5 V	$\mu$ A7805C
6 V	$\mu$ A7806C
8 V	$\mu$ A7808C
8.5 V	$\mu$ A7885C
10 V	$\mu$ A7810C
12 V	$\mu$ A7812C
15 V	$\mu$ A7815C
18 V	$\mu$ A7818C
24 V	$\mu$ A7824C

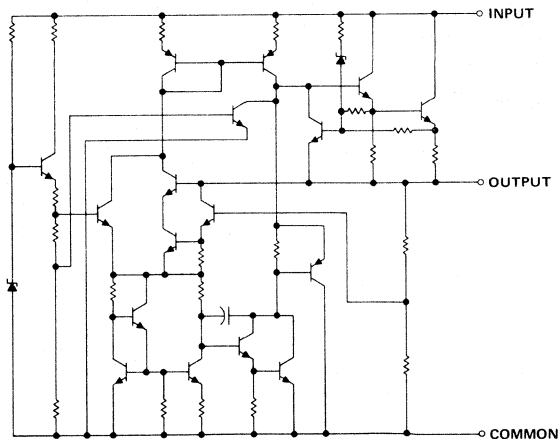
**description**

This series of fixed-voltage monolithic integrated-circuit voltage regulators is designed for a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Each of these regulators can deliver up to 1.5 amperes of output current. The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. In addition to use as fixed-voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents and also as the power-pass element in precision regulators.

**KC PACKAGE**



**schematic**



Resistor values shown are nominal and in ohms.

# SERIES $\mu$ A7800

## POSITIVE-VOLTAGE REGULATORS

absolute maximum ratings over operating temperature range (unless otherwise noted)

	$\mu$ A7824C	$\mu$ A78...C	UNIT
Input voltage	$\mu$ A7824C	40	V
	All others	35	
Continuous total dissipation at 25°C free-air temperature (see Note 1)		2	W
Continuous total dissipation at (or below) 25°C case temperature (see Note 1)		15	W
Operating free-air, case, or virtual junction temperature range		0 to 150	°C
Storage temperature range		-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds		260	°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

FREE-AIR TEMPERATURE  
DISSIPATION DERATING CURVE

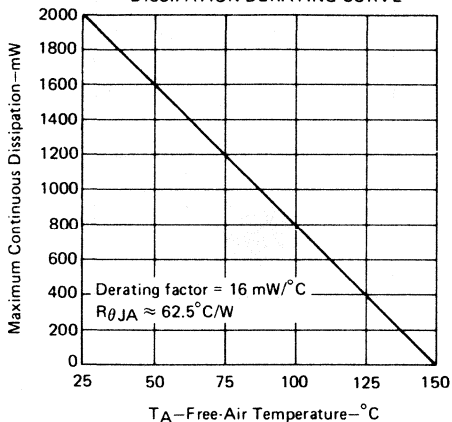


FIGURE 1

CASE TEMPERATURE  
DISSIPATION DERATING CURVE

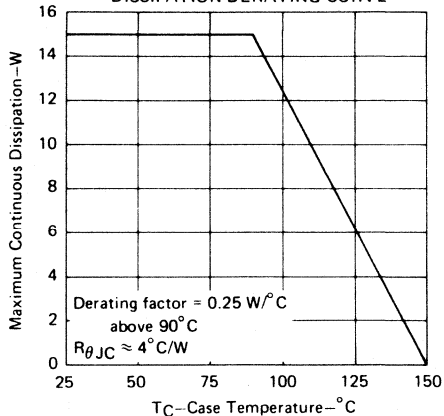


FIGURE 2

### recommended operating conditions

	MIN	MAX	UNIT	
Input voltage, $V_I$	$\mu$ A7805C	7	25	V
	$\mu$ A7806C	8	25	
	$\mu$ A7808C	10.5	25	
	$\mu$ A7885C	10.5	25	
	$\mu$ A7810C	12.5	28	
	$\mu$ A7812C	14.5	30	
	$\mu$ A7815C	17.5	30	
	$\mu$ A7818C	21	33	
	$\mu$ A7824C	27	38	
Output current, $I_O$		1.5	A	
Operating virtual junction temperature, $T_J$	0	125	°C	

## TYPES $\mu$ A7805C, $\mu$ A7806C POSITIVE-VOLTAGE REGULATORS

$\mu$ A7805C electrical characteristics at specified virtual junction temperature,  
 $V_I = 10\text{ V}$ ,  $I_O = 500\text{ mA}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	$\mu$ A7805C			UNIT	
		MIN	TYP	MAX		
Output voltage	$I_O = 5\text{ mA to }1\text{ A}$ , $P \leq 15\text{ W}$ $V_I = 7\text{ V to }20\text{ V}$	$25^\circ\text{C}$	4.8	5	5.2	V
		$0^\circ\text{C to }125^\circ\text{C}$	4.75		5.25	
Input regulation	$V_I = 7\text{ V to }25\text{ V}$	$25^\circ\text{C}$		3	100	mV
	$V_I = 8\text{ V to }12\text{ V}$			1	50	
Ripple rejection	$V_I = 8\text{ V to }18\text{ V}$ , $f = 120\text{ Hz}$	$0^\circ\text{C to }125^\circ\text{C}$	62	78		dB
Output regulation	$I_O = 5\text{ mA to }1.5\text{ A}$	$25^\circ\text{C}$		15	100	mV
	$I_O = 250\text{ mA to }750\text{ mA}$			5	50	
Output resistance	$f = 1\text{ kHz}$	$0^\circ\text{C to }125^\circ\text{C}$	0.017			$\Omega$
Temperature coefficient of output voltage	$I_O = 5\text{ mA}$	$0^\circ\text{C to }125^\circ\text{C}$	-1.1			mV/°C
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$	$25^\circ\text{C}$	40			$\mu\text{V}$
Dropout voltage	$I_O = 1\text{ A}$	$25^\circ\text{C}$	2.0			V
Bias current		$25^\circ\text{C}$	4.2		8	mA
Bias current change	$V_I = 7\text{ V to }25\text{ V}$	$0^\circ\text{C to }125^\circ\text{C}$			1.3	mA
	$I_O = 5\text{ mA to }1\text{ A}$				0.5	
Short-circuit output current		$25^\circ\text{C}$	750			mA
Peak output current		$25^\circ\text{C}$	2.2			A

$\mu$ A7806C electrical characteristics at specified virtual junction temperature,  
 $V_I = 11\text{ V}$ ,  $I_O = 500\text{ mA}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	$\mu$ A7806C			UNIT	
		MIN	TYP	MAX		
Output voltage	$I_O = 5\text{ mA to }1\text{ A}$ , $P \leq 15\text{ W}$ $V_I = 8\text{ V to }21\text{ V}$	$25^\circ\text{C}$	5.75	6	6.25	V
		$0^\circ\text{C to }125^\circ\text{C}$	5.7		6.3	
Input regulation	$V_I = 8\text{ V to }25\text{ V}$	$25^\circ\text{C}$		5	120	mV
	$V_I = 9\text{ V to }13\text{ V}$			1.5	60	
Ripple rejection	$V_I = 9\text{ V to }19\text{ V}$ , $f = 120\text{ Hz}$	$0^\circ\text{C to }125^\circ\text{C}$	59	75		dB
Output regulation	$I_O = 5\text{ mA to }1.5\text{ A}$	$25^\circ\text{C}$		14	120	mV
	$I_O = 250\text{ mA to }750\text{ mA}$			4	60	
Output resistance	$f = 1\text{ kHz}$	$0^\circ\text{C to }125^\circ\text{C}$	0.019			$\Omega$
Temperature coefficient of output voltage	$I_O = 5\text{ mA}$	$0^\circ\text{C to }125^\circ\text{C}$	-0.8			mV/°C
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$	$25^\circ\text{C}$	45			$\mu\text{V}$
Dropout voltage	$I_O = 1\text{ A}$	$25^\circ\text{C}$	2.0			V
Bias current		$25^\circ\text{C}$	4.3		8	mA
Bias current change	$V_I = 8\text{ V to }25\text{ V}$	$0^\circ\text{C to }125^\circ\text{C}$			1.3	mA
	$I_O = 5\text{ mA to }1\text{ A}$				0.5	
Short-circuit output current		$25^\circ\text{C}$	550			mA
Peak output current		$25^\circ\text{C}$	2.2			A

†All characteristics are measured with a capacitor across the input of  $0.33\ \mu\text{F}$  and a capacitor across the output of  $0.1\ \mu\text{F}$ . All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_W \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

## TYPES $\mu$ A7808C, $\mu$ A7885C POSITIVE-VOLTAGE REGULATORS

$\mu$ A7808C electrical characteristics at specified virtual junction temperature,  
 $V_I = 14$  V,  $I_O = 500$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A7808C			UNIT
			MIN	TYP	MAX	
Output voltage	$I_O = 5$ mA to 1 A, $P \leq 15$ W	$V_I = 10.5$ V to 23 V, 25°C	7.7	8	8.3	V
		$0^\circ$ C to 125°C	7.6		8.4	
Input regulation	$V_I = 10.5$ V to 25 V	25°C		6	160	mV
	$V_I = 11$ V to 17 V			2	80	
Ripple rejection	$V_I = 11.5$ V to 21.5 V, $f = 120$ Hz	$0^\circ$ C to 125°C	56	72		dB
Output regulation	$I_O = 5$ mA to 1.5 A	25°C		12	160	mV
	$I_O = 250$ mA to 750 mA			4	80	
Output resistance	$f = 1$ kHz	$0^\circ$ C to 125°C		0.016		$\Omega$
Temperature coefficient of output voltage	$I_O = 5$ mA	$0^\circ$ C to 125°C		-0.8		mV/°C
Output noise voltage	$f = 10$ Hz to 100 kHz	25°C		52		$\mu$ V
Dropout voltage	$I_O = 1$ A	25°C		2.0		V
Bias current		25°C		4.3	8	mA
Bias current change	$V_I = 10.5$ V to 25 V	$0^\circ$ C to 125°C			1	mA
	$I_O = 5$ mA to 1 A				0.5	
Short-circuit output current		25°C		450		mA
Peak output current		25°C		2.2		A

$\mu$ A7885C electrical characteristics at specified virtual junction temperature,  
 $V_I = 15$  V,  $I_O = 500$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A7885C			UNIT
			MIN	TYP	MAX	
Output voltage	$I_O = 5$ mA to 1 A, $P \leq 15$ W	$V_I = 11$ V to 23.5 V, 25°C	8.15	8.5	8.85	V
		$0^\circ$ C to 125°C	8.1		8.9	
Input regulation	$V_I = 10.5$ V to 25 V	25°C		6	170	mV
	$V_I = 11$ V to 17 V			2	85	
Ripple rejection	$V_I = 11.5$ V to 21.5 V, $f = 120$ Hz	$0^\circ$ C to 125°C	54	70		dB
Output regulation	$I_O = 5$ mA to 1.5 A	25°C		12	170	mV
	$I_O = 250$ mA to 750 mA			4	85	
Output resistance	$f = 1$ kHz	$0^\circ$ C to 125°C		0.016		$\Omega$
Temperature coefficient of output voltage	$I_O = 5$ mA	$0^\circ$ C to 125°C		-0.8		mV/°C
Output noise voltage	$f = 10$ Hz to 100 kHz	25°C		55		$\mu$ V
Dropout voltage	$I_O = 1$ A	25°C		2.0		V
Bias current		25°C		4.3	8	mA
Bias current change	$V_I = 10.5$ V to 25 V	$0^\circ$ C to 125°C			1	mA
	$I_O = 5$ mA to 1 A				0.5	
Short-circuit output current		25°C		450		mA
Peak output current		25°C		2.2		A

† All characteristics are measured with a capacitor across the input of 0.33  $\mu$ F and a capacitor across the output of 0.1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

## TYPES $\mu$ A7810C, $\mu$ A7812C POSITIVE-VOLTAGE REGULATORS

$\mu$ A7810C electrical characteristics at specified virtual junction temperature,  
 $V_I = 17\text{ V}$ ,  $I_O = 500\text{ mA}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A7810C			UNIT	
			MIN	TYP	MAX		
Output voltage			25°C	9.6	10	10.4	V
	$I_O = 5\text{ mA to }1\text{ A}$ , $P \leq 15\text{ W}$	$V_I = 12.5\text{ V to }25\text{ V}$	0°C to 125°C	9.5	10	10.5	
Input regulation	$V_I = 12.5\text{ V to }28\text{ V}$		25°C	7		200	mV
	$V_I = 14\text{ V to }20\text{ V}$			2		100	
Ripple rejection	$V_I = 13\text{ V to }23\text{ V}$ ,	$f = 120\text{ Hz}$	0°C to 125°C	55	71		dB
Output regulation	$I_O = 5\text{ mA to }1.5\text{ A}$		25°C	12		200	mV
	$I_O = 250\text{ mA to }750\text{ mA}$			4		100	
Output resistance	$f = 1\text{ kHz}$		0°C to 125°C	0.018			$\Omega$
Temperature coefficient of output voltage	$I_O = 5\text{ mA}$		0°C to 125°C	-1.0			mV/°C
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$		25°C	70			$\mu\text{V}$
Dropout voltage	$I_O = 1\text{ A}$		25°C	2.0			V
Bias current			25°C	4.3	8		mA
Bias current change	$V_I = 12.5\text{ V to }28\text{ V}$		0°C to 125°C	1			mA
	$I_O = 5\text{ mA to }1\text{ A}$			0.5			
Short-circuit output current			25°C	400			mA
Peak output current			25°C	2.2			A

$\mu$ A7812C electrical characteristics at specified virtual junction temperature,  
 $V_I = 19\text{ V}$ ,  $I_O = 500\text{ mA}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A7812C			UNIT	
			MIN	TYP	MAX		
Output voltage			25°C	11.5	12	12.5	V
	$I_O = 5\text{ mA to }1\text{ A}$ , $P \leq 15\text{ W}$	$V_I = 14.5\text{ V to }27\text{ V}$	0°C to 125°C	11.4		12.6	
Input regulation	$V_I = 14.5\text{ V to }30\text{ V}$		25°C	10		240	mV
	$V_I = 16\text{ V to }22\text{ V}$			3		120	
Ripple rejection	$V_I = 15\text{ V to }25\text{ V}$ ,	$f = 120\text{ Hz}$	0°C to 125°C	55	71		dB
Output regulation	$I_O = 5\text{ mA to }1.5\text{ A}$		25°C	12		240	mV
	$I_O = 250\text{ mA to }750\text{ mA}$			4		120	
Output resistance	$f = 1\text{ kHz}$		0°C to 125°C	0.018			$\Omega$
Temperature coefficient of output voltage	$I_O = 5\text{ mA}$		0°C to 125°C	-1.0			mV/°C
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$		25°C	75			$\mu\text{V}$
Dropout voltage	$I_O = 1\text{ A}$		25°C	2.0			V
Bias current			25°C	4.3	8		mA
Bias current change	$V_I = 14.5\text{ V to }30\text{ V}$		0°C to 125°C	1			mA
	$I_O = 5\text{ mA to }1\text{ A}$			0.5			
Short-circuit output current			25°C	350			mA
Peak output current			25°C	2.2			A

† All characteristics are measured with a capacitor across the input of 0.33  $\mu\text{F}$  and a capacitor across the output of 0.1  $\mu\text{F}$ . All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_W \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

## TYPES $\mu$ A7815C, $\mu$ A7818C POSITIVE-VOLTAGE REGULATORS

$\mu$ A7815C electrical characteristics at specified virtual junction temperature,  
 $V_I = 23$  V,  $I_O = 500$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A7815C			UNIT
			MIN	TYP	MAX	
Output voltage	$I_O = 5$ mA to 1 A, $P \leq 15$ W	$V_I = 17.5$ V to 30 V, $0^\circ\text{C}$ to $125^\circ\text{C}$	14.4	15	15.6	V
		$0^\circ\text{C}$ to $125^\circ\text{C}$	14.25		15.75	
Input regulation	$V_I = 17.5$ V to 30 V	$25^\circ\text{C}$		11	300	mV
	$V_I = 20$ V to 26 V			3	150	
Ripple rejection	$V_I = 18.5$ V to 28.5 V, $f = 120$ Hz	$0^\circ\text{C}$ to $125^\circ\text{C}$	54	70		dB
Output regulation	$I_O = 5$ mA to 1.5 A	$25^\circ\text{C}$		12	300	mV
	$I_O = 250$ mA to 750 mA			4	150	
Output resistance	$f = 1$ kHz	$0^\circ\text{C}$ to $125^\circ\text{C}$	0.019			$\Omega$
Temperature coefficient of output voltage	$I_O = 5$ mA	$0^\circ\text{C}$ to $125^\circ\text{C}$	-1.0			$\text{mV}/^\circ\text{C}$
Output noise voltage	$f = 10$ Hz to 100 kHz	$25^\circ\text{C}$	90			$\mu\text{V}$
Dropout voltage	$I_O = 1$ A	$25^\circ\text{C}$	2.0			V
Bias current		$25^\circ\text{C}$	4.4	8		mA
Bias current change	$V_I = 17.5$ V to 30 V	$0^\circ\text{C}$ to $125^\circ\text{C}$			1	mA
	$I_O = 5$ mA to 1 A				0.5	
Short-circuit output current		$25^\circ\text{C}$	230			mA
Peak output current		$25^\circ\text{C}$	2.1			A

$\mu$ A7818C electrical characteristics at specified virtual junction temperature,  
 $V_I = 27$  V,  $I_O = 500$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A7818C			UNIT
			MIN	TYP	MAX	
Output voltage	$I_O = 5$ mA to 1 A, $P \leq 15$ W	$V_I = 21$ V to 33 V, $0^\circ\text{C}$ to $125^\circ\text{C}$	17.3	18	18.7	V
		$0^\circ\text{C}$ to $125^\circ\text{C}$	17.1		18.9	
Input regulation	$V_I = 21$ V to 33 V	$25^\circ\text{C}$		15	360	mV
	$V_I = 24$ V to 30 V			5	180	
Ripple rejection	$V_I = 22$ V to 32 V, $f = 120$ Hz	$0^\circ\text{C}$ to $125^\circ\text{C}$	53	69		dB
Output regulation	$I_O = 5$ mA to 1.5 A	$25^\circ\text{C}$		12	360	mV
	$I_O = 250$ mA to 750 mA			4	180	
Output resistance	$f = 1$ kHz	$0^\circ\text{C}$ to $125^\circ\text{C}$	0.022			$\Omega$
Temperature coefficient of output voltage	$I_O = 5$ mA	$0^\circ\text{C}$ to $125^\circ\text{C}$	-1.0			$\text{mV}/^\circ\text{C}$
Output noise voltage	$f = 10$ Hz to 100 kHz	$25^\circ\text{C}$	110			$\mu\text{V}$
Dropout voltage	$I_O = 1$ A	$25^\circ\text{C}$	2.0			V
Bias current		$25^\circ\text{C}$	4.5	8		mA
Bias current change	$V_I = 21$ V to 33 V	$0^\circ\text{C}$ to $125^\circ\text{C}$			1	mA
	$I_O = 5$ mA to 1 A				0.5	
Short-circuit output current		$25^\circ\text{C}$	200			mA
Peak output current		$25^\circ\text{C}$	2.1			A

† All characteristics are measured with a capacitor across the input of 0.33  $\mu\text{F}$  and a capacitor across the output of 0.1  $\mu\text{F}$ . All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.



## TYPES $\mu$ A7822C, $\mu$ A7824C POSITIVE-VOLTAGE REGULATORS

$\mu$ A7824C electrical characteristics at specified virtual junction temperature,  
 $V_I = 33$  V,  $I_O = 500$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	$\mu$ A7824C			UNIT	
		MIN	TYP	MAX		
Output voltage	$I_O = 5$ mA to 1 A, $V_I = 27$ V to 38 V, $P \leq 15$ W	25°C	23	24	25	V
		0°C to 125°C	22.8		25.2	
Input regulation	$V_I = 27$ V to 38 V	25°C	18	480		mV
	$V_I = 30$ V to 36 V		6	240		
Ripple rejection	$V_I = 28$ V to 38 V, $f = 120$ Hz	0°C to 125°C	50	66		dB
Output regulation	$I_O = 5$ mA to 1.5 A	25°C	12	480		mV
	$I_O = 250$ mA to 750 mA		4	240		
Output resistance	$f = 1$ kHz	0°C to 125°C	0.028			$\Omega$
Temperature coefficient of output voltage	$I_O = 5$ mA	0°C to 125°C	-1.5			mV/°C
Output noise voltage	$f = 10$ Hz to 100 kHz	25°C	170			$\mu$ V
Dropout voltage	$I_O = 1$ A	25°C	2.0			V
Bias current		25°C	4.6	8		mA
Bias current change	$V_I = 27$ V to 38 V	0°C to 125°C		1		mA
	$I_O = 5$ mA to 1 A			0.5		
Short-circuit output current		25°C	150			mA
Peak output current		25°C	2.1			A

† All characteristics are measured with a capacitor across the input of 0.33  $\mu$ F and a capacitor across the output of 0.1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.



# LINEAR INTEGRATED CIRCUITS

# SERIES $\mu$ A78L00 POSITIVE-VOLTAGE REGULATORS

D2203, JANUARY 1976—REVISED AUGUST 1983

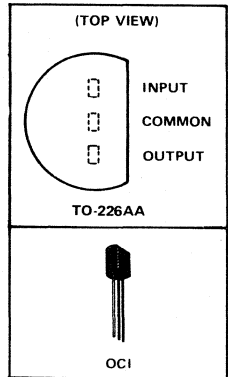
- 3-Terminal Regulators
- Output Current up to 100 mA
- No External Components
- Internal Thermal Overload Protection
- Unusually High Power Dissipation Capability
- Internal Short-Circuit Current Limiting
- Direct Replacement for Fairchild  $\mu$ A78L00 Series

NOMINAL OUTPUT VOLTAGE	5% OUTPUT VOLTAGE TOLERANCE	10% OUTPUT VOLTAGE TOLERANCE
2.6 V	$\mu$ A78L02AC	$\mu$ A78L02C
5 V	$\mu$ A78L05AC	$\mu$ A78L05C
6.2 V	UA78L06AC	$\mu$ A78L06C
8 V	$\mu$ A78L08AC	$\mu$ A78L08C
9 V	$\mu$ A78L09AC	$\mu$ A78L09C
10 V	$\mu$ A78L10AC	$\mu$ A78L10C
12 V	$\mu$ A78L12AC	$\mu$ A78L12C
15 V	$\mu$ A78L15AC	$\mu$ A78L15C

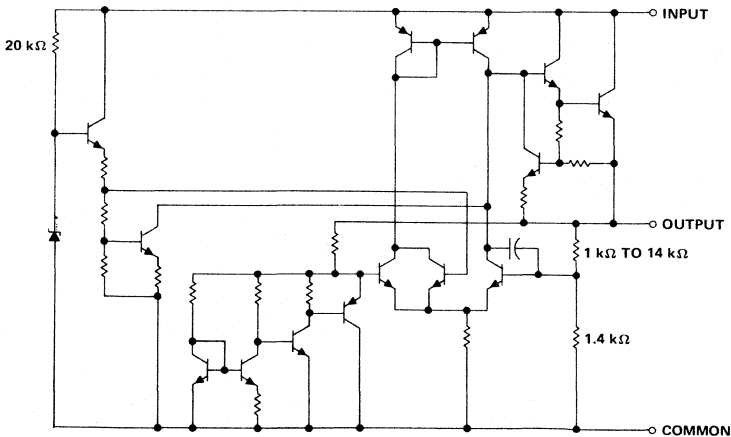
## description

This series of fixed-voltage monolithic integrated-circuit voltage regulators is designed for a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. In addition, they can be used with power-pass elements to make high-current voltage regulators. One of these regulators can deliver up to 100 mA of output current. The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. When used as a replacement for a Zener-diode—resistor combination, an effective improvement in output impedance of typically two orders of magnitude can be obtained together with lower-bias current.

## LP SILECT PACKAGE



## schematic



Resistor values shown are nominal

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TEXAS INSTRUMENTS

# SERIES $\mu$ A78L00 POSITIVE-VOLTAGE REGULATORS

absolute maximum ratings over operating temperature range (unless otherwise noted)

	$\mu$ A78L02AC, $\mu$ A78L02C THRU $\mu$ A78L10AC, $\mu$ A78L10C	$\mu$ A78L12AC, $\mu$ A78L12C $\mu$ A78L15AC, $\mu$ A78L15C	UNIT
Input voltage	30	35	V
Continuous total dissipation at 25°C free-air temperature (see Note 1)	LP package 775	775	mW
Continuous total dissipation at (or below) 25°C case temperature (see Note 1)	1600	1600	mW
Operating free-air, case, or virtual junction temperature range	0 to 150	0 to 150	°C
Storage temperature range	-65 to 150	-65 to 150	°C
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds	260	260	°C

NOTE 1: For operation above 25°C free-air temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

FREE-AIR TEMPERATURE  
DISSIPATION DERATING CURVE

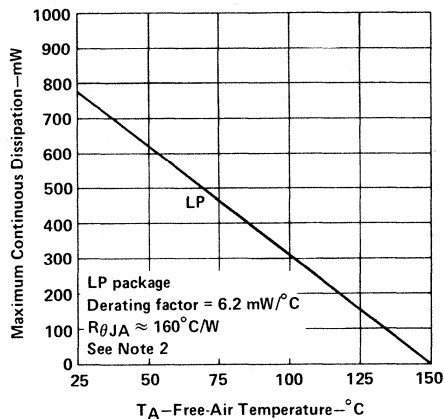


FIGURE 1

CASE TEMPERATURE  
DISSIPATION DERATING CURVE

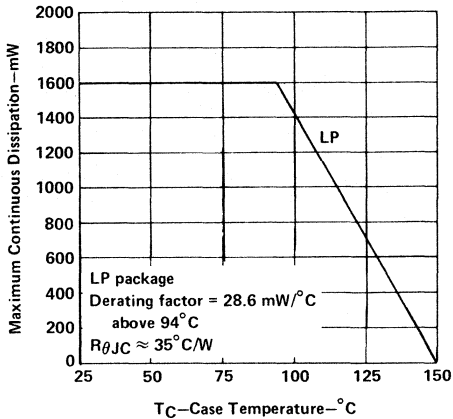


FIGURE 2

NOTE 2: This curve for the LP package is based on thermal resistance,  $R_{\theta JA}$ , measured in still air with the device mounted in an Augat socket. The bottom of the package was 3/8 inch above the socket.

## recommended operating conditions

		MIN	MAX	UNIT
		Input voltage, $V_I$	$\mu$ A78L02C, $\mu$ A78L02AC	
	$\mu$ A78L05C, $\mu$ A78L05AC	7	20	
	$\mu$ A78L06C, $\mu$ A78L06AC	8.5	20	
	$\mu$ A78L08C, $\mu$ A78L08AC	10.5	23	
	$\mu$ A78L09C, $\mu$ A78L09AC	11.5	24	
	$\mu$ A78L10C, $\mu$ A78L10AC	12.5	25	
	$\mu$ A78L12C, $\mu$ A78L12AC	14.5	27	
	$\mu$ A78L15C, $\mu$ A78L15AC	17.5	30	
Output current, $I_O$			100	mA
Operating virtual junction temperature, $T_J$		0	125	°C

**SERIES  $\mu$ A78L00**  
**POSITIVE-VOLTAGE REGULATORS**

**$\mu$ A78L02AC,  $\mu$ A78L02C electrical characteristics at specified virtual junction temperature,  
 $V_I = 9\text{ V}$ ,  $I_O = 40\text{ mA}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS <sup>†</sup>	$\mu$ A78L02AC			$\mu$ A78L02C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage	$V_I = 4.75\text{ V to }20\text{ V}$ , $I_O = 1\text{ mA to }40\text{ mA}$ $I_O = 1\text{ mA to }70\text{ mA}$	25°C	2.5	2.6	2.7	2.4	2.6	2.8
		0°C to 125°C	2.45		2.75	2.35		2.85
			2.45		2.75	2.35		2.85
Input regulation	$V_I = 4.75\text{ V to }20\text{ V}$ $V_I = 5\text{ V to }20\text{ V}$	25°C	20		100		20	125
			16		75		16	100
Ripple rejection	$V_I = 6\text{ V to }16\text{ V}$ , $f = 120\text{ Hz}$	25°C	43	51	42	51	dB	
Output regulation	$I_O = 1\text{ mA to }100\text{ mA}$ $I_O = 1\text{ mA to }40\text{ mA}$	25°C	12		50		12	50
			6		25		6	25
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$	25°C	30			30		$\mu$ V
Dropout voltage		25°C	1.7		1.7		V	
		25°C	3.6		6		3.6	6
Bias current		125°C	5.5		5.5		mA	
		0°C to 125°C	2.5		2.5		2.5	
Bias current change	$V_I = 5\text{ V to }20\text{ V}$ $I_O = 1\text{ mA to }40\text{ mA}$	0°C to 125°C	0.1		0.2		mA	

**$\mu$ A78L05AC,  $\mu$ A78L05C electrical characteristics at specified virtual junction temperature,  
 $V_I = 10\text{ V}$ ,  $I_O = 40\text{ mA}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS <sup>†</sup>	$\mu$ A78L05AC			$\mu$ A78L05C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage	$V_I = 7\text{ V to }20\text{ V}$ , $I_O = 1\text{ mA to }40\text{ mA}$ $I_O = 1\text{ mA to }70\text{ mA}$	25°C	4.8	5	5.2	4.6	5	5.4
		0°C to 125°C	4.75		5.25	4.5		5.5
			4.75		5.25	4.5		5.5
Input regulation	$V_I = 7\text{ V to }20\text{ V}$ $V_I = 8\text{ V to }20\text{ V}$	25°C	32		150		32	200
			26		100		26	150
Ripple rejection	$V_I = 8\text{ V to }18\text{ V}$ , $f = 120\text{ Hz}$	25°C	41	49	40	49	dB	
Output regulation	$I_O = 1\text{ mA to }100\text{ mA}$ $I_O = 1\text{ mA to }40\text{ mA}$	25°C	15		60		15	60
			8		30		8	30
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$	25°C	42			42		$\mu$ V
Dropout voltage		25°C	1.7		1.7		V	
		25°C	3.8		6		3.8	6
Bias current		125°C	5.5		5.5		mA	
		0°C to 125°C	1.5		1.5		1.5	
Bias current change	$V_I = 8\text{ V to }20\text{ V}$ $I_O = 1\text{ mA to }40\text{ mA}$	0°C to 125°C	0.1		0.2		mA	

<sup>†</sup> All characteristics are measured with a capacitor across the input of 0.33  $\mu$ F and a capacitor across the output of 0.1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

## SERIES $\mu$ A78L00 POSITIVE-VOLTAGE REGULATORS

$\mu$ A78L06AC,  $\mu$ A78L06C electrical characteristics at specified virtual junction temperature,  
 $V_I = 12$  V,  $I_O = 40$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		$\mu$ A78L06AC			$\mu$ A78L06C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage	$V_I = 8.5$ V to 20 V, $I_O = 1$ mA to 40 mA $I_O = 1$ mA to 70 mA	25°C	5.95	6.2	6.45	5.7	6.2	6.7	V
		0°C to 125°C	5.9		6.5	5.6		6.8	
Input regulation	$V_I = 8.5$ V to 20 V $V_I = 9$ V to 20 V	25°C	35			35			mV
			175			200			
Ripple rejection	$V_I = 10$ V to 20 V, $f = 120$ Hz	25°C	40	48		39	48	dB	
Output regulation	$I_O = 1$ mA to 100 mA $I_O = 1$ mA to 40 mA	25°C	16			16			mV
			80			80			
Output noise voltage	$f = 10$ Hz to 100 kHz	25°C	46			46			$\mu$ V
Dropout voltage		25°C	1.7			1.7			V
		25°C	3.9			6			
Bias current		125°C	5.5			5.5			mA
		0°C to 125°C	1.5			1.5			
Bias current change	$V_I = 9$ V to 20 V $I_O = 1$ mA to 40 mA	0°C to 125°C	0.1			0.2			mA

$\mu$ A78L08AC,  $\mu$ A78L08C electrical characteristics at specified virtual junction temperature,  
 $V_I = 14$  V,  $I_O = 40$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		$\mu$ A78L08AC			$\mu$ A78L08C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage	$V_I = 10.5$ V to 23 V, $I_O = 1$ mA to 40 mA $I_O = 1$ mA to 70 mA	25°C	7.7	8	8.3	7.36	8	8.64	V
		0°C to 125°C	7.6			8.4			
			7.6			8.4			
Input regulation	$V_I = 10.5$ V to 23 V $V_I = 11$ V to 23 V	25°C	42			42			mV
			175			200			
Ripple rejection	$V_I = 13$ V to 23 V, $f = 120$ Hz	25°C	37	46		36	46	dB	
Output regulation	$I_O = 1$ mA to 100 mA $I_O = 1$ mA to 40 mA	25°C	18			18			mV
			80			80			
Output noise voltage	$f = 10$ Hz to 100 kHz	25°C	54			54			$\mu$ V
Dropout voltage		25°C	1.7			1.7			V
		25°C	4			6			
Bias current		125°C	5.5			5.5			mA
		0°C to 125°C	1.5			1.5			
Bias current change	$V_I = 11$ V to 23 V $I_O = 1$ mA to 40 mA	0°C to 125°C	0.1			0.2			mA

<sup>†</sup> All characteristics are measured with a capacitor across the input of 0.33  $\mu$ F and a capacitor across the output of 0.1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# SERIES $\mu$ A78L00 POSITIVE-VOLTAGE REGULATORS

$\mu$ A78L09AC,  $\mu$ A78L09C electrical characteristics at specified virtual junction temperature,  
 $V_I = 16\text{ V}$ ,  $I_O = 40\text{ mA}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		$\mu$ A78L09AC			$\mu$ A78L09C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage	$V_I = 12\text{ V to }24\text{ V}$ , $I_O = 1\text{ mA to }40\text{ mA}$	25°C	8.6	9	9.4	8.3	9	9.7	V
		0°C to 125°C	8.55		9.45	8.1		9.9	
	$I_O = 1\text{ mA to }70\text{ mA}$			8.55		9.45	8.1		
Input regulation	$V_I = 12\text{ V to }24\text{ V}$	25°C		45	175		45	225	mV
	$V_I = 13\text{ V to }24\text{ V}$			40	125		40	175	
Ripple rejection	$V_I = 13\text{ V to }24\text{ V}$ , $f = 120\text{ Hz}$	25°C	37	45		36	45	dB	
Output regulation	$I_O = 1\text{ mA to }100\text{ mA}$	25°C		19	90		19	90	mV
	$I_O = 1\text{ mA to }40\text{ mA}$			11	40		11	40	
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$	25°C		58		58		$\mu$ V	
Dropout voltage		25°C		1.7		1.7		V	
Bias current		25°C		4.1	6		4.1	6	mA
		125°C			5.5			5.5	
Bias current change	$V_I = 13\text{ V to }24\text{ V}$	0°C to 125°C			1.5			1.5	mA
	$I_O = 1\text{ mA to }40\text{ mA}$				0.1			0.2	

$\mu$ A78L10AC,  $\mu$ A78L10C electrical characteristics at specified virtual junction temperature,  
 $V_I = 17\text{ V}$ ,  $I_O = 40\text{ mA}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		$\mu$ A78L10AC			$\mu$ A78L10C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage	$V_I = 13\text{ V to }25\text{ V}$ , $I_O = 1\text{ mA to }40\text{ mA}$	25°C	9.6	10	10.4	9.2	10	10.8	V
		0°C to 125°C	9.5		10.5	9		10	
	$I_O = 1\text{ mA to }70\text{ mA}$			9.5		10.5	9		
Input regulation	$V_I = 13\text{ V to }25\text{ V}$	25°C		51	175		51	225	mV
	$V_I = 14\text{ V to }25\text{ V}$			42	125		42	175	
Ripple rejection	$V_I = 14\text{ V to }25\text{ V}$ , $f = 120\text{ Hz}$	25°C	37	44		36	44	dB	
Output regulation	$I_O = 1\text{ mA to }100\text{ mA}$	25°C		20	90		20	90	mV
	$I_O = 1\text{ mA to }40\text{ mA}$			11	40		11	40	
Output noise voltage	$f = 10\text{ Hz to }100\text{ kHz}$	25°C		62		62		$\mu$ V	
Dropout voltage		25°C		1.7		1.7		V	
Bias current		25°C		4.2	6		4.2	6	mA
		125°C			5.5			5.5	
Bias current change	$V_I = 14\text{ V to }25\text{ V}$	0°C to 125°C			1.5			1.5	mA
	$I_O = 1\text{ mA to }40\text{ mA}$				0.1			0.2	

<sup>†</sup> All characteristics are measured with a capacitor across the input of 0.33  $\mu$ F and a capacitor across the output of 0.1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_W \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# SERIES $\mu$ A78L00 POSITIVE-VOLTAGE REGULATORS

$\mu$ A78L12AC,  $\mu$ A78L12C electrical characteristics at specified virtual junction temperature,  
 $V_I = 19$  V,  $I_O = 40$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A78L12AC			$\mu$ A78L12C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage		25 °C	11.5	12	12.5	11.1	12	12.9	V
	$V_I = 14.5$ V to 27 V, $I_O = 1$ mA to 40 mA	0 °C to 125 °C	11.4		12.6	10.8		13.2	
	$I_O = 1$ mA to 70 mA		11.4		12.6	10.8		13.2	
Input regulation	$V_I = 14.5$ V to 27 V	25 °C		55	250		55	250	mV
	$V_I = 16$ V to 27 V			49	200		49	200	
Ripple rejection	$V_I = 15$ V to 25 V, $f = 120$ Hz	25 °C	37	42		36	42		dB
Output regulation	$I_O = 1$ mA to 100 mA	25 °C		22	100		22	100	mV
	$I_O = 1$ mA to 40 mA			13	50		13	50	
Output noise voltage	$f = 10$ Hz to 100 kHz	25 °C		70		70			$\mu$ V
Dropout voltage		25 °C		1.7		1.7			V
		25 °C		4.3	6.5		4.3	6.5	mA
Bias current		125 °C		6		6			
Bias current change	$V_I = 16$ V to 27 V	0 °C to 125 °C			1.5			1.5	mA
	$I_O = 1$ mA to 40 mA				0.1			0.2	

$\mu$ A78L15AC,  $\mu$ A78L15C electrical characteristics at specified virtual junction temperature,  
 $V_I = 23$  V,  $I_O = 40$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A78L15AC			$\mu$ A78L15C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage		25 °C	14.4	15	15.6	13.8	15	16.2	V
	$V_I = 17.5$ V to 30 V, $I_O = 1$ mA to 40 mA	0 °C to 125 °C	14.25		15.75	13.5		16.5	
	$I_O = 1$ mA to 70 mA		14.25		15.75	13.5		16.5	
Input regulation	$V_I = 17.5$ V to 30 V	25 °C		65	300		65	300	mV
	$V_I = 20$ V to 30 V			58	250		58	250	
Ripple rejection	$V_I = 18.5$ to 28.5 V, $f = 120$ Hz	25 °C	34	39		33	39		dB
Output regulation	$I_O = 1$ mA to 100 mA	25 °C		25	150		25	150	mV
	$I_O = 1$ mA to 40 mA			15	75		15	75	
Output noise voltage	$f = 10$ Hz to 100 kHz	25 °C		82		82			$\mu$ V
Dropout voltage		25 °C		1.7		1.7			V
		25 °C		4.6	6.5		4.6	6.5	mA
Bias current		125 °C		6		6			
Bias current change	$V_I = 10$ V to 30 V	0 °C to 125 °C			1.5			1.5	mA
	$I_O = 1$ mA to 40 mA				0.1			0.2	

† All characteristics are measured with a capacitor across the input of 0.33  $\mu$ F and a capacitor across the output of 0.1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.



- 3-Terminal Regulators
- Output Current up to 500 mA
- No External Components
- Internal Thermal Overload Protection
- High Power Dissipation Capability
- Internal Short-Circuit Current Limiting
- Output Transistor Safe-Area Compensation
- Direct Replacements for Fairchild  $\mu$ A78M00 Series and National LM78MXX and LM341 Series

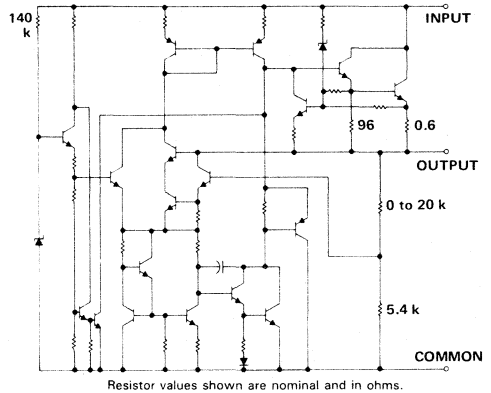
NOMINAL OUTPUT VOLTAGE	-55°C to 150°C OPERATING TEMPERATURE RANGE	0°C to 125°C OPERATING TEMPERATURE RANGE
5 V	$\mu$ A78M05M	$\mu$ A78M05C
6 V	$\mu$ A78M06M	$\mu$ A78M06C
8V	$\mu$ A78M08M	$\mu$ A78M08C
10 V	$\mu$ A78M10M	$\mu$ A78M10C
12 V	$\mu$ A78M12M	$\mu$ A78M12C
15 V	$\mu$ A78M15M	$\mu$ A78M15C
20 V		$\mu$ A78M20C
24 V		$\mu$ A78M24C
PACKAGES	JG	KC

**description**

This series of fixed-voltage monolithic integrated-circuit voltage regulators is designed for a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Each of these regulators can deliver up to 500 milliamperes of output current. The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. In addition to use as fixed-voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents and also as the power pass element in precision regulators.

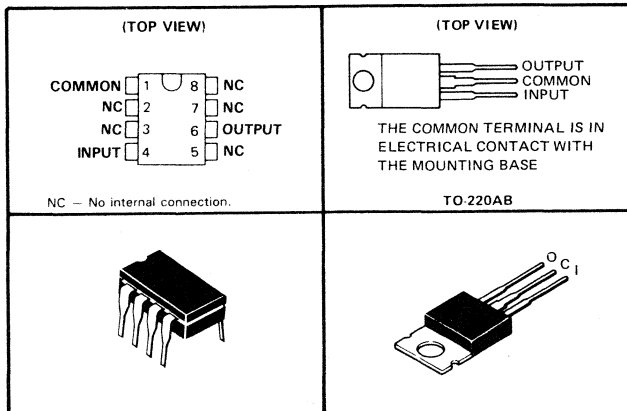
**terminal assignments**

**schematic**



$\mu$ A78M\_M . . . JG PACKAGE

$\mu$ A78M\_C . . . KC PACKAGE



# SERIES $\mu$ A78M00 POSITIVE-VOLTAGE REGULATORS

absolute maximum ratings over operating temperature range (unless otherwise noted)

		$\mu$ A78M05M THRU $\mu$ A78M24M	$\mu$ A78M05C THRU $\mu$ A78M24C	UNIT
Input voltage	$\mu$ A78M20 thru $\mu$ A78M24		40	V
	All others	35	35	
Continuous total dissipation at 25°C free-air temperature (see Note 1)	JG package	1.05		W
	KC (TO-220AB) package		2	
Continuous total dissipation at (or below) 25°C case temperature (see Note 1)	KC package		7.5	W
Operating free-air, case, or virtual junction temperature range		-55 to 150	0 to 150	°C
Storage temperature range		-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	JG package	300		°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	KC package		260	°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 through 3. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

## recommended operating conditions

		MIN	MAX	UNIT
Input voltage, $V_I$	$\mu$ A78M05M, $\mu$ A78M05C	7	25	V
	$\mu$ A78M06M, $\mu$ A78M06C	8	25	
	$\mu$ A78M08M, $\mu$ A78M08C	10.5	25	
	$\mu$ A78M10M, $\mu$ A78M10C	12.5	28	
	$\mu$ A78M12M, $\mu$ A78M12C	14.5	30	
	$\mu$ A78M15M, $\mu$ A78M15C	17.5	30	
	$\mu$ A78M20C	23	35	
	$\mu$ A78M24C	27	38	
Output current, $I_O$	All devices		500	mA
Operating virtual junction temperature, $T_J$	$\mu$ A78M05M thru $\mu$ A78M15M	-55	150	°C
	$\mu$ A78M05C thru $\mu$ A78M24C	0	125	



**TYPES  $\mu$ A78M05M,  $\mu$ A78M05C  
POSITIVE-VOLTAGE REGULATORS**

$\mu$ A78M05M,  $\mu$ A78M05C electrical characteristics at specified virtual junction temperature,  
 $V_I = 10$  V,  $I_O = 350$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>1</sup>		$\mu$ A78M05M			$\mu$ A78M05C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage	$I_O = 5$ mA to 350 mA	$V_I = 8$ V to 20 V	4.8	5	5.2	4.8	5	5.2	V
		$V_I = 7$ V to 20 V	4.7		5.3	4.75		5.25	
Input regulation	$I_O = 200$ mA	$V_I = 7$ V to 25 V		3	50		3	100	mV
		$V_I = 8$ V to 20 V		1	25		1	50	
Ripple rejection	$V_I = 8$ V to 18 V, $f = 120$ Hz	$I_O = 100$ mA	62			62			dB
		$I_O = 300$ mA	62	80		62	80		
Output regulation	$I_O = 5$ mA to 500 mA	$V_I = 8$ V to 20 V	20	50		20	100		mV
		$V_I = 7$ V to 25 V	10	25		10	50		
Temperature coefficient of output voltage	$I_O = 5$ mA	$-55^\circ\text{C}$ to $25^\circ\text{C}$			-2				mV/ $^\circ\text{C}$
		$25^\circ\text{C}$ to $150^\circ\text{C}$			-1.5			-1	
Output noise voltage	$f = 10$ Hz to 100 kHz	$0^\circ\text{C}$ to $150^\circ\text{C}$		40	200		40	200	$\mu$ V
		$25^\circ\text{C}$		2	2.5		2	2.5	
Dropout voltage	Bias current	$25^\circ\text{C}$		4.5	7		4.5	6	mA
		$-55^\circ\text{C}$ to $150^\circ\text{C}$			0.8			0.8	
Bias current change	$I_O = 200$ mA, $V_I = 8$ V to 25 V	$0^\circ\text{C}$ to $125^\circ\text{C}$						0.5	mA
		$-55^\circ\text{C}$ to $150^\circ\text{C}$						0.5	
Short-circuit output current	$V_I = 35$ V	$25^\circ\text{C}$	300	600		300	600		mA
		$25^\circ\text{C}$	0.5	0.7	1.4	0.7	1.4	0.7	
Peak output current								A	

<sup>1</sup>All characteristics are measured with a capacitor across the input of 0.33  $\mu$ F and a capacitor across the output of 0.1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_{pw} \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

**TYPES  $\mu$ A78M06M,  $\mu$ A78M06C  
POSITIVE-VOLTAGE REGULATORS**

$\mu$ A78M06M,  $\mu$ A78M06C electrical characteristics at specified virtual junction temperature,  
 $V_I = 11$  V,  $I_O = 350$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		$\mu$ A78M06M			$\mu$ A78M06C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage	$I_O = 5$ mA to 350 mA	25°C	5.75	6	6.25	5.75	6	6.25	V
		-55°C to 150°C 0°C to 125°C	5.7	6.3	6.3	5.7	6.3	6.3	
Input regulation	$I_O = 200$ mA	25°C		5	60		5	100	mV
				1.5	30		1.5	50	
Ripple rejection	$V_I = 9$ V to 19 V, $f = 120$ Hz	-55°C to 150°C	59			59			dB
		0°C to 125°C	59	80		59	80		
Output regulation	$I_O = 5$ mA to 500 mA $I_O = 5$ mA to 200 mA	25°C	59	80		59	80		mV
		25°C		20	60		20	120	
Temperature coefficient of output voltage	$I_O = 5$ mA	-55°C to 25°C							mV/°C
		25°C to 150°C			-2.4				
		0°C to 125°C			-1.8				
Output noise voltage	$f = 10$ Hz to 100 kHz	25°C		45	240		45		$\mu$ V
		25°C		2	2.5		2		
Dropout voltage		25°C		4.5	7		4.5	6	V
		25°C							
Bias current		-55°C to 150°C			0.8				mA
		0°C to 125°C					0.8		
		-55°C to 150°C			0.5				
Short-circuit output current	$V_I = 35$ V	25°C		270	600		270		mA
		25°C	0.5	0.7	1.4		0.7		
Peak output current								A	

<sup>†</sup>All characteristics are measured with a capacitor across the input of 0.33  $\mu$ F and a capacitor across the output of 0.1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_{pw} \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# TYPES $\mu$ A78M08M, $\mu$ A78M08C POSITIVE-VOLTAGE REGULATORS

$\mu$ A78M08M,  $\mu$ A78M08C electrical characteristics at specified virtual junction temperature,  
 $V_I = 14$  V,  $I_O = 350$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS †		$\mu$ A78M08M			$\mu$ A78M08C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage	$I_O = 5$ mA to 350 mA	$V_I = 11.5$ V to 23 V	7.7	8	8.3	7.7	8	8.3	V
		$V_I = 10.5$ V to 23 V	7.6		8.4	7.6		8.4	
Input regulation	$I_O = 200$ mA	$V_I = 10.5$ V to 25 V		6	60		6	100	mV
		$V_I = 11$ V to 20 V		2	30				
		$V_I = 11$ V to 25 V					2	50	
Ripple rejection	$V_I = 11.5$ V to 21.5 V, $f = 120$ Hz	$-55^\circ\text{C}$ to $150^\circ\text{C}$	56			56			dB
		$0^\circ\text{C}$ to $125^\circ\text{C}$	56	80		56	80		
Output regulation	$I_O = 5$ mA to 500 mA $I_O = 5$ mA to 200 mA	$25^\circ\text{C}$		25	80		25	160	mV
		$-55^\circ\text{C}$ to $150^\circ\text{C}$		10	40		10	80	
Temperature coefficient of output voltage	$I_O = 5$ mA	$-55^\circ\text{C}$ to $25^\circ\text{C}$			-3.2				mV/ $^\circ\text{C}$
		$25^\circ\text{C}$ to $150^\circ\text{C}$			-2.4				
		$0^\circ\text{C}$ to $125^\circ\text{C}$					-1		
Output noise voltage	$f = 10$ Hz to 100 kHz	$25^\circ\text{C}$		52	320		52		$\mu\text{V}$
		$25^\circ\text{C}$		2	2.5		2		
Dropout voltage		$25^\circ\text{C}$		4.6	7		4.6	6	mA
		$25^\circ\text{C}$							
Bias current	$I_O = 200$ mA, $I_O = 5$ mA to 350 mA	$V_I = 11.5$ V to 25 V			0.8				mA
		$V_I = 10.5$ V to 25 V						0.8	
		$-55^\circ\text{C}$ to $150^\circ\text{C}$			0.5			0.5	
Short-circuit output current	$V_I = 35$ V	$25^\circ\text{C}$		250	600		250		mA
		$25^\circ\text{C}$		0.5	0.7	1.4	0.7		
Peak output current								A	

† All characteristics are measured with a capacitor across the input of 0.33  $\mu\text{F}$  and a capacitor across the output of 0.1  $\mu\text{F}$ . All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_{\text{pw}} \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

## TYPES $\mu$ A78M10M, $\mu$ A78M10C POSITIVE-VOLTAGE REGULATORS

$\mu$ A78M10M,  $\mu$ A78M10C electrical characteristics at specified virtual junction temperature,  $V_I = 17$  V,  $I_O = 350$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A78M10M			$\mu$ A78M10C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage	$I_O = 5$ mA to 350 mA	$V_I = 13.5$ V to 25 V $V_I = 12.5$ V to 25 V	25°C						V
			-55°C to 150°C						
			0°C to 125°C						
Input regulation	$I_O = 200$ mA	$V_I = 12.5$ V to 28 V $V_I = 14$ V to 20 V $V_I = 14$ V to 28 V	25°C						mV
			7						
			2						
			30						
Ripple rejection	$V_I = 15$ V to 25 V, $f = 120$ Hz	$I_O = 100$ mA $I_O = 300$ mA	-55°C to 150°C						dB
			0°C to 125°C						
Output regulation	$I_O = 5$ mA to 500 mA $I_O = 5$ mA to 200 mA	25°C						mV	
		25							
Temperature coefficient of output voltage	$I_O = 5$ mA	$V_I = 13.5$ V to 28 V $V_I = 12.5$ V to 28 V	-55°C to 25°C						mV/°C
			25°C to 150°C						
			0°C to 125°C						
Output noise voltage	$f = 10$ Hz to 100 kHz	25°C						$\mu$ V	
		64							
Dropout voltage		25°C						V	
		2							
Bias current		25°C						mA	
		4.7							
Bias current change	$I_O = 200$ mA, $I_O = 5$ mA to 350 mA	$V_I = 13.5$ V to 28 V $V_I = 12.5$ V to 28 V	-55°C to 150°C						mA
			0°C to 125°C						
			-55°C to 150°C						
Short-circuit output current	$V_I = 35$ V	25°C						mA	
		245							
Peak output current			0.5	0.7	1.4		0.7	A	

† All characteristics are measured with a capacitor across the input of 0.33  $\mu$ F and a capacitor across the output of 0.1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_{PW} \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

**TYPES  $\mu$ A78M12M,  $\mu$ A78M12C  
POSITIVE-VOLTAGE REGULATORS**

$\mu$ A78M12M,  $\mu$ A78M12C electrical characteristics at specified virtual junction temperature,  
 $V_I = 19$  V,  $I_O = 350$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		$\mu$ A78M12M		$\mu$ A78M12C		UNIT	
			MIN	TYP	MAX	MIN		TYP
Output voltage	$I_O = 5$ mA to 350 mA	$V_I = 15.5$ V to 27 V	11.5	12	12.5	11.5	12	12.5
		$V_I = 14.5$ V to 27 V	11.4		12.6	11.4		12.6
Input regulation	$I_O = 200$ mA	$V_I = 14.5$ V to 30 V		8	60		8	100
		$V_I = 16$ V to 25 V		2	30		2	50
		$V_I = 16$ V to 30 V						
Ripple rejection	$V_I = 15$ V to 25 V, $f = 120$ Hz	$I_O = 100$ mA	55			55		
		$I_O = 300$ mA	55	80		55	80	
Output regulation	$I_O = 5$ mA to 500 mA $I_O = 5$ mA to 200 mA	$25^\circ\text{C}$		25	120		25	240
		$25^\circ\text{C}$		10	60		10	120
Temperature coefficient of output voltage	$I_O = 5$ mA	$-55^\circ\text{C}$ to $25^\circ\text{C}$			-4.8			
		$25^\circ\text{C}$ to $150^\circ\text{C}$			-3.6			
		$0^\circ\text{C}$ to $125^\circ\text{C}$						-1
Output noise voltage	$f = 10$ Hz to 100 kHz	$25^\circ\text{C}$		75	480		75	$\mu$ V
		$25^\circ\text{C}$		2	2.5		2	V
Bias current		$25^\circ\text{C}$		4.8	7		4.8	6 mA
		$25^\circ\text{C}$			0.8			
Bias current change	$I_O = 200$ mA, $I_O = 5$ mA to 350 mA	$V_I = 15$ V to 30 V			0.8			0.8 mA
		$V_I = 14.5$ V to 30 V			0.5			0.5 mA
Short-circuit output current	$V_I = 35$ V	$25^\circ\text{C}$		240	600		240	mA
		$25^\circ\text{C}$		0.5	0.7	1.4	0.7	A
Peak output current								

<sup>†</sup>All characteristics are measured with a capacitor across the input of 0.33  $\mu$ F and a capacitor across the output of 0.1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.



**TYPES  $\mu$ A78M15M,  $\mu$ A78M15C  
POSITIVE-VOLTAGE REGULATORS**

$\mu$ A78M15M,  $\mu$ A78M15C electrical characteristics at specified virtual junction temperature,  $V_I = 23$  V,  $I_O = 350$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A78M15M			$\mu$ A78M15C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage	$I_O = 5$ mA to 350 mA	$V_I = 18.5$ V to 30 V	14.4	15	15.6	14.4	15	15.6	V
		$V_I = 17.5$ V to 30 V	14.25		15.75	14.25		15.75	
Input regulation	$I_O = 200$ mA	$V_I = 17.5$ V to 30 V							mV
		$V_I = 20$ V to 30 V		10	60		10	100	
Ripple rejection	$V_I = 18.5$ V to 28.5 V, $f = 120$ Hz	$I_O = 100$ mA	54			54			dB
		$I_O = 300$ mA	54	70		54	70		
Output regulation	$I_O = 5$ mA to 500 mA $I_O = 5$ mA to 200 mA	25°C		25	150		25	300	mV
		-55°C to 150°C 0°C to 125°C		10	75		10	150	
Temperature coefficient of output voltage	$I_O = 5$ mA	-55°C to 25°C			-6				mV/°C
		25°C to 150°C			-4.5				
Output noise voltage	$f = 10$ Hz to 100 kHz	25°C		90	600		90		$\mu$ V
		0°C to 125°C							
Dropout voltage		25°C		2	2.5		2		V
		0°C to 125°C							
Bias current		25°C		4.8	7		4.8	6	mA
		0°C to 125°C							
Bias current change	$I_O = 200$ mA, $I_O = 5$ mA to 350 mA	$V_I = 18.5$ V to 30 V			0.8				mA
		$V_I = 17.5$ V to 30 V						0.8	
Short-circuit output current	$V_I = 35$ V	-55°C to 150°C			0.5				mA
		0°C to 125°C						0.5	
Peak output current		25°C		240	600		240		mA
		0°C to 125°C		0.5	0.7	1.4		0.7	

†All characteristics are measured with a capacitor across the input of 0.33  $\mu$ F and a capacitor across the output of 0.1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_{pw} \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.



$\mu$ A78M20C electrical characteristics at specified virtual junction temperature,  
 $V_I = 29$  V,  $I_O = 350$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		$\mu$ A78M20C			UNIT
			MIN	TYP	MAX	
Output voltage	$I_O = 5$ mA to 350 mA, $f = 120$ Hz	$V_I = 23$ V to 35 V	19.2	20	20.8	V
		$V_I = 24$ V to 35 V	19		21	
Input regulation	$I_O = 200$ mA	$V_I = 23$ V to 35 V		10	100	mV
		$V_I = 24$ V to 35 V		5	50	
Ripple rejection	$V_I = 24$ V to 34 V, $f = 120$ Hz	$I_O = 100$ mA	53			dB
		$I_O = 300$ mA	53	70		
Output regulation	$I_O = 5$ mA to 500 mA $I_O = 5$ mA to 200 mA	25 °C		30	400	mV
		0 °C to 125 °C		10	200	
Temperature coefficient of output voltage	$I_O = 5$ mA	0 °C to 125 °C		-1.1		mV/°C
Output noise voltage	$f = 10$ Hz to 100 kHz	25 °C		110		$\mu$ V
		25 °C		2		
Dropout voltage		25 °C		4.9	6	V
		25 °C		4.9	6	
Bias current	$I_O = 200$ mA, $I_O = 5$ mA to 350 mA	0 °C to 125 °C		0.8		mA
		0 °C to 125 °C		0.5		
Short-circuit output current	$V_I = 35$ V	25 °C		240		mA
Peak output current		25 °C		0.7		A

<sup>†</sup>All characteristics are measured with a capacitor across the input of 0.33  $\mu$ F and a capacitor across the output of 0.1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

**TYPE  $\mu$ A78M24C  
POSITIVE-VOLTAGE REGULATOR**

$\mu$ A78M24C electrical characteristics at specified virtual junction temperature,  $V_I = 33$  V,  $I_O = 350$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	$\mu$ A78M24C			UNIT
		MIN	TYP	MAX	
Output voltage	$I_O = 5$ mA to 350 mA, $V_I = 27$ V to 38 V	23	24	25	V
		22.8		25.2	
Input regulation	$I_O = 200$ mA, $V_I = 27$ V to 38 V $V_I = 28$ V to 38 V	10	10	100	mV
			5	50	
Ripple rejection	$V_I = 28$ V to 38 V, $f = 120$ Hz, $I_O = 100$ mA $I_O = 300$ mA	-55°C to 150°C			dB
		0°C to 125°C			
		50	70	50	
Output regulation	$I_O = 5$ mA to 500 mA, $I_O = 5$ mA to 200 mA	30	480		mV
		10	240		
Temperature coefficient of output voltage	$I_O = 5$ mA		-1.2		mV/°C
Output noise voltage	$f = 10$ Hz to 100 kHz	170			$\mu$ V
			2		
Dropout voltage		25°C			V
		25°C	5	6	
Bias current	$I_O = 200$ mA, $I_O = 5$ mA to 350 mA	0.8			mA
			0.5		
Short-circuit output current	$V_I = 35$ V	240			mA
Peak output current		0.7			A

<sup>†</sup>All characteristics are measured with a capacitor across the input of 0.33  $\mu$ F and a capacitor across the output of 0.1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

THERMAL INFORMATION

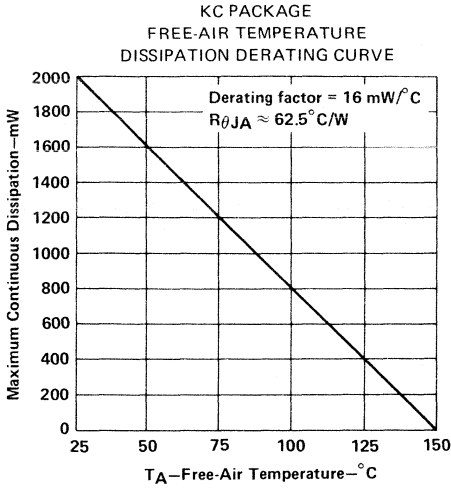


FIGURE 1

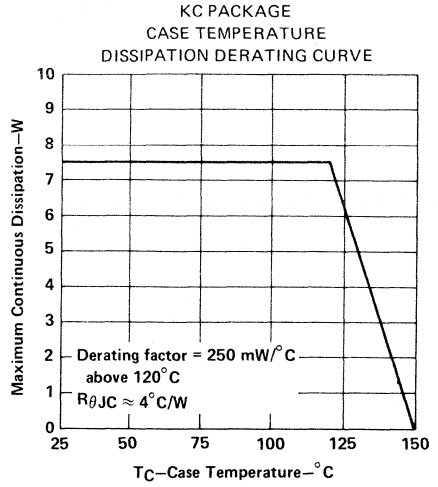


FIGURE 2

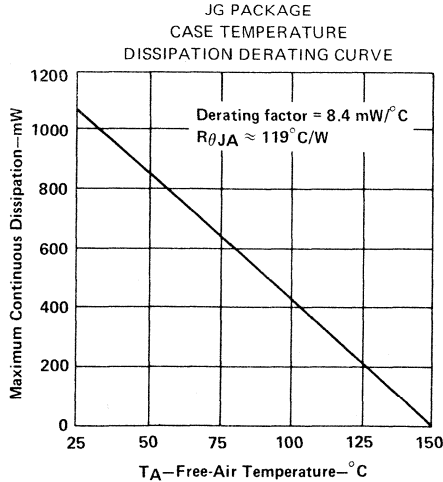


FIGURE 3



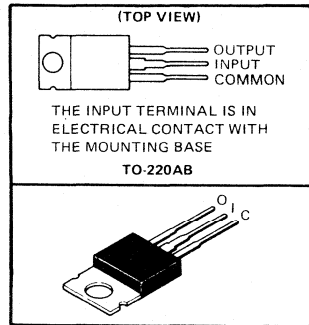
- 3-Terminal Regulators
- Output Current up to 1.5 A
- No External Components
- Internal Thermal Overload Protection
- High Power Dissipation Capability
- Internal Short-Circuit Current Limiting
- Output Transistor Safe-Area Compensation
- Essentially Equivalent to National LM320 Series
- Direct Replacements for Fairchild  $\mu$ A7900 Series and National LM79XX Series

NOMINAL OUTPUT VOLTAGE	REGULATOR
-5 V	$\mu$ A7905C
-5.2 V	$\mu$ A7952C
-6 V	$\mu$ A7906C
-8 V	$\mu$ A7908C
-12 V	$\mu$ A7912C
-15 V	$\mu$ A7915C
-18 V	$\mu$ A7918C
-24 V	$\mu$ A7924C

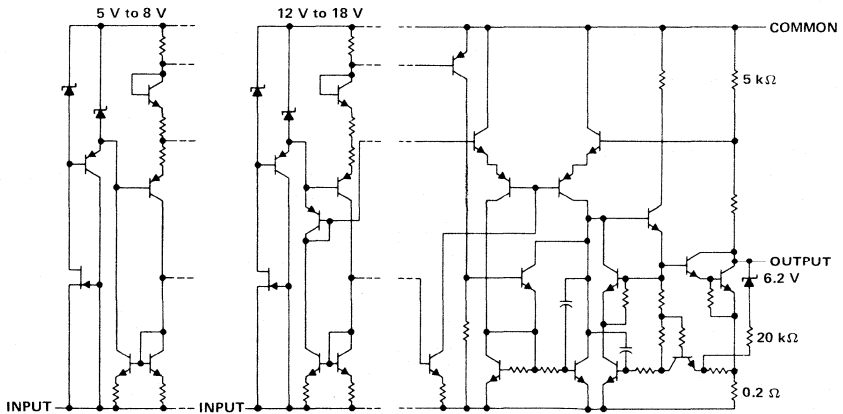
**description**

This series of fixed-negative-voltage monolithic integrated-circuit voltage regulators is designed to complement Series  $\mu$ A7800 in a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Each of these regulators can deliver up to 1.5 amperes of output current. The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. In addition to use as fixed-voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents and also as the power pass element in precision regulators.

**KC PACKAGE**



**schematic**



All component values are nominal.

# SERIES $\mu$ A7900 NEGATIVE-VOLTAGE REGULATORS

absolute maximum ratings over operating temperature range (unless otherwise noted)

		$\mu$ A7905C THRU $\mu$ A7924C	UNIT
Input voltage	$\mu$ A7924C	-40	V
	All others	-35	
Continuous total dissipation at 25°C free-air temperature (see Note 1)		2	W
Continuous total dissipation at (or below) 25°C case temperature (see Note 1)		15	W
Operating free-air, case, or virtual junction temperature range		0 to 150	°C
Storage temperature range		-65 to 150	°C
Lead temperature 3,2 mm (1/8 inch) from case for 10 seconds		260	°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

FREE-AIR TEMPERATURE  
DISSIPATION DERATING CURVE

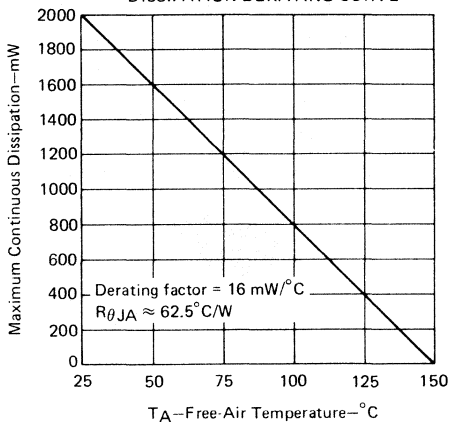


FIGURE 1

CASE TEMPERATURE  
DISSIPATION DERATING CURVE

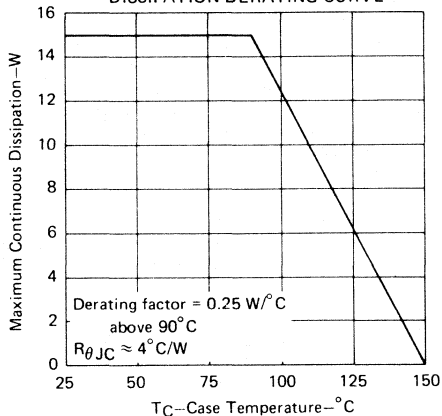


FIGURE 2

recommended operating conditions

		MIN	MAX	UNIT
Input voltage, $V_I$	$\mu$ A7905C	-7	-25	V
	$\mu$ A7952C	-7.2	-25	
	$\mu$ A7906C	-8	-25	
	$\mu$ A7908C	-10.5	-25	
	$\mu$ A7912C	-14.5	-30	
	$\mu$ A7915C	-17.5	-30	
	$\mu$ A7918C	-21	-33	
	$\mu$ A7924C	-27	-38	
Output current, $I_O$			1.5	A
Operating virtual junction temperature, $T_J$		0	125	°C

# TYPES $\mu$ A7905C, $\mu$ A7952C NEGATIVE-VOLTAGE REGULATORS

$\mu$ A7905C electrical characteristics at specified virtual junction temperature,  
 $V_I = -10$  V,  $I_O = 500$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		$\mu$ A7905C			UNIT	
			MIN	TYP	MAX		
Output voltage	$I_O = 5$ mA to 1 A, $P \leq 15$ W	$V_I = -7$ V to $-20$ V, $0^\circ$ C to $125^\circ$ C	25° C	-4.8	-5	-5.2	V
				-4.75		-5.25	
Input regulation	$V_I = -7$ V to $-25$ V $V_I = -8$ V to $-12$ V	25° C		12.5	50	mV	
				4	15		
Ripple rejection	$V_I = -8$ V to $-18$ V, $I_O = 5$ mA to 1.5 A	$f = 120$ Hz $0^\circ$ C to $125^\circ$ C	54	60		dB	
Output regulation	$I_O = 250$ mA to 750 mA	25° C		15	100	mV	
				5	50		
Temperature coefficient of output voltage	$I_O = 5$ mA	$0^\circ$ C to $125^\circ$ C		-0.4		mV/°C	
Output noise voltage	$f = 10$ Hz to 100 kHz	25° C		125		$\mu$ V	
Dropout voltage	$I_O = 1$ A	25° C		1.1		V	
Bias current		25° C		1.5	2	mA	
Bias current change	$V_I = -7$ V to $-25$ V $I_O = 5$ mA to 1 A	$0^\circ$ C to $125^\circ$ C		0.15	0.5	mA	
				0.08	0.5		
Peak output current		25° C		2.1		A	

$\mu$ A7952C electrical characteristics at specified virtual junction temperature,  
 $V_I = -10$  V,  $I_O = 500$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		$\mu$ A7952C			UNIT	
			MIN	TYP	MAX		
Output voltage	$I_O = 5$ mA to 1 A, $P \leq 15$ W	$V_I = -7.2$ V to $-20$ V, $0^\circ$ C to $125^\circ$ C	25° C	-5	-5.2	-5.4	V
				-4.95		-5.45	
Input regulation	$V_I = -7.2$ V to $-25$ V $V_I = -8.2$ V to $-12$ V	25° C		12.5	100	mV	
				4	50		
Ripple rejection	$V_I = -8.2$ V to $-18$ V, $I_O = 5$ mA to 1.5 A	$f = 120$ Hz $0^\circ$ C to $125^\circ$ C	54	60		dB	
Output regulation	$I_O = 250$ mA to 750 mA	25° C		15	100	mV	
				5	50		
Temperature coefficient of output voltage	$I_O = 5$ mA	$0^\circ$ C to $125^\circ$ C		-0.4		mV/°C	
Output noise voltage	$f = 10$ Hz to 100 kHz	25° C		125		$\mu$ V	
Dropout voltage	$I_O = 1$ A	25° C		1.1		V	
Bias current		25° C		1.5	2	mA	
Bias current change	$V_I = -7.2$ V to $-25$ V $I_O = 5$ mA to 1 A	$0^\circ$ C to $125^\circ$ C		0.15	1.3	mA	
				0.08	0.5		
Peak output current		25° C		2.1		A	

<sup>†</sup>All characteristics are measured with a solid-tantalum capacitor across the input of 2  $\mu$ F and a solid-tantalum capacitor across the output of 1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

## TYPES $\mu$ A7906C, $\mu$ A7908C NEGATIVE-VOLTAGE REGULATORS

$\mu$ A7906C electrical characteristics at specified virtual junction temperature,  
 $V_I = -11$  V,  $I_O = 500$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A7906C			UNIT	
			MIN	TYP	MAX		
Output voltage	$I_O = 5$ mA to 1 A, $P \leq 15$ W	$V_I = -8$ V to $-21$ V, 0°C to 125°C	25°C	-5.75	-6	-6.25	V
				-5.7		-6.3	
Input regulation	$V_I = -8$ V to $-25$ V $V_I = -9$ V to $-13$ V	25°C		12.5	120	mV	
				4	60		
Ripple rejection	$V_I = -9$ V to $-19$ V, $f = 120$ Hz	0°C to 125°C	54	60		dB	
Output regulation	$I_O = 5$ mA to 1.5 A $I_O = 250$ mA to 750 mA	25°C		15	120	mV	
				5	60		
Temperature coefficient of output voltage	$I_O = 5$ mA	0°C to 125°C		-0.4		mV/°C	
Output noise voltage	$f = 10$ Hz to 100 kHz	25°C		150		$\mu$ V	
Dropout voltage	$I_O = 1$ A	25°C		1.1		V	
Bias current		25°C		1.5	2	mA	
Bias current change	$V_I = -8$ V to $-25$ V $I_O = 5$ mA to 1 A	0°C to 125°C		0.15	1.3	mA	
				0.08	0.5		
Peak output current		25°C		2.1		A	

$\mu$ A7908C electrical characteristics at specified virtual junction temperature,  
 $V_I = -14$  V,  $I_O = 500$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A7908C			UNIT	
			MIN	TYP	MAX		
Output voltage	$I_O = 5$ mA to 1 A, $P \leq 15$ W	$V_I = -10.5$ V to $-23$ V, 0°C to 125°C	25°C	-7.7	-8	-8.3	V
				-7.6		-8.4	
Input regulation	$V_I = -10.5$ V to $-25$ V $V_I = -11$ V to $-17$ V	25°C		12.5	160	mV	
				4	80		
Ripple rejection	$V_I = -11.5$ V to $-21.5$ V, $f = 120$ Hz	0°C to 125°C	54	60		dB	
Output regulation	$I_O = 5$ mA to 1.5 A $I_O = 250$ mA to 750 mA	25°C		15	160	mV	
				5	80		
Temperature coefficient of output voltage	$I_O = 5$ mA	0°C to 125°C		-0.6		mV/°C	
Output noise voltage	$f = 10$ Hz to 100 kHz	25°C		200		$\mu$ V	
Dropout voltage	$I_O = 1$ A	25°C		1.1		V	
Bias current		25°C		1.5	2	mA	
Bias current change	$V_I = -10.5$ V to $-25$ V $I_O = 5$ mA to 1 A	0°C to 125°C		0.15	1	mA	
				0.08	0.5		
Peak output current		25°C		2.1		A	

† All characteristics are measured with a solid-tantalum capacitor across the input of 2  $\mu$ F and a solid-tantalum capacitor across the output of 1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.



## TYPES $\mu$ A7912C, $\mu$ A7915C NEGATIVE-VOLTAGE REGULATORS

$\mu$ A7912C electrical characteristics at specified virtual junction temperature,  
 $V_I = -19$  V,  $I_O = 500$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		$\mu$ A7912C			UNIT
			MIN	TYP	MAX	
Output voltage	$I_O = 5$ mA to 1 A, $V_I = -14.5$ V to $-27$ V, $P \leq 15$ W	25°C	-11.5	-12	-12.5	V
		0°C to 125°C	-11.4		-12.6	
Input regulation	$V_I = -14.5$ V to $-30$ V	25°C		5	80	mV
	$V_I = -16$ V to $-22$ V			3	30	
Ripple rejection	$V_I = -15$ V to $-25$ V, $f = 120$ Hz	0°C to 125°C	54	60		dB
Output regulation	$I_O = 5$ mA to 1.5 A	25°C		15	200	mV
	$I_O = 250$ mA to 750 mA			5	75	
Temperature coefficient of output voltage	$I_O = 5$ mA	0°C to 125°C		-0.8		mV/°C
Output noise voltage	$f = 10$ Hz to 100 kHz	25°C		300		$\mu$ V
Dropout voltage	$I_O = 1$ A	25°C		1.1		V
Bias current		25°C		2	3	mA
Bias current change	$V_I = -14.5$ V to $-30$ V	0°C to 125°C		0.04	0.5	mA
	$I_O = 5$ mA to 1 A			0.06	0.5	
Peak output current		25°C		2.1		A

$\mu$ A7915C electrical characteristics at specified virtual junction temperature,  
 $V_I = -23$  V,  $I_O = 500$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>		$\mu$ A7915C			UNIT
			MIN	TYP	MAX	
Output voltage	$I_O = 5$ mA to 1 A, $V_I = -17.5$ V to $-30$ V, $P \leq 15$ W	25°C	-14.4	-15	-15.6	V
		0°C to 125°C	-14.25		-15.75	
Input regulation	$V_I = -17.5$ V to $-30$ V	25°C		5	100	mV
	$V_I = -20$ V to $-26$ V			3	50	
Ripple rejection	$V_I = -18.5$ V to $-28.5$ V, $f = 120$ Hz	0°C to 125°C	54	60		dB
Output regulation	$I_O = 5$ mA to 1.5 A	25°C		15	200	mV
	$I_O = 250$ mA to 750 mA			5	75	
Temperature coefficient of output voltage	$I_O = 5$ mA	0°C to 125°C		-1		mV/°C
Output noise voltage	$f = 10$ Hz to 100 kHz	25°C		375		$\mu$ V
Dropout voltage	$I_O = 1$ A	25°C		1.1		V
Bias current		25°C		2	3	mA
Bias current change	$V_I = -17.5$ V to $-30$ V	0°C to 125°C		0.04	0.5	mA
	$I_O = 5$ mA to 1 A			0.06	0.5	
Peak output current		25°C		2.1		A

<sup>†</sup>All characteristics are measured with a solid-tantalum capacitor across the input of 2  $\mu$ F and a solid-tantalum capacitor across the output of 1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_W \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# TYPES $\mu$ A7918C, $\mu$ A7924C

## NEGATIVE-VOLTAGE REGULATORS

$\mu$ A7918C electrical characteristics at specified virtual junction temperature,  
 $V_I = -27$  V,  $I_O = 500$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	$\mu$ A7918C			UNIT	
		MIN	TYP	MAX		
Output voltage	$I_O = 5$ mA to 1 A, $V_I = -21$ V to $-33$ V, $P \leq 15$ W	25°C	-17.3	-18	-18.7	V
		0°C to 125°C	-17.1		-18.9	
Input regulation	$V_I = -21$ V to $-33$ V	25°C		5	360	mV
	$V_I = -24$ V to $-30$ V			3	180	
Ripple rejection	$V_I = -22$ V to $-32$ V, $f = 120$ Hz	0°C to 125°C	54	60		dB
Output regulation	$I_O = 5$ mA to 1.5 A	25°C		30	360	mV
	$I_O = 250$ mA to 750 mA			10	180	
Temperature coefficient of output voltage	$I_O = 5$ mA	0°C to 125°C		-1		mV/°C
Output noise voltage	$f = 10$ Hz to 100 kHz	25°C		450		$\mu$ V
Dropout voltage	$I_O = 1$ A	25°C		1.1		V
Bias current		25°C		2	3	mA
Bias current change	$V_I = -21$ V to $-33$ V	0°C to 125°C		0.04	1	mA
	$I_O = 5$ mA to 1 A			0.06	0.5	
Peak output current		25°C		2.1		A

$\mu$ A7924C electrical characteristics at specified virtual junction temperature,  
 $V_I = -33$  V,  $I_O = 500$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>†</sup>	$\mu$ A7924C			UNIT	
		MIN	TYP	MAX		
Output voltage	$I_O = 5$ mA to 1 A, $V_I = -27$ V to $-38$ V, $P \leq 15$ W	25°C	-23	-24	-25	V
		0°C to 125°C	-22.8		-25.2	
Input regulation	$V_I = -27$ V to $-38$ V	25°C		5	480	mV
	$V_I = -30$ V to $-36$ V			3	240	
Ripple rejection	$V_I = -28$ V to $-38$ V, $f = 120$ Hz	0°C to 125°C	54	60		dB
Output regulation	$I_O = 5$ mA to 1.5 A	25°C		85	480	mV
	$I_O = 250$ mA to 750 mA			25	240	
Temperature coefficient of output voltage	$I_O = 5$ mA	0°C to 125°C		-1		mV/°C
Output noise voltage	$f = 10$ Hz to 100 kHz	25°C		600		$\mu$ V
Dropout voltage	$I_O = 1$ A	25°C		1.1		V
Bias current		25°C		2	3	mA
Bias current change	$V_I = -27$ V to $-38$ V	0°C to 125°C		0.04	1	mA
	$I_O = 5$ mA to 1 A			0.06	0.5	
Peak output current		25°C		2.1		A

<sup>†</sup> All characteristics are measured with a solid-tantalum capacitor across the input of 2  $\mu$ F and a solid-tantalum capacitor across the output of 1  $\mu$ F. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

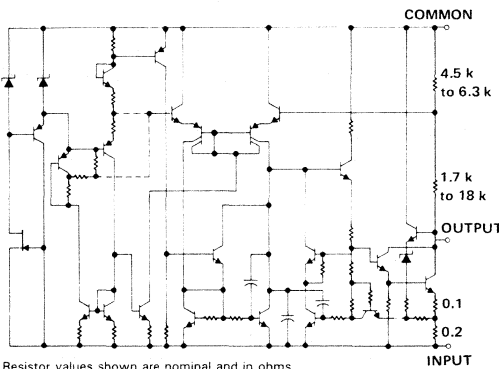
- 3-Terminal Regulators
- Output Current up to 500 mA
- No External Components
- High Power Dissipation Capability
- Internal Short-Circuit Current Limiting
- Output Transistor Safe-Area Compensation
- Direct Replacements for Fairchild  $\mu$ A79M00 Series

NOMINAL OUTPUT VOLTAGE	-55 C to 150 C OPERATING TEMPERATURE RANGE	0 C to 125 C OPERATING TEMPERATURE RANGE
-5 V	$\mu$ A79M05M	$\mu$ A79M05C
-6 V	$\mu$ A79M06M	$\mu$ A79M06C
-8 V	$\mu$ A79M08M	$\mu$ A79M08C
-12 V	$\mu$ A79M12M	$\mu$ A79M12C
-15 V	$\mu$ A79M15M	$\mu$ A79M15C
-20 V		$\mu$ A79M20C
-24 V		$\mu$ A79M24C
PACKAGE	JG	KC

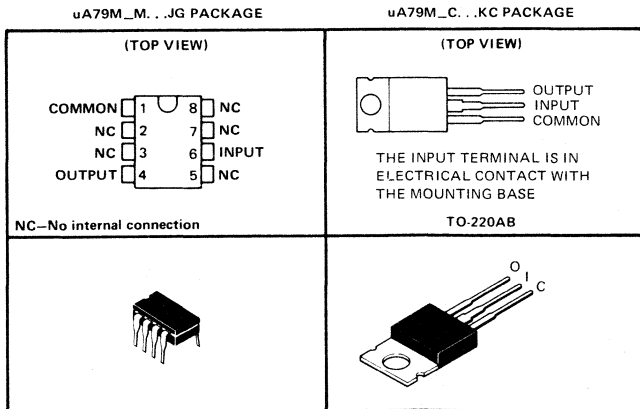
**description**

This series of fixed-negative-voltage monolithic integrated-circuit voltage regulators is designed to complement Series  $\mu$ A78M00 in a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Each of these regulators can deliver up to 500 milliamperes of output current. The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. In addition to use as fixed-voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents and also as the power pass element in precision regulators.

**schematic**



**terminal assignments**



**Voltage Regulators**



# SERIES $\mu$ A79M00 NEGATIVE-VOLTAGE REGULATORS

absolute maximum ratings over operating temperature range (unless otherwise noted)

		$\mu$ A79M05M THRU $\mu$ A79M15M	$\mu$ A79M05C THRU $\mu$ A79M24C	UNIT
Input voltage	$\mu$ A79M20, $\mu$ A79M24		-40	V
	All others	-35	-35	
Continuous total dissipation at 25°C free-air temperature (see Note 1)	JG package	1.05		W
	KC (TO-220AB) package		2	
Continuous total dissipation at (or below) 25°C case temperature (see Note 1)	KC package		7.5	W
	Operating free-air, case or virtual junction temperature range	-55 to 150	0 to 150	°C
Storage temperature range		-65 to 150	-65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	JG package	300		°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	KC package		260	°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 through 3. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

## recommended operating conditions

		MIN	MAX	UNIT
Input voltage, $V_I$	$\mu$ A79M05M, $\mu$ A79M05C	-7	-25	V
	$\mu$ A79M06M, $\mu$ A79M06C	-8	-25	
	$\mu$ A79M08M, $\mu$ A79M08C	-10.5	-25	
	$\mu$ A79M12M, $\mu$ A79M12C	-14.5	-30	
	$\mu$ A79M15M, $\mu$ A79M15C	-17.5	-30	
	$\mu$ A79M20C $\mu$ A79M24C	-23 -27	-35 -38	
Output current, $I_O$			500	mA
Operating virtual junction temperature, $T_J$	$\mu$ A79M05M thru $\mu$ A79M15M	-55	150	°C
	$\mu$ A79M05C thru $\mu$ A79M24C	0	125	

## TYPES $\mu$ A79M05M, $\mu$ A79M05C NEGATIVE-VOLTAGE REGULATORS

$\mu$ A79M05M,  $\mu$ A79M05C electrical characteristics at specified virtual junction temperature,  
 $V_I = -10$  V,  $I_O = 350$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A79M05M			$\mu$ A79M05C			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX		
Output voltage	$I_O = 5$ mA to 350 mA, $V_I = -7$ V to $-25$ V		25°C	-4.8	-5	-5.2	-4.8	-5	-5.2	V
			-55°C to 150°C	-4.75		-5.25				
			0°C to 125°C				-4.75		-5.25	
Input regulation	$V_I = -7$ V to $-25$ V		25°C	7	50		7	50	mV	
	$V_I = -8$ V to $-18$ V			3	30		3	30		
Ripple rejection	$V_I = -8$ V to $-18$ V, $f = 120$ Hz	$I_O = 100$ mA	-55°C to 150°C	50						dB
			0°C to 125°C				50			
		$I_O = 300$ mA	25°C	54	60		54	60		
Output regulation	$I_O = 5$ mA to 500 mA		25°C	75	100		75	100	mV	
	$I_O = 5$ mA to 350 mA			50			50			
Temperature coefficient of output voltage	$I_O = 5$ mA		-55°C to 150°C				-1.5			mV/°C
			0°C to 125°C				-0.4			
Output noise voltage	$f = 10$ Hz to 100 kHz		25°C	125	400		125		$\mu$ V	
Dropout voltage			25°C	1.1	2.3		1.1		V	
Bias current			25°C	1	2		1	2	mA	
Bias current change	$V_I = -8$ V to $-25$ V		-55°C to 150°C	0.4						mA
			0°C to 125°C				0.4			
	$I_O = 5$ mA to 350 mA		-55°C to 150°C	0.4						
			0°C to 125°C				0.4			
Short-circuit output current	$V_I = -30$ V		25°C	600			140			mA
Peak output current			25°C	0.5	0.65	1.4	0.65			A

† All characteristics are measured with a 2- $\mu$ F capacitor across the input and a 1- $\mu$ F capacitor across the output. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# TYPES $\mu$ A79M06M, $\mu$ A79M06C NEGATIVE-VOLTAGE REGULATORS

$\mu$ A79M06M,  $\mu$ A79M06C electrical characteristics at specified virtual junction temperature,  
 $V_I = -11$  V,  $I_O = 350$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A79M06M			$\mu$ A79M06C			UNIT				
			MIN	TYP	MAX	MIN	TYP	MAX					
Output voltage			25°C		-5.75	-6	-6.25	-5.75	-6	-6.25	V		
	$I_O = 5$ mA to 350 mA, $V_I = -8$ V to -25 V		-55°C to 150°C		-5.7		-6.3						
			0°C to 125°C				-5.7		-6.3				
Input regulation	$V_I = -8$ V to -25 V		25°C		7		60		7		60		mV
	$V_I = -9$ V to -19 V				3		40		3		40		
Ripple rejection	$V_I = -9$ V to -19 V, $f = 120$ Hz	$I_O = 100$ mA	-55°C to 150°C		50								dB
			0°C to 125°C				50						
		$I_O = 300$ mA	25°C		54		60		54		60		
Output regulation	$I_O = 5$ mA to 500 mA		25°C		80		120		80		120		mV
	$I_O = 5$ mA to 350 mA				55				55				
Temperature coefficient of output voltage	$I_O = 5$ mA		-55°C to 150°C		-1.5								mV/°C
			0°C to 125°C				-0.4						
Output noise voltage	$f = 10$ Hz to 100 kHz		25°C		150		480		150				$\mu$ V
Dropout voltage			25°C		1.1		2.3		1.1				V
Bias current			25°C		1		2		1		2		mA
Bias current change	$V_I = -9$ V to -25 V		-55°C to 150°C		0.4								mA
			0°C to 125°C				0.4						
	$I_O = 5$ mA to 350 mA		-55°C to 150°C		0.4								
			0°C to 125°C				0.4						
Short-circuit output current	$V_I = -30$ V		25°C		600				140				mA
Peak output current			25°C		0.5		0.65		1.4		0.65		A

† All characteristics are measured with a 2- $\mu$ F capacitor across the input and a 1- $\mu$ F capacitor across the output. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

## TYPES $\mu$ A79M08M, $\mu$ A79M08C NEGATIVE-VOLTAGE REGULATORS

$\mu$ A79M08M,  $\mu$ A79M08C electrical characteristics at specified virtual junction temperature,  
 $V_I = -19$  V,  $I_O = 350$  mA (unless noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A79M08M			$\mu$ A79M08C			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX		
Output voltage	$I_O = 5$ mA to 350 mA, $V_I = -10.5$ V to $-25$ V		25° C	-7.7	-8	-8.3	-7.7	-8	-8.3	V
			-55° C to 150° C	-7.6		-8.4				
			0° C to 125° C				-7.6		-8.4	
Input regulation	$V_I = -10.5$ V to $-25$ V		25° C	8	80		8	80	mV	
	$V_I = -11$ V to $-21$ V			4	50		4	50		
Ripple rejection	$V_I = -11.5$ V to $-21.5$ V, $f = 120$ Hz	$I_O = 100$ mA	-55° C to 150° C	50					dB	
			0° C to 125° C			50				
		$I_O = 300$ mA	25° C	54	59		54	59		
Output regulation	$I_O = 5$ mA to 500 mA		25° C	90	160		90	160	mV	
	$I_O = 5$ mA to 350 mA			60			60			
Temperature coefficient of output voltage	$I_O = 5$ mA		-55° C to 150° C			-2.4			mV/°C	
			0° C to 125° C				-0.6			
Output noise voltage	$f = 10$ Hz to 100 kHz		25° C	200	640		200		$\mu$ V	
Dropout voltage			25° C	1.1	2.3		1.1		V	
Bias current			25° C		1	2		1	2	mA
Bias current change	$V_I = -10.5$ V to $-25$ V		-55° C to 150° C			0.4			mA	
			0° C to 125° C				0.4			
	$I_O = 5$ mA to 350 mA		-55° C to 150° C			0.4				
			0° C to 125° C				0.4			
Short-circuit output current	$V_I = -30$ V		25° C		600		140		mA	
Peak output current			25° C	0.5	0.65	1.4	0.65		A	

† All characteristics are measured with a 2- $\mu$ F capacitor across the input and a 1- $\mu$ F capacitor across the output. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

## TYPES $\mu$ A79M12M, $\mu$ A79M12C NEGATIVE-VOLTAGE REGULATORS

$\mu$ A79M12M,  $\mu$ A79M12C electrical characteristics at specified virtual junction temperature,  
 $V_I = -19$  V,  $I_O = 350$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A79M12M			$\mu$ A79M12C			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX		
Output voltage			25° C	-11.5	-12	-12.5	-11.5	-12	-12.5	V
	$I_O = 5$ mA to 350 mA, $V_I = -14.5$ V to $-30$ V		-55° C to 150° C	-11.4		-12.6				
			0° C to 125° C				-11.4		-12.6	
Input regulation	$V_I = -14.5$ V to $-30$ V		25° C	9	80	9	80		mV	
	$V_I = -15$ V to $-25$ V			5	50	5	50			
Ripple rejection	$V_I = -15$ V to $-25$ V, $f = 120$ Hz	$I_O = 100$ mA	-55° C to 150° C	50					dB	
			0° C to 125° C			50				
		$I_O = 300$ mA	25° C	54	60	54	60			
Output regulation	$I_O = 5$ mA to 500 mA		25° C	65	240	65	240		mV	
	$I_O = 5$ mA to 350 mA			45		45				
Temperature coefficient of output voltage	$I_O = 5$ mA		-55° C to 150° C		-3.6				mV/°C	
			0° C to 125° C			-0.8				
Output noise voltage	$f = 10$ Hz to 100 kHz		25° C	300	960	300			$\mu$ V	
Dropout voltage			25° C	1.1	2.3	1.1			V	
Bias current			25° C	1.5	3	1.5	3		mA	
Bias current change	$V_I = -14.5$ V to $-30$ V		-55° C to 150° C		0.4				mA	
			0° C to 125° C				0.4			
	$I_O = 5$ mA to 350 mA		-55° C to 150° C		0.4					
			0° C to 125° C				0.4			
Short-circuit output current	$V_I = -30$ V		25° C	600		140		mA		
Peak output current			25° C	0.5	0.65	1.4	0.65		A	

† All characteristics are measured with a 2- $\mu$ F capacitor across the input and a 1- $\mu$ F capacitor across the output. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.



## TYPES $\mu$ A79M15M, $\mu$ A79M15C NEGATIVE-VOLTAGE REGULATORS

$\mu$ A79M15M,  $\mu$ A79M15C electrical characteristics at specified virtual junction temperature,  
 $V_I = -23$  V,  $I_O = 350$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A79M15M			$\mu$ A79M15C			UNIT	
			MIN	TYP	MAX	MIN	TYP	MAX		
Output voltage	$I_O = 5$ mA to 350 mA, $V_I = -17.5$ V to $-30$ V		25 C	-14.4	-15	-15.6	-14.4	-15	-15.6	V
			-55 C to 150 C	-14.25		-15.75				
			0 C to 125 C				-14.25		-15.75	
Input regulation	$V_I = -17.5$ V to $-30$ V		25 C	9	80	9	80	mV		
	$V_I = -18$ V to $-28$ V			7	50	7	50			
Ripple rejection	$V_I = -18.5$ V to $-28.5$ V, $f = 120$ Hz	$I_O = 100$ mA	-55 C to 150 C	50				dB		
		$I_O = 300$ mA	0 C to 125 C			50				
			25 C	54	59	54	59			
Output regulation	$I_O = 5$ mA to 500 mA		25 C	65	240	65	240	mV		
	$I_O = 5$ mA to 350 mA			45		45				
Temperature coefficient of output voltage	$I_O = 5$ mA		-55 C to 150 C	-4.5				mV/ C		
			0 C to 125 C			-1				
Output noise voltage	$f = 10$ Hz to 100 kHz		25 C	375	1200	375		$\mu$ V		
Dropout voltage			25 C	1.1	2.3	1.1		V		
Bias current			25 C	1.5	3	1.5	3	mA		
Bias current change	$V_I = -17.5$ V to $-30$ V $I_O = 5$ mA to 350 mA		-55 C to 150 C	0.4				mA		
			0 C to 125 C			0.4				
			-55 C to 150 C	0.4						
			0 C to 125 C			0.4				
Short-circuit output current	$V_I = -30$ V		25 C	600		140		mA		
Peak output current			25 C	0.5	0.65	0.65		A		

† All characteristics are measured with a 2- $\mu$ F capacitor across the input and a 1- $\mu$ F capacitor across the output. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

## TYPE $\mu$ A79M20C NEGATIVE-VOLTAGE REGULATORS

$\mu$ A79M20C electrical characteristics at specified virtual junction temperature  
 $V_I = -29$  V,  $I_O = 350$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A79M20C			UNIT	
			MIN	TYP	MAX		
Output voltage	$I_O = 5$ mA to 350 mA, $V_I = -23$ V to $-35$ V		25°C	-19.2	-20	-20.8	V
			0°C to 125°C	-19		-21	
Input regulation	$V_I = -23$ V to $-35$ V		25°C	12	80	mV	
	$V_I = -24$ V to $-34$ V			10	70		
Ripple rejection	$V_I = -24$ V to $-34$ V, $f = 120$ Hz	$I_O = 100$ mA	0°C to 125°C	50		dB	
		$I_O = 300$ mA	25°C	54	58		
Output regulation	$I_O = 5$ mA to 500 mA		25°C	75	300	mV	
	$I_O = 5$ mA to 350 mA			50			
Temperature coefficient of output voltage	$I_O = 5$ mA		0°C to 125°C	-1		mV/°C	
Output noise voltage	$f = 10$ Hz to 100 kHz		25°C	500		$\mu$ V	
Dropout voltage			25°C	1.1		V	
Bias current			25°C	1.5	3.5	mA	
Bias current change	$V_I = -23$ V to $-35$ V		0°C to 125°C		0.4	mA	
	$I_O = 5$ mA to 350 mA				0.4		
Short-circuit output current	$V_I = -30$ V		25°C	140		mA	
Peak output current			25°C	650		A	

† All characteristics are measured with a 2  $\mu$ F capacitor across the input and a 1  $\mu$ F capacitor across the output. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# TYPE $\mu$ A79M24C NEGATIVE-VOLTAGE REGULATORS

$\mu$ A79M24C electrical characteristics at specified virtual junction temperature,  
 $V_I = -33$  V,  $I_O = 350$  mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		$\mu$ A79M24C			UNIT	
			MIN	TYP	MAX		
Output voltage	$I_O = 5$ mA to 350 mA, $V_I = -27$ V to $-38$ V		25°C	-23	-24	-25	V
			0°C to 125°C	-22.8		-25.2	
Input regulation	$V_I = -27$ V to $-38$ V		25°C	12	80	mV	
	$V_I = -28$ V to $-38$ V			12	70		
Ripple rejection	$V_I = -28$ V to $-38$ V, $f = 120$ Hz	$I_O = 100$ mA	0°C to 125°C	50		dB	
		$I_O = 300$ mA	25°C	54	58		
Output regulation	$I_O = 5$ mA to 500 mA		25°C	75	300	mV	
	$I_O = 5$ mA to 350 mA			50			
Temperature coefficient of output voltage	$I_O = 5$ mA		0°C to 125°C	-1		mV/°C	
Output noise voltage	$f = 10$ Hz to 100 kHz		25°C	600		$\mu$ V	
Dropout voltage			25°C	1.1		V	
Bias current			25°C	1.5	3.5	mA	
Bias current change	$V_I = -27$ V to $-38$ V		0°C to 125°C		0.4	mA	
	$I_O = 5$ mA to 350 mA				0.4		
Short-circuit output current	$V_I = -30$ V		25°C	140		mA	
Peak output current			25°C	650		A	

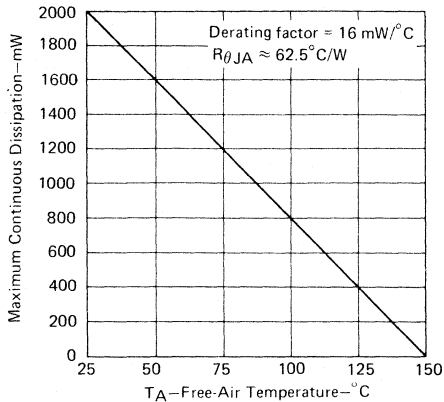
† All characteristics are measured with a 2- $\mu$ F capacitor across the input and a 1- $\mu$ F capacitor across the output. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.



**SERIES  $\mu$ A79M00**  
**NEGATIVE-VOLTAGE REGULATORS**

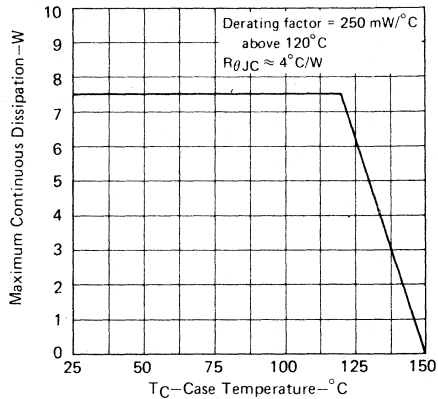
**THERMAL INFORMATION**

**KC PACKAGE**  
**FREE-AIR TEMPERATURE**  
**DISSIPATION DERATING CURVE**



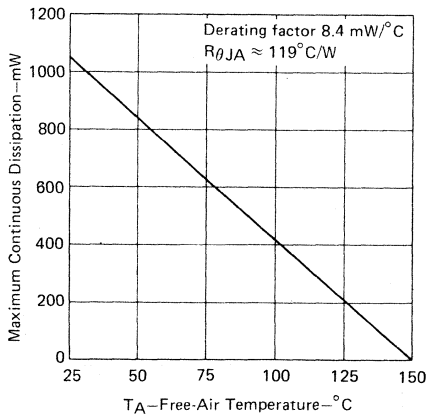
**FIGURE 1**

**KC PACKAGE**  
**CASE TEMPERATURE**  
**DISSIPATION DERATING CURVE**



**FIGURE 2**

**JG PACKAGE**  
**FREE-AIR TEMPERATURE**  
**DISSIPATION DERATING CURVE**



**FIGURE 3**



**General Information**

**1**

**Thermal Information**

**2**

**Operational Amplifiers**

**3**

**Voltage Comparators**

**4**

**Special Functions**

**5**

**Voltage Regulators**

**6**

**Data Acquisition**

**7**

**Appendix**

**A**



## single- and dual-slope A/D converters

DEVICE NUMBER	FUNCTION	RESOLUTION	RECOMMENDED COMPLEMENT	TEMP <sup>†</sup> RANGE	PACKAGE	PAGE
TL500	Dual-slope analog processors	13 Bits	TL502, TL505	C	N	7-43
TL501		10-12 Bits		C	N	7-43
TL505		8-10 Bits	Microprocessor	C	N	7-57
TL502	Digital processors with seven segment outputs	4 1/2 Digits	Microprocessor	C	N	7-43
TL503	Digital processors with BCD outputs	4 1/2 Digits	Microprocessor	C	N	7-43
TL507	Pulse-width modulator for single-slope converter	7 Bits	Microprocessor	C	N	7-63

## successive-approximation A/D converters

DEVICE NUMBER	SIGNAL INPUTS		ADDRESS AND DATA I/O FORMAT	CONVERSION SPEED <sup>§</sup> (μs)	UNADJUSTED ERROR ± LSB	POWER DISSIPATION (mW)	TEMP <sup>†</sup> RANGE	PACKAGE	PAGE
	DEDICATED ANALOG	ANALOG/DIGITAL <sup>‡</sup>							
ADC0801	1	0	Parallel	100	—	29	I	N	7-5
ADC0802	1	0	Parallel	100	0.5	29	I	N	7-5
ADC0803	1	0	Parallel	100	—	29	I	N	7-5
ADC0805	1	0	Parallel	100	0.5	29	I	N	7-5
ADC0804C	1	0	Parallel	100	1	29	C	N	7-11
ADC0808	8	0	Parallel	100	0.75	12	I	N	7-17
ADC0809	8	0	Parallel	100	1.25	12	I	N	7-17
ADC0831	1	0	Serial	84	0.5	15	I	N	7-23
ADC0832	2	0	Serial	84	0.5	15	I	N	7-23
ADC0834	4	0	Serial	84	0.5	15	I	N	7-23
ADC0838	8	0	Serial	84	0.5	15	I	N	7-23
TL520	8	0	Parallel	70	0.75	2	I	N	7-67
TL521	8	0	Parallel	100	1	2	I	N	7-67
TL522	8	0	Parallel	208	0.5	0.3	I	N	7-67
TL530 <sup>¶</sup>	8	6	Parallel	300	0.5	15	I	N	7-77
TL531 <sup>¶</sup>	8	6	Parallel	300	1	15	I	N	7-77
TL532	5	6	Parallel	300	0.5	15	I	N	7-87
TLC532A	5	6	Parallel	15	0.5	6	M,I	FH,J,N	7-101
TL533	5	6	Parallel	300	1	15	I	N	7-87
TLC533A	5	6	Parallel	15	1	6	M,I	FH,J,N	7-101
TLC540	11	0	Serial	12	0.5	6	M,I	FK,FN,J,N	7-109
TLC541	11	0	Serial	34	1	6	M,I	FK,FN,J,N	7-109
TLC549	1	0	Serial	19	0.5	6	M,I	JG,P	7-115

<sup>†</sup>M = -55°C to 125°C, I = -40°C to 85°C, C = 0°C to 70°C.

<sup>‡</sup>Analog/digital signal inputs can be used either as digital inputs for limiting sensing or digital data, or they can be used as analog inputs. For example: the TL530 can have 15 analog inputs and 6 digital outputs, 9 analog inputs and 12 digital inputs, or any combination in between.

<sup>§</sup>Includes access time.

<sup>¶</sup>The TL530 and TL531 devices also have 6 dedicated digital inputs.

## SELECTION GUIDE

### analog switches

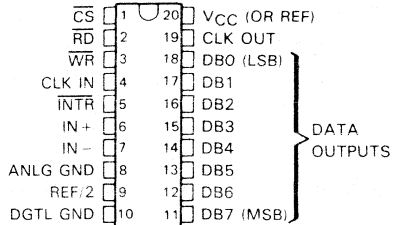
DEVICE NUMBER	FUNCTION	TYPICAL IMPEDANCE (OHM)	VOLTAGE RANGE (V)	POWER SUPPLIES (V)	TEMP <sup>†</sup> RANGE	PACKAGE	PAGE
TL182	Twin SPDT	100	± 10	± 15, 5	M,I,C	J,N	7-37
TL185	Twin DPST	150	± 10	± 15, 5	M,I,C	J,N	7-37
TL188	Dual SPST	100	± 10	± 15, 5	M,I,C	J,N	7-37
TL191	Twin dual SPST	150	+ 10	+ 15, 5	M,I,C	J,N	7-37
TL601	SPDT	Not recommended for new designs			M,I,C	JG,P	7-95
TL604	Dual SPST				M,I,C	JG,P	7-95
TL607	SPDT with enable				M,I,C	JG,P	7-95
TL610	SPST with logic inputs				M,I,C	JG,P	7-95

<sup>†</sup>M ≡ -55°C to 125°C, I ≡ -40°C to 85°C, C ≡ 0°C to 70°C.



- 8-Bit Resolution
- Ratiometric Conversion
- 100  $\mu$ s Conversion Time
- 135 ns Access Time
- Guaranteed Monotonicity
- High Reference Ladder Impedance  
8 k $\Omega$  Typical
- No Zero Adjust Requirement
- On-Chip Clock Generator
- Single 5-Volt Power Supply
- Operates With Microprocessor or as Stand-Alone
- Designed to be Interchangeable with National Semiconductor ADC0801, ADC0802, ADC0803, ADC0805

**N DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



**description**

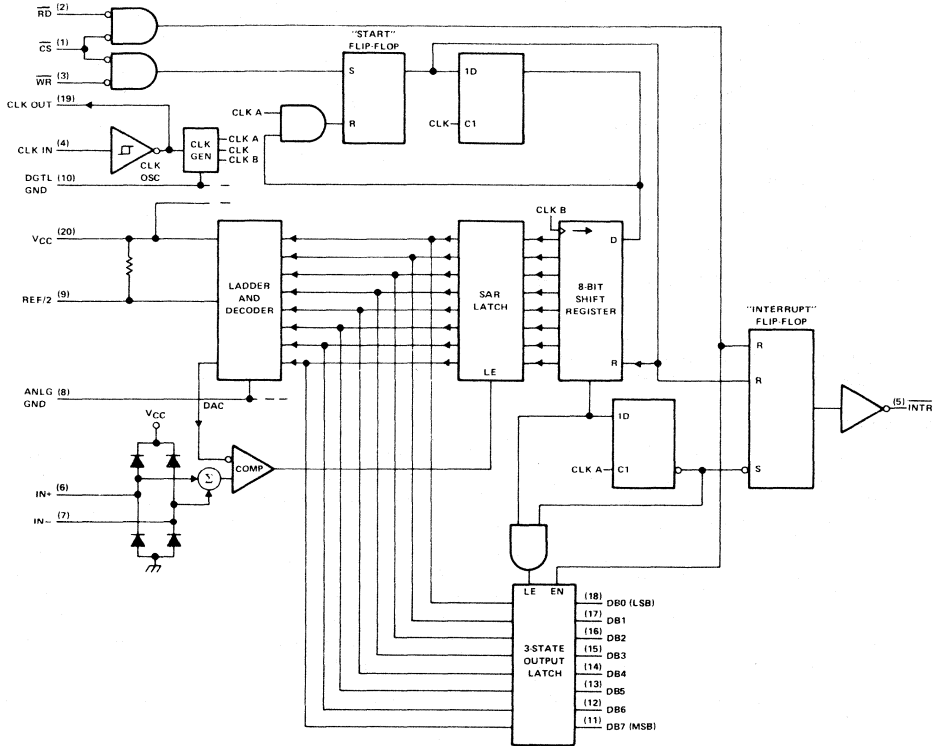
The ADC0801, ADC0802, ADC0803, and ADC0805 are CMOS 8-bit successive-approximation analog-to-digital converters that use a modified potentiometric (256R) ladder. These devices are designed to operate from common microprocessor control buses, with the three-state output latches driving the data bus. The devices can be made to appear to the microprocessor as a memory location or an I/O port.

A differential analog voltage input allows increased common-mode rejection and offset of the zero-input analog voltage value. Although a reference input (REF/2) is available to allow 8-bit conversion over smaller analog voltage spans or to make use of an external reference, ratiometric conversion is possible with the REF/2 input open. Without an external reference, the conversion takes place over a span from V<sub>CC</sub> to analog ground (ANALG GND). The devices can operate with an external clock signal or, with an additional resistor and capacitor, can operate using an on-chip clock generator.

The ADC0801I, ADC0802I, ADC0803I, and ADC0805I will be characterized for operation from -40 °C to 85 °C.

**TYPES ADC0801, ADC0802, ADC0803, ADC0805  
8-BIT ANALOG-TO-DIGITAL CONVERTERS  
WITH DIFFERENTIAL INPUTS**

functional block diagram (positive logic)



# TYPES ADC0801, ADC0802, ADC0803, ADC0805 8-BIT ANALOG-TO-DIGITAL CONVERTERS WITH DIFFERENTIAL INPUTS

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	6.5 V
Input voltage range $\overline{CS}$ , $\overline{RD}$ , $\overline{WR}$	-0.3 V to 18 V
Other inputs	-0.3 V to $V_{CC} + 0.3$ V
Output voltage range	-0.3 V to $V_{CC} + 0.3$ V
Continuous total power dissipation at 25°C free-air temperature (see Note 2)	875 mW
Operating free-air temperature range	-40°C to 85°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

- NOTES: 1. All voltage values are with respect to digital ground (DGTL GND) with DGTL GND and ANLG GND connected together (unless otherwise noted).  
2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, section 2.

## recommended operating conditions

		MIN	NOM	MAX	UNIT
$V_{CC}$	Supply voltage	4.5	5	6.3	V
$V_{REF/2}$	Voltage at REF/2 (see Note 3)	0.25	2.5		V
$V_{IH}$	High-level input voltage at $\overline{CS}$ , $\overline{RD}$ , or $\overline{WR}$	2		15	V
$V_{IL}$	Low-level input voltage at $\overline{CS}$ , $\overline{RD}$ , or $\overline{WR}$			0.8	V
	Analog ground voltage (see Note 4)	-0.05	0	1	V
	Analog input voltage (see Note 5)	GND - 0.05		$V_{CC} + 0.05$	V
$f_{clock}$	Clock input frequency (see Note 6)	100	640	1460	kHz
	Duty cycle above 640 kHz (see Note 6)	40		60	%
$t_{w(CLK)}$	Pulse duration clock input (high or low)	275	781		ns
$t_{w(WR)}$	Pulse duration, $\overline{WR}$ input low	100			ns
$T_A$	Operating free-air temperature	-40		85	°C

- NOTES: 3. Proper operation is achieved over a differential input range of 0 V to  $V_{CC}$  when the REF/2 input is open.  
4. These values are with respect to digital ground (pin 10).  
5. When the positive analog input with respect to the negative analog input ( $V_{in+} - V_{in-}$ ) is zero or negative, the output code is 0000 0000.  
6. Total unadjusted error is guaranteed only at an  $f_{clock}$  of 640 kHz with a duty cycle of 40% to 60% (pulse duration 625 ns to 937 ns). For frequencies above this limit or pulse duration below 625 ns, error may increase. The duty cycle limits should be observed for an  $f_{clock}$  greater than 640 kHz. Below 640 kHz, this duty cycle limit can be exceeded provided  $t_{w(CLK)}$  remains within limits.

# TYPES ADC0801, ADC0802, ADC0803, ADC0805

## 8-BIT ANALOG-TO-DIGITAL CONVERTERS

### WITH DIFFERENTIAL INPUTS

electrical characteristics over recommended operating free-air temperature range,  $V_{CC} = 5\text{ V}$ ,  
 $f_{\text{clock}} = 640\text{ kHz}$ ,  $V_{\text{REF}/2} = 2\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP <sup>†</sup>	MAX	UNIT
$V_{OH}$	High-level output voltage	All outputs	$V_{CC} = 4.75\text{ V}$ , $I_{OH} = -360\text{ }\mu\text{A}$	2.4			V
		DB and INTR	$V_{CC} = 4.75\text{ V}$ , $I_{OH} = -10\text{ }\mu\text{A}$	4.5			
$V_{OL}$	Low-level output voltage	Data outputs	$V_{CC} = 4.75\text{ V}$ , $I_{OL} = 1.6\text{ mA}$			0.4	V
		INTR output	$V_{CC} = 4.75\text{ V}$ , $I_{OL} = 1\text{ mA}$			0.4	
		CLK OUT	$V_{CC} = 4.75\text{ V}$ , $I_{OL} = 360\text{ }\mu\text{A}$			0.4	
$V_{T+}$	Clock positive-going threshold voltage			2.7	3.1	3.5	V
$V_{T-}$	Clock negative-going threshold voltage			1.5	1.8	2.1	V
$V_{T+} - V_{T-}$	Clock input hysteresis			0.6	1.3	2	V
$I_{IH}$	High-level input current				0.005	1	$\mu\text{A}$
$I_{IL}$	Low-level input current				-0.005	-1	$\mu\text{A}$
$I_{OZ}$	Off-state output current	$V_O = 0$				-3	$\mu\text{A}$
		$V_O = 5\text{ V}$				3	
$I_{OHS}$	Short-current output current	Output high	$V_O = 0$ , $T_A = 25^\circ\text{C}$	-4.5		-6	mA
$I_{OLS}$	Short-circuit output current	Output low	$V_O = 5\text{ V}$ , $T_A = 25^\circ\text{C}$	9	16		mA
$I_{CC}$	Supply current plus reference current		$V_{\text{REF}/2} = \text{open}$ , $T_A = 25^\circ\text{C}$ , $\overline{\text{CS}}$ at 5 V		1.1	1.8	mA
$R_{\text{REF}/2}$	Input resistance to reference ladder		See Note 7	2.5	8		k $\Omega$
$C_i$	Input capacitance (control)				5	7.5	pF
$C_o$	Output capacitance (DB)				5	7.5	pF

NOTE 7: Resistance is calculated from the current drawn from a 5-volt supply applied to pins 8 and 9.

operating characteristics over recommended operating free-air temperature,  $V_{CC} = 5\text{ V}$ ,  
 $V_{\text{REF}/2} = 2.5\text{ V}$ ,  $f_{\text{clock}} = 640\text{ kHz}$  (unless otherwise noted)

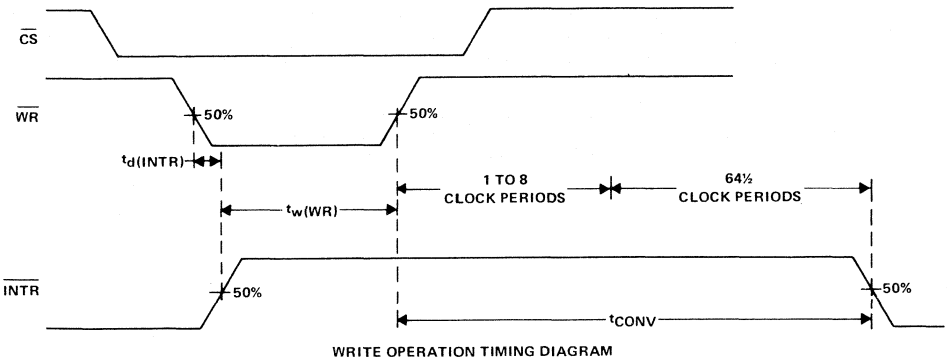
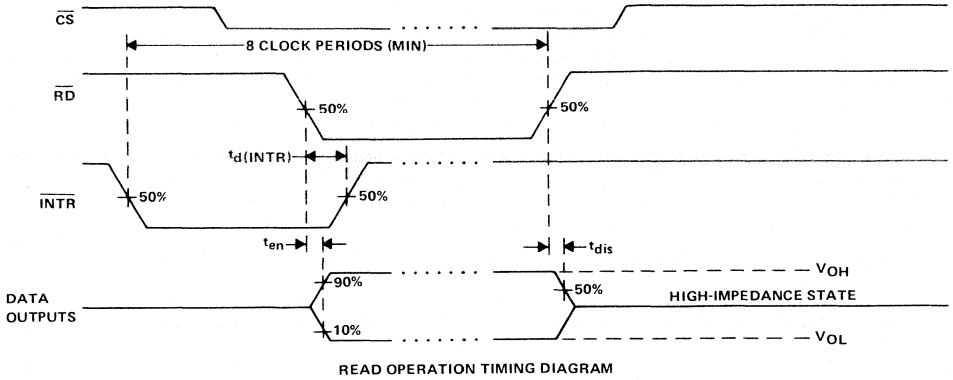
PARAMETER		TEST CONDITIONS		MIN	TYP <sup>†</sup>	MAX	UNIT
Supply-voltage-variation error		$V_{CC} = 4.5\text{ V}$ to $5.5\text{ V}$ , See Note 8			$\pm 1/16$	$\pm 1/8$	LSB
Total adjusted error	ADC0801	With full-scale adjust, See Notes 8 and 9				$\pm 1/4$	LSB
	ADC0803					$\pm 1/2$	
Total unadjusted error	ADC0802	$V_{\text{REF}/2} = 2.5\text{ V}$ , See Notes 8 and 9				$\pm 1/2$	LSB
	ADC0805	$V_{\text{REF}/2}$ open, See Notes 8 and 9				$\pm 1$	
DC common-mode error		See Note 8 and 9			$\pm 1/16$	$\pm 1/8$	LSB
$t_{\text{en}}$	Output enable time	$C_L = 100\text{ pF}$			135	200	ns
$t_{\text{dis}}$	Output disable time	$C_L = 10\text{ pF}$ , $R_L = 10\text{ k}\Omega$			125	200	ns
$t_{\text{d}}(\text{INTR})$	Delay time to reset INTR				300	450	ns
$t_{\text{conv}}$	Conversion cycle time	$f_{\text{clock}} = 100\text{ kHz}$ to $1.46\text{ MHz}$ , See Note 10		66		73	clock cycles
CR	Free-running conversion rate	INTR connected to WR, $\overline{\text{CS}}$ at 0 V				8770	conv/s

<sup>†</sup>All typical values are at  $T_A = 25^\circ\text{C}$ .

- NOTES: 8. These parameters are guaranteed over the recommended analog input voltage range.  
9. All errors are measured with reference to an ideal straight line through the end-points of the analog-to-digital transfer characteristic.  
10. Although internal conversion is completed in 64 clock periods, a  $\overline{\text{CS}}$  or  $\overline{\text{WR}}$  low-to-high transition is followed by 1 to 8 clock periods before conversion starts. After conversion is completed, part of another clock period is required before a high-to-low transition of INTR completes the cycle.

**TYPES ADC0801, ADC0802, ADC0803, ADC0805**  
**8-BIT ANALOG-TO-DIGITAL CONVERTERS**  
**WITH DIFFERENTIAL INPUTS**

**PARAMETER MEASUREMENT INFORMATION**



# TYPES ADC0801, ADC0802, ADC0803, ADC0805 8-BIT ANALOG-TO-DIGITAL CONVERTERS WITH DIFFERENTIAL INPUTS

## PRINCIPLES OF OPERATION

The ADC0801, ADC0802, ADC0803, and ADC0805 each contain a circuit equivalent to a 256-resistor network. Analog switches are sequenced by successive approximation logic to match an analog differential input voltage ( $V_{IN+} - V_{IN-}$ ) to a corresponding tap on the 256R network. The most-significant bit (MSB) is tested first. After eight comparisons (64 clock periods), an eight-bit binary code (1111 1111 = full scale) is transferred to an output latch and the interrupt ( $\overline{INTR}$ ) output goes low. The device can be operated in a free-running mode by connecting the  $\overline{INTR}$  output to the write ( $\overline{WR}$ ) input and holding the conversion start ( $\overline{CS}$ ) input at a low level. To ensure start-up under all conditions, a low-level  $\overline{WR}$  input is required during the power-up cycle. Taking  $\overline{CS}$  low anytime after that will interrupt a conversion in process.

When the  $\overline{WR}$  input goes low, the internal successive approximation register (SAR) and eight-bit shift register are reset. As long as both  $\overline{CS}$  and  $\overline{WR}$  remain low, the analog-to-digital converter will remain in a reset state. One to eight clock periods after  $\overline{CS}$  or  $\overline{WR}$  makes a low-to-high transition, conversion starts.

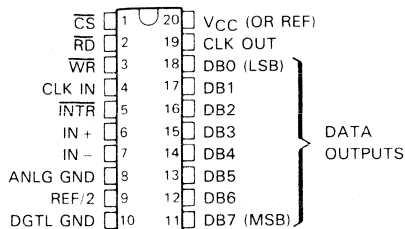
When the  $\overline{CS}$  and  $\overline{WR}$  inputs are low, the start flip-flop is set and the interrupt flip-flop and eight-bit register are reset. The next clock pulse transfers a logic high to the output of the start flip-flop. The logic high is ANDed with the next clock pulse placing a logic high on the reset input of the start flip-flop. If either  $\overline{CS}$  or  $\overline{WR}$  have gone high, the set signal to the start flip-flop is removed causing it to be reset. A logic high is placed on the D input of the eight-bit shift register and the conversion process is started. If the  $\overline{CS}$  and  $\overline{WR}$  inputs are still low, the start flip-flop, the eight-bit shift register, and the SAR remain reset. This action allows for wide  $\overline{CS}$  and  $\overline{WR}$  inputs with conversion starting from one to eight clock periods after one of the inputs goes high.

When the logic high input has been clocked through the eight-bit shift register, completing the SAR search, it is applied to an AND gate controlling the output latches and to the D input of a flip-flop. On the next clock pulse, the digital word is transferred to the three-state output latches and the interrupt flip-flop is set. The output of the interrupt flip-flop is inverted to provide an  $\overline{INTR}$  output that is high during conversion and low when the conversion is completed.

When a low is at both the  $\overline{CS}$  and  $\overline{RD}$  inputs, an output is applied to the DB0 through DB7 outputs and the interrupt flip-flop is reset. When either the  $\overline{CS}$  or  $\overline{RD}$  inputs return to a high state, the DB0 through DB7 outputs are disabled (returned to the high-impedance state). The interrupt flip-flop remains reset.

- 8-Bit Resolution
- Ratiometric Conversion
- 100  $\mu$ s Conversion Time
- 135 ns Access Time
- No Zero Adjust Requirement
- On-Chip Clock Generator
- Single 5-Volt Power Supply
- Operates With Microprocessor or as Stand-Alone
- Designed to be Interchangeable with National Semiconductor ADC0804LCN

N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**description**

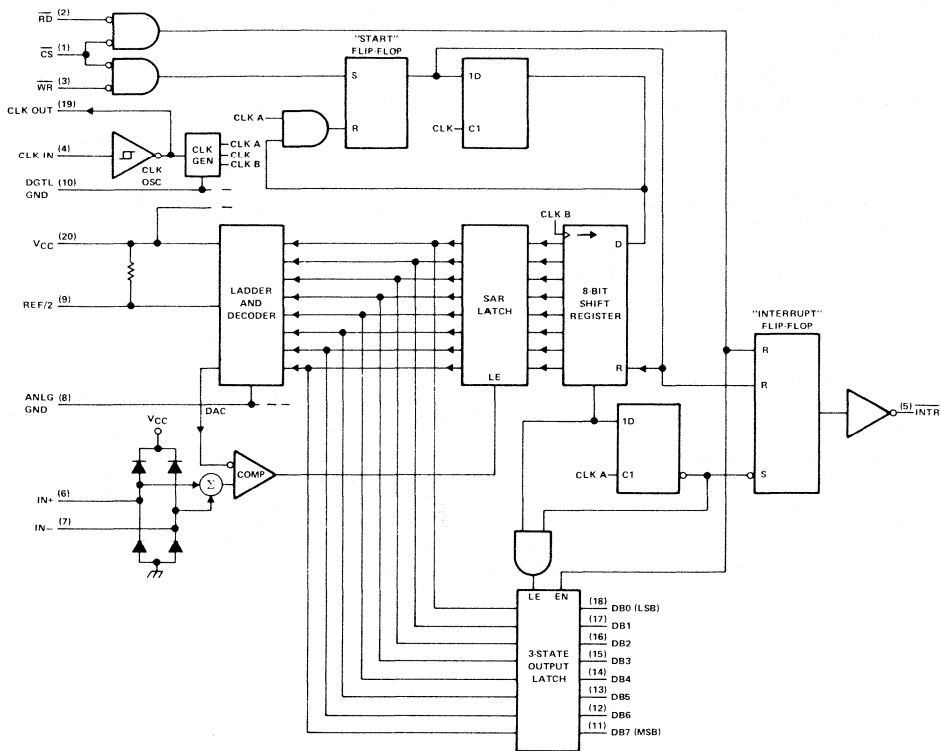
The ADC0804C is a CMOS 8-bit successive-approximation analog-to-digital converter that uses a modified potentiometric (256R) ladder. The ADC0804 is designed to operate from common microprocessor control buses, with the three-state output latches driving the data bus. The ADC0804 can be made to appear to the microprocessor as a memory location or an I/O port.

A differential analog voltage input allows increased common-mode rejection and offset of the zero-input analog voltage value. Although a reference input (REF/2) is available to allow 8-bit conversion over smaller analog voltage spans or to make use of an external reference, ratiometric conversion is possible with the REF/2 input open. Without an external reference, the conversion takes place over a span from VCC to analog ground (ANLG GND). The ADC0804 can operate with an external clock signal or, with an additional resistor and capacitor, can operate using an on-chip clock generator.

The ADC0804C is characterized for operation from 0°C to 70°C.

# TYPE ADC0804C 8-BIT ANALOG-TO-DIGITAL CONVERTER WITH DIFFERENTIAL INPUTS

functional block diagram (positive logic)



Data Acquisition

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# TYPE ADC0804C

## 8-BIT ANALOG-TO-DIGITAL CONVERTER WITH DIFFERENTIAL INPUTS

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	6.5 V
Input voltage range $\overline{CS}$ , $\overline{RD}$ , $\overline{WR}$	-0.3 V to 18 V
other inputs	-0.3 V to $V_{CC} + 0.3$ V
Output voltage range	-0.3 V to $V_{CC} + 0.3$ V
Continuous total power dissipation at 25°C free-air temperature (see Note 2)	875 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

- NOTES: 1. All voltage values are with respect to digital ground (DGTL GND) with DGTL GND and ANLG GND connected together (unless otherwise noted).  
 2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2.

### recommended operating conditions

	MIN	NOM	MAX	UNIT
$V_{CC}$ Supply voltage	4.5	5	6.3	V
$V_{REF/2}$ Voltage at REF/2 (see Note 3)	0.25	2.5		V
$V_{IH}$ High-level input voltage at $\overline{CS}$ , $\overline{RD}$ , or $\overline{WR}$	2		15	V
$V_{IL}$ Low-level input voltage at $\overline{CS}$ , $\overline{RD}$ , or $\overline{WR}$			0.8	V
Analog ground voltage (see Note 4)	-0.05	0	1	V
Analog input voltage (see Note 5)	GND - 0.05		$V_{CC} + 0.05$	V
$f_{clock}$ Clock input frequency (see Note 6)	100	640	1460	kHz
Duty cycle above 640 kHz (see Note 6)	40		60	%
$t_{w(CLK)}$ Pulse duration clock input (high or low) (see Note 6)	275	781		ns
$t_{w(WR)}$ Pulse duration, $\overline{WR}$ input low	100			ns
$T_A$ Operating free-air temperature	0		70	°C

- NOTES: 3. Proper operation is achieved over a differential input range of 0 V to  $V_{CC}$  when the REF/2 input is open.  
 4. These values are with respect to digital ground (pin 10).  
 5. When the positive analog input with respect to the negative analog input ( $V_{in+} - V_{in-}$ ) is zero or negative, the output code is 0000 0000.  
 6. Total unadjusted error is guaranteed only at an  $f_{clock}$  of 640 kHz this with a duty cycle of 40% to 60% (pulse duration 625 ns to 937 ns). For frequencies above this limit or pulse duration below 625 ns, error may increase. The duty cycle limits should be observed for an  $f_{clock}$  greater than 640 kHz. Below 640 kHz, this duty cycle limit can be exceeded provided  $t_{w(CLK)}$  remains within limits.

# TYPE ADC0804C

## 8-BIT ANALOG-TO-DIGITAL CONVERTER

### WITH DIFFERENTIAL INPUTS

electrical characteristics over recommended operating free-air temperature range,  
 $V_{CC} = 5\text{ V}$ ,  $f_{clock} = 640\text{ kHz}$ ,  $REF/2 = 2.5\text{ V}$  (unless otherwise noted)

PARAMETER			TEST CONDITIONS		MIN	TYP <sup>†</sup>	MAX	UNIT
$V_{OH}$	High-level output voltage	All outputs	$V_{CC} = 4.75\text{ V}$ , $I_{OH} = -360\text{ }\mu\text{A}$		2.4			V
		DB and INTR	$V_{CC} = 4.75\text{ V}$ , $I_{OH} = -10\text{ }\mu\text{A}$		4.5			
$V_{OL}$	Low-level output voltage	Data outputs	$V_{CC} = 4.75\text{ V}$ , $I_{OL} = 1.6\text{ mA}$				0.4	V
		INTR output	$V_{CC} = 4.75\text{ V}$ , $I_{OL} = 1\text{ mA}$				0.4	
		CLK OUT	$V_{CC} = 4.75\text{ V}$ , $I_{OL} = 360\text{ }\mu\text{A}$				0.4	
$V_{T+}$	Clock positive-going threshold voltage				2.7	3.1	3.5	V
$V_{T-}$	Clock negative-going threshold voltage				1.5	1.8	2.1	V
$V_{T+} - V_{T-}$	Clock input hysteresis				0.6	1.3	2	V
$I_{IH}$	High-level input current					0.005	1	$\mu\text{A}$
$I_{IL}$	Low-level input current					-0.005	-1	$\mu\text{A}$
$I_{OZ}$	Off-state output current		$V_O = 0$				-3	$\mu\text{A}$
			$V_O = 5\text{ V}$				3	
$I_{OHS}$	Short-circuit output current	Output high	$V_O = 0$ , $T_A = 25^\circ\text{C}$		-4.5	-6		mA
$I_{OLS}$	Short-circuit output current	Output low	$V_O = 5\text{ V}$ , $T_A = 25^\circ\text{C}$		9	16		mA
$I_{CC}$	Supply current plus reference current		REF/2 open, CS at 5 V, $T_A = 25^\circ\text{C}$			1.9	2.5	mA
$R_{REF/2}$	Input resistance to reference ladder		See Note 7		1	1.3		k $\Omega$
$C_i$	Input capacitance (control)					5	7.5	pF
$C_o$	Output capacitance (DB)					5	7.5	pF

<sup>†</sup>All typical values are at  $T_A = 25^\circ\text{C}$ .

NOTE 7: The resistance is calculated from the current drawn from a 5-volt supply applied to pins 8 and 9.

operating characteristics over recommended operating free-air temperature,  
 $V_{CC} = 5\text{ V}$ ,  $V_{REF/2} = 2.5\text{ V}$ ,  $f_{clock} = 640\text{ kHz}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP <sup>†</sup>	MAX	UNIT
Supply-voltage-variation error		$V_{CC} = 4.5\text{ V}$ to $5.5\text{ V}$ , See Note 8			$\pm 1/16$	$\pm 1/8$	LSB
Total unadjusted error		See Notes 8 and 9				$\pm 1$	LSB
DC common-mode error		See Note 9			$\pm 1/16$	$\pm 1/8$	LSB
$t_{en}$	Output enable time	$C_L = 100\text{ pF}$			135	200	ns
$t_{dis}$	Output disable time	$C_L = 10\text{ pF}$ , $R_L = 10\text{ k}\Omega$			125	200	ns
$t_d(\text{INTR})$	Delay time to reset INTR				300	450	ns
$t_{conv}$	Conversion cycle time	$f_{clock} = 100\text{ kHz}$ to $1.46\text{ MHz}$ , See Note 10		66		73	clock cycles
CR	Free-running conversion rate	INTR connected to $\overline{WR}$ , CS at 0 V				8770	conv/s

<sup>†</sup>All typical values are at  $T_A = 25^\circ\text{C}$ .

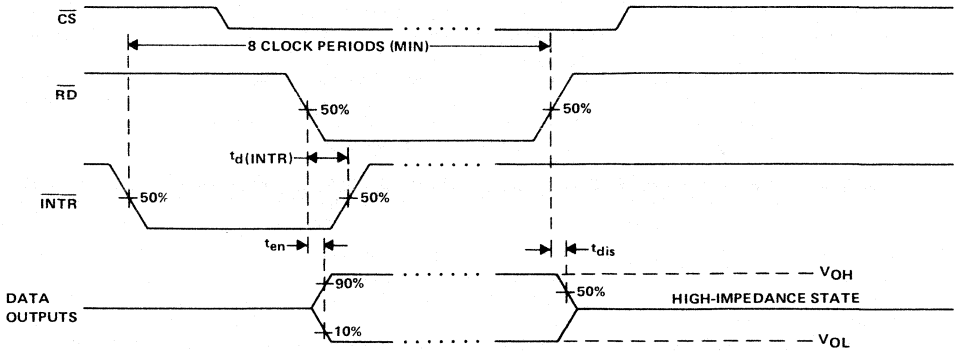
NOTES: 8. These parameters are guaranteed over the recommended analog input voltage range.

9. All errors are measured with reference to an ideal straight line through the end-points of the analog-to-digital transfer characteristic.

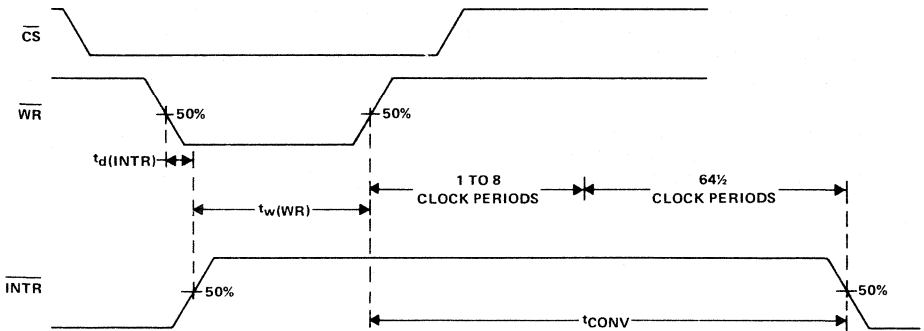
10. Although internal conversion is completed in 64 clock periods, a CS or  $\overline{WR}$  low-to-high transition is followed by 1 to 8 clock periods before conversion starts. After conversion is completed, part of another clock period is required before a high-to-low transition of INTR completes the cycle.

**TYPE ADC0804C**  
**8-BIT ANALOG-TO-DIGITAL CONVERTER**  
**WITH DIFFERENTIAL INPUTS**

timing diagrams



READ OPERATION TIMING DIAGRAM



WRITE OPERATION TIMING DIAGRAM

# TYPE ADC0804C

## 8-BIT ANALOG-TO-DIGITAL CONVERTER WITH DIFFERENTIAL INPUTS

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### PRINCIPLES OF OPERATION

The ADC0804 contains a circuit equivalent to a 256-resistor network. Analog switches are sequenced by successive approximation logic to match an analog differential input voltage ( $V_{in+} - V_{in-}$ ) to a corresponding tap on the 256-resistor network. The most-significant bit (MSB) is tested first. After eight comparisons (64 clock periods), an eight-bit binary code (1111 1111 = full scale) is transferred to an output latch and the interrupt ( $\overline{INTR}$ ) output goes low. The device can be operated in a free-running mode by connecting the  $\overline{INTR}$  output to the write ( $\overline{WR}$ ) input and holding the conversion start ( $\overline{CS}$ ) input at a low level. To ensure start-up under all conditions, a low-level  $\overline{WR}$  input is required during the power-up cycle. Taking  $\overline{CS}$  low anytime after that will interrupt a conversion in process.

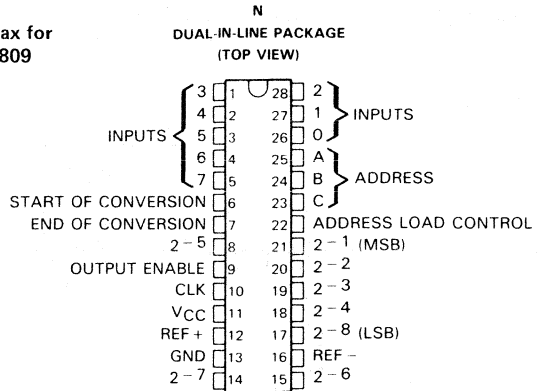
When the  $\overline{WR}$  input goes low, the ADC0804 successive approximation register (SAR) and eight-bit shift register are reset. As long as both  $\overline{CS}$  and  $\overline{WR}$  remain low, the ADC0804C will remain in a reset state. One to eight clock periods after  $\overline{CS}$  or  $\overline{WR}$  makes a low-to-high transition, conversion starts.

When the  $\overline{CS}$  and  $\overline{WR}$  inputs are low, the start flip-flop is set and the interrupt flip-flop and eight-bit register are reset. The next clock pulse transfers a logic high to the output of the start flip-flop. The logic high is ANDed with the next clock pulse placing a logic high on the reset input of the start flip-flop. If either  $\overline{CS}$  or  $\overline{WR}$  have gone high, the set signal to the start flip-flop is removed causing it to be reset. A logic high is placed on the D input of the eight-bit shift register and the conversion process is started. If the  $\overline{CS}$  and  $\overline{WR}$  inputs are still low, the start flip-flop, the eight-bit shift register, and the SAR remain reset. This action allows for wide  $\overline{CS}$  and  $\overline{WR}$  inputs with conversion starting from one to eight clock periods after one of the inputs goes high.

When the logic high input has been clocked through the eight-bit shift register, completing the SAR search, it is applied to an AND gate controlling the output latches and to the D input of a flip-flop. On the next clock pulse, the digital word is transferred to the three-state output latches and the interrupt flip-flop is set. The output of the interrupt flip-flop is inverted to provide an  $\overline{INTR}$  output that is high during conversion and low when the conversion is completed.

When a low is at both the  $\overline{CS}$  and  $\overline{RD}$  inputs, an output is applied to the DB0 through DB7 outputs and the interrupt flip-flop is reset. When either the  $\overline{CS}$  or  $\overline{RD}$  inputs return to a high state, the DB0 through DB7 outputs are disabled (returned to the high-impedance state). The interrupt flip-flop remains reset.

- Total Unadjusted Error . . .  $\pm\frac{1}{2}$  LSB Max for ADC0808 and  $\pm 1$  LSB Max for ADC0809
- Resolution of 8 Bits
- 100  $\mu$ s Conversion Time
- Ratiometric Conversion
- Guaranteed Monotonicity
- No Missing Codes
- Easy Interface with Microprocessors
- Latched 3-State Outputs
- Latched Address Inputs
- Single 5-Volt Supply
- Low Power Consumption
- Designed to be Interchangeable with National Semiconductor ADC0808, ADC0809



**description**

The ADC0808 and ADC0809 are monolithic CMOS devices with an 8-channel multiplexer, an 8-bit analog-to-digital (A/D) converter, and microprocessor-compatible control logic. The 8-channel multiplexer can be controlled by a microprocessor through a 3-bit address decoder with address load to select any one of eight single-ended analog switches connected directly to the comparator. The 8-bit A/D converter uses the successive-approximation conversion technique featuring a high-impedance threshold detector, a switched-capacitor array, a sample-and-hold, and a successive-approximation register (SAR).

The comparison and converting methods used eliminate the possibility of missing codes, nonmonotonicity, and the need for zero or full-scale adjustment. Also featured are latched 3-state outputs from the SAR and latched inputs to the multiplexer address decoder. The single 5-volt supply and low power requirements make the ADC0808 and ADC0809 especially useful for a wide variety of applications. Ratiometric conversion is made possible by access to the reference voltage input terminals.

The ADC0808 and ADC0809 are characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

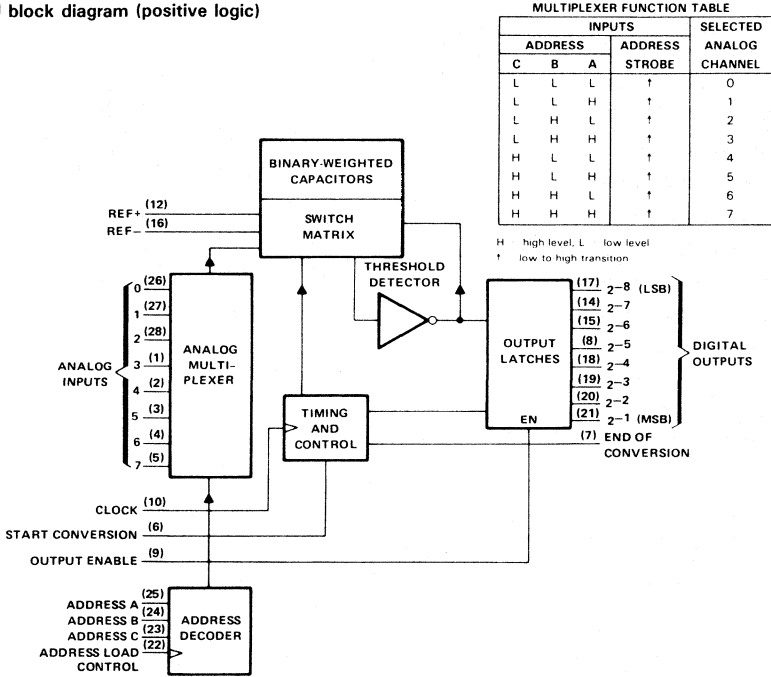
**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage, $V_{CC}$ (see Note 1)	6.5 V
Input voltage range: control inputs	$-0.3$ V to 15 V
all other inputs	$-0.3$ V to $V_{CC} + 0.3$ V
Continuous total dissipation at (or below) $25^{\circ}\text{C}$ free-air temperature (see Note 2)	875 mW
Operating free-air temperature range	$-40^{\circ}\text{C}$ to $85^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1,6 mm (1/16 inch) from case of 10 seconds	$260^{\circ}\text{C}$

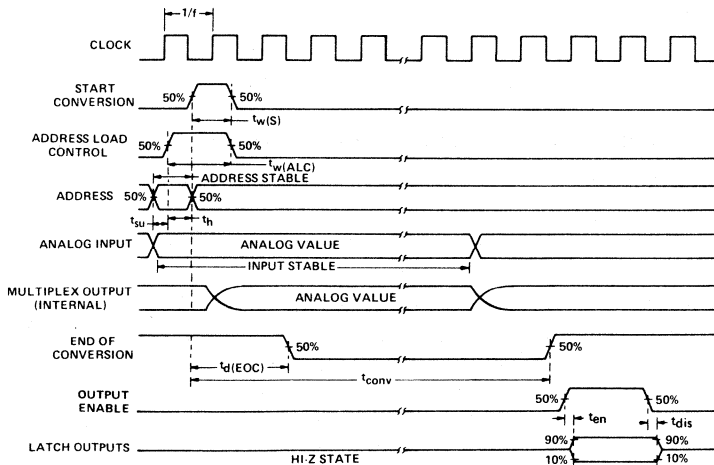
- NOTES: 1. All voltage values are with respect to network ground terminal.  
2. For operations above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Curves, Section 2.

# TYPES ADC0808, ADC0809 CMOS ANALOG-TO-DIGITAL CONVERTERS WITH 8-CHANNEL MULTIPLEXERS

functional block diagram (positive logic)



operating sequence



Data Acquisition

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# TYPES ADC0808, ADC0809

## CMOS ANALOG-TO-DIGITAL CONVERTERS WITH 8-CHANNEL MULTIPLEXERS

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	4.5	5	6	V
Positive reference voltage, $V_{ref+}$ (see Note 3)		$V_{CC}$	$V_{CC} + 0.1$	V
Negative reference voltage, $V_{ref-}$		0	-0.1	V
Differential reference voltage, $V_{ref+} - V_{ref-}$		5		V
Start pulse duration $t_{w(S)}$	200			ns
Address load control pulse width, $t_{w(ALC)}$	200			ns
Address setup time, $t_{su}$	50			ns
Address hold time, $t_h$	50			ns
Clock frequency, $f_{clock}$	10	640	1280	kHz

NOTE 3: Care must be taken that this rating is observed even during power-up.

electrical characteristics over recommended operating free-air temperature range.  $V_{CC} = 4.75$  V to 5.25 V (unless otherwise noted)

### total device

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>1</sup>	MAX	UNIT
$V_{IH}$	High-level input voltage, control inputs	$V_{CC} = 5$ V	$V_{CC} - 1.5$			V
$V_{IL}$	Low-level input voltage, control inputs	$V_{CC} = 5$ V			1.5	V
$V_{OH}$	High-level output voltage	$I_O = -360$ $\mu$ A	$V_{CC} - 0.4$			V
$V_{OL}$	Low-level output voltage	$I_O = 1.6$ mA			0.45	V
	Data outputs End of conversion	$I_O = 1.2$ mA			0.45	
$I_{OZ}$	Off-state (high-impedance-state) output current	$V_O = 5$ V			3	$\mu$ A
		$V_O = 0$			-3	
$I_I$	Control input current at maximum input voltage	$V_I = 15$ V			1	$\mu$ A
$I_{IL}$	Low-level control input current	$V_I = 0$			-1	$\mu$ A
$I_{CC}$	Supply Current	$f_{clock} = 640$ kHz		0.3	3	mA
$C_i$	Input capacitance, control inputs	$T_A = 25$ °C		10	15	pF
$C_o$	Output capacitance, data outputs	$T_A = 25$ °C		10	15	pF
	Resistance from pin 12 to pin 16		1	1000		k $\Omega$

### analog multiplexer

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT	
$I_{on}$	Channel on-state current (see Note 4)	$V_I = 5$ V, $f_{clock} = 640$ kHz			2	$\mu$ A	
		$V_I = 0$ V, $f_{clock} = 640$ kHz			-2		
$I_{off}$	Channel off-state current	$V_{CC} = 5$ V, $T_A = 25$ °C	$V_I = 5$ V		10	200	nA
			$V_I = 0$		-10	-200	
		$V_{CC} = 5$ V	$V_I = 5$ V			1	
			$V_I = 0$			-1	$\mu$ A

<sup>†</sup>Typical values are at  $V_{CC} = 5$  V and  $T_A = 25$  °C.

NOTE 4: Channel on-state current is primarily due to the bias current into or out of the threshold detector, and it varies directly with clock frequency.

# TYPES ADC0808, ADC0809

## CMOS ANALOG-TO-DIGITAL CONVERTERS

### WITH 8-CHANNEL MULTIPLEXERS

operating characteristics,  $T_A = 25^\circ\text{C}$ ,  $V_{CC} = V_{REF+} = 5\text{ V}$ ,  $V_{REF-} = 0\text{ V}$ ,  $f_{\text{clock}} = 640\text{ kHz}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	ADC0808			ADC0809			UNIT
		MIN	TYP <sup>1</sup>	MAX	MIN	TYP <sup>1</sup>	MAX	
$k_{\text{SVS}}$ Supply voltage sensitivity	$V_{CC} = V_{\text{ref}+} = 4.75\text{ V to }5.25\text{ V}$ , $T_A = -40^\circ\text{C to }85^\circ\text{C}$ , See Note 5	$\pm 0.05$			$\pm 0.05$			%/V
Linearity error (see Note 6)		$\pm 0.25$			$\pm 0.5$			LSB
Zero error (see Note 7)		$\pm 0.25$			$\pm 0.25$			LSB
Total unadjusted error (See Note 8)	$T_A = 25^\circ\text{C}$	$\pm 0.25$			$\pm 0.5$			LSB
	$T_A = -40^\circ\text{C to }85^\circ\text{C}$	$\pm 0.75$			$\pm 1.25$			
	$T_A = 0^\circ\text{C to }70^\circ\text{C}$				$\pm 1$			
$t_{\text{en}}$ Output enable time	$C_L = 50\text{ pF}$ , $R_L = 10\text{ k}\Omega$	80	250		80	250	ns	
$t_{\text{dis}}$ Output disable time	$C_L = 10\text{ pF}$ , $R_L = 10\text{ k}\Omega$	105	250		105	250	ns	
$t_{\text{conv}}$ Conversion time	See Note 10	90	100	116	90	100	116	$\mu\text{s}$
$t_{\text{d(EOC)}}$ Delay time, end of conversion output	See Notes 9 and 10	0	14.5		0	14.5	$\mu\text{s}$	

<sup>1</sup>Typical values for all except supply voltage sensitivity are at  $V_{CC} = 5\text{ V}$ , and all are at  $T_A 25^\circ\text{C}$ .

- NOTES:
- Supply voltage sensitivity relates to the ability of an analog-to-digital converter to maintain accuracy as the supply voltage varies. The supply and  $V_{\text{ref}+}$  are varied together and the change in accuracy is measured with respect to full-scale.
  - Linearity error is the maximum deviation from a straight line through the end points of the A/D transfer characteristic.
  - Zero error is the difference between the output of an ideal converter and the actual A/D converter for zero input voltage.
  - Total unadjusted error is the maximum sum of linearity error, zero error, and full-scale error.
  - For clock frequencies other than 640 kHz,  $t_{\text{d(EOC)}}$  maximum is 8 clock periods plus 2  $\mu\text{s}$ .
  - Refer to the operating sequence diagram.



# TYPES ADC0808, ADC0809 CMOS ANALOG-TO-DIGITAL CONVERTERS WITH 8-CHANNEL MULTIPLEXERS

The ADC0808 and ADC0809 each consists of an analog signal multiplexer, an 8-bit successive-approximation converter, and related control and output circuitry.

## multiplexer

The analog multiplexer selects 1 of 8 single-ended input channels as determined by the address decoder. Address load control loads the address code into the decoder on a low-to-high transition.

## converter

The CMOS threshold detector in the successive-approximation conversion system determines each bit by examining the charge on a series of binary-weighted capacitors (Figure 1). In the first phase of the conversion process, the analog input is sampled by closing switch  $S_C$  and all  $S_T$  switches, and by simultaneously charging all the capacitors to the input voltage.

In the next phase of the conversion process, all  $S_T$  and  $S_C$  switches are opened and the threshold detector begins identifying bits by identifying the charge (voltage) on each capacitor relative to the reference voltage. In the switching sequence, all eight capacitors are examined separately until all 8 bits are identified, and then the charge-convert sequence is repeated. In the first step of the conversion phase, the threshold detector looks at the first capacitor (weight = 128). Node 128 of this capacitor is switched to the reference voltage, and the equivalent nodes of all the other capacitors on the ladder are switched to  $REF^-$ . If the voltage at the summing node is greater than the trip-point of the threshold detector (approximately one-half the  $V_{CC}$  voltage), a bit is placed in the output register, and the 128-weight capacitor is switched to  $REF^-$ . If the voltage at the summing node is less than the trip point of the threshold detector, this 128-weight capacitor remains connected to  $REF^+$  through the remainder of the capacitor-sampling (bit-counting) process. The process is repeated for the 64-weight capacitor, the 32-weight capacitor, and so forth down the line, until all bits are counted.

With each step of the capacitor-sampling process, the initial charge is redistributed among the capacitors. The conversion process is successive approximation, but relies on charge redistribution rather than a successive-approximation register (and reference D/A) to count and weigh the bits from MSB to LSB.

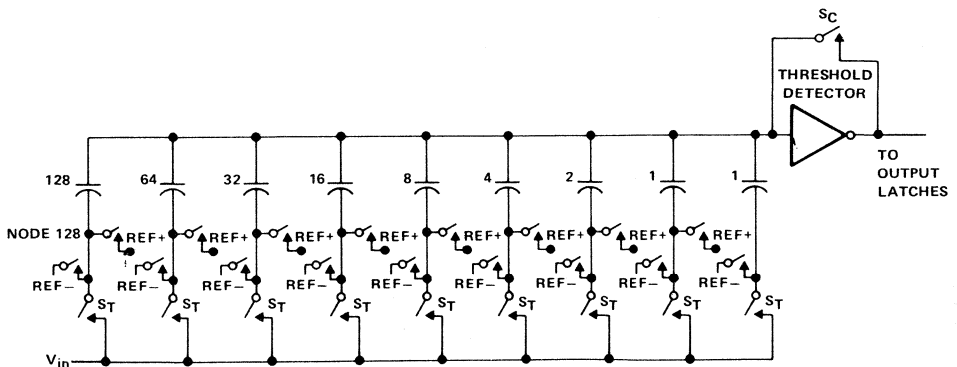
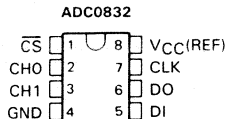
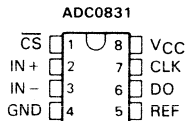


FIGURE 1—SIMPLIFIED MODEL OF THE SUCCESSIVE-APPROXIMATION SYSTEM

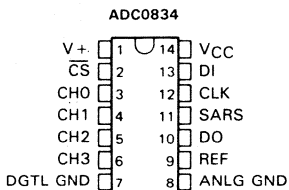


- Easy Interface to Microprocessors or Stand-Alone Operation
- Operates Ratiometrically or With 5-V Reference
- No Full Scale or Zero Adjust
- 2-, 4-, or 8-Channel Multiplexer Options With Address Logic
- Shunt Regulator Allows Operation With High-Voltage Supplies
- 0-V to 5-V Input Range With Single 5-V Power Supply
- Remote Operation With Serial Data Link
- TTL/MOS Input/Output Compatible
- 8-, 14-, or 20-Pin DIP Package
- Designed to be Interchangeable with National Semiconductor ADC0831BC, ADC0832BC, ADC0834BC, and ADC0838BC Over Operating Temperature Range of  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$

**P DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



**N DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



**description**

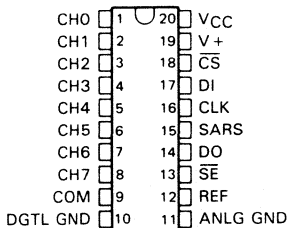
The ADC0831, ADC0832, ADC0834, and ADC0838 are 8-bit successive-approximation analog-to-digital converters each with a serial input/output and configurable input multiplexers with up to 8 channels. The serial input/output is configured to interface with standard shift registers or microprocessors.

The 2-, 4-, or 8-channel multiplexers are software configured for single-ended or differential inputs as well as channel assignment.

The differential analog voltage input allows increasing of the common-mode rejection and offsetting the analog zero input voltage value. In addition, the voltage reference input can be adjusted to allow encoding any smaller analog voltage span to the full 8 bits of resolution.

The ADC08311, ADC0832I, ADC0834I, and ADC0838I are characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

**ADC0838**



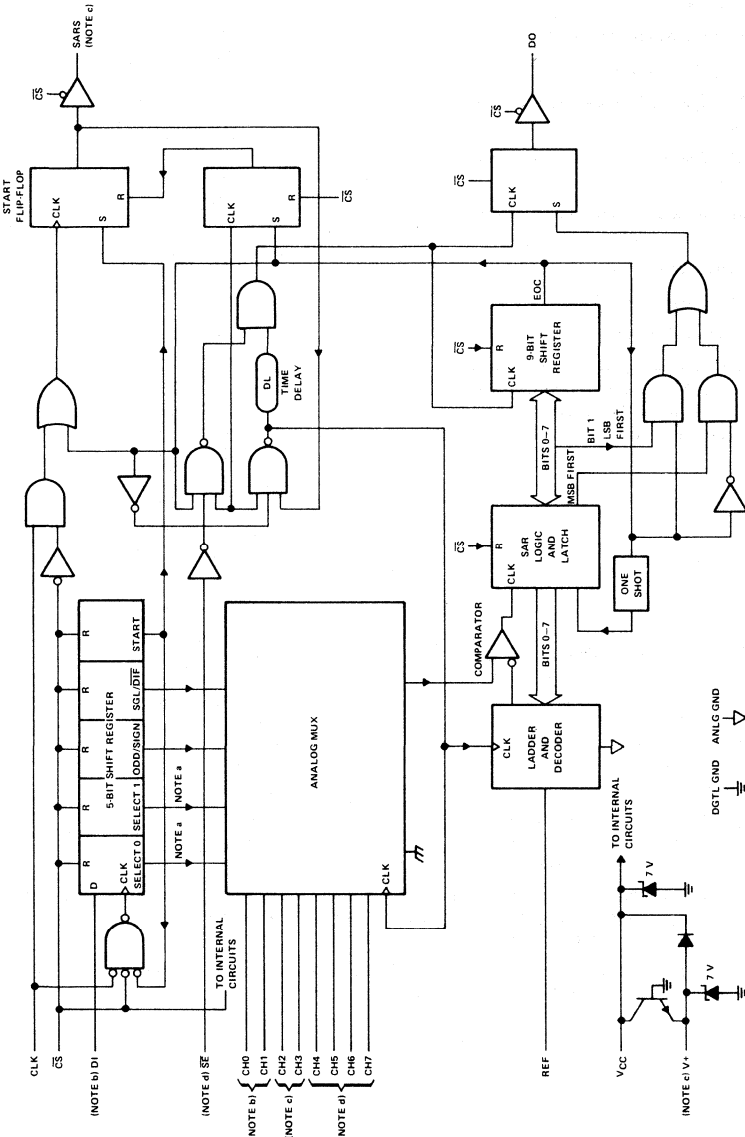
**PRODUCT PREVIEW**

This document contains information on a product under development. Texas Instruments reserves the right to change or discontinue this product without notice.

# TYPES ADC0831, ADC0832, ADC0834, ADC0838

## 2-, 4-, 8-CHANNEL A/D PERIPHERALS WITH SERIAL CONTROL AND MULTIPLEXER OPTIONS

functional block diagram (ADC0838)



NOTES:

- a. For the ADC0834, DI is input directly to the D input of SELECT 1. For the ADC0832, DI is input directly to the D input of ODD/SIGN. SELECT 0 is forced to a low and SELECT 1 is forced to a high. (See multiplexer addressing tables.)
- b. ADC0832, ADC0834, and ADC0838 only.
- c. ADC0834 and ADC0838 only.
- d. ADC0838 only.

# TYPES ADC0831, ADC0832, ADC0834, ADC0838 2-, 4-, 8-CHANNEL A/D PERIPHERALS WITH SERIAL CONTROL AND MULTIPLEXER OPTIONS

## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	6.5 V
Logic input voltage range	-0.3 V to 15 V
Analog input voltage range	-0.3 V to $V_{CC} + 0.3$ V
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2):	
P package	725 mW
N package	800 mW
Operating free-air temperature range	-40°C to 85°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.  
2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2.

## recommended operating conditions

		MIN	NOM	MAX	UNIT
$V_{CC}$	Supply voltage	4.5	5	6.3	V
$V_{IH}$	High-level input voltage	2		15	V
$V_{IL}$	Low-level input voltage			0.8	V
$t_w(\text{CSH})$	Pulse duration, CS high	120			ns
$t_{su}$	Setup time, CS or SE low, or data valid before clock ↑	250			ns
$t_h$	Hold time, data input valid after clock ↑	90			ns
$f_{\text{clock}}$	Clock frequency	10		400	kHz
	Clock duty cycle (see Note 3)	40		60	%
$T_A$	Operating free-air temperature	-40		85	°C

- NOTE 3: The clock duty cycle range ensures proper operation at all clock frequencies. If a clock frequency is used outside the recommended duty cycle range, the minimum pulse duration (high or low) is 1  $\mu$ s.

# TYPES ADC0831, ADC0832, ADC0834, ADC0838

## 2-, 4-, 8-CHANNEL A/D PERIPHERALS WITH SERIAL CONTROL AND MULTIPLEXER OPTIONS

electrical characteristics over recommended operating free-air temperature range,  
 $V_{CC} = V_+ = 5\text{ V}$  ( $V_+$  applies to ADC0834 and ADC0838 only),  $f_{clock} = 250\text{ kHz}$   
 (unless otherwise noted)

PARAMETER		TEST CONDITIONS <sup>†</sup>		MIN	TYP <sup>‡</sup>	MAX	UNIT
V <sub>OH</sub>	High-level output voltage	V <sub>CC</sub> = 4.75 V,	I <sub>OH</sub> = -360 μA	2.4			V
		V <sub>CC</sub> = 4.75 V,	I <sub>OH</sub> = -10 μA	4.5			
V <sub>OL</sub>	Low-level output voltage	V <sub>CC</sub> = 4.75 V,	I <sub>OL</sub> = 1.6 mA			0.4	V
I <sub>IH</sub>	High-level input current	V <sub>I</sub> = V <sub>CC</sub>			0.005	1	μA
I <sub>IL</sub>	Low-level input current	V <sub>I</sub> = 0			-0.005	-1	μA
I <sub>OZ</sub>	High-impedance output current (DO, SARS)	V <sub>O</sub> = 0.4 V,	T <sub>A</sub> = 25°C		-0.1	-3	μA
		V <sub>O</sub> = 5 V,	T <sub>A</sub> = 25°C		0.1	3	
I <sub>OHS</sub>	Source current	V <sub>O</sub> = 0,	T <sub>A</sub> = 25°C		-14		mA
I <sub>OIS</sub>	Sink current	V <sub>O</sub> = V <sub>CC</sub> ,	T <sub>A</sub> = 25°C		16		mA
V <sub>ICR</sub>	Common-mode input range (see Note 4)			-0.05 to V <sub>CC</sub> + 0.05			V
I <sub>on</sub>	On-channel leakage current (see Note 8)	On-channel input at 0 V				-1	μA
		Off-channel inputs at 5 V, T <sub>A</sub> = 25°C				-200	nA
		On-channel input at 0 V				1	μA
		Off-channel inputs at 5 V				200	nA
I <sub>off</sub>	Off-channel leakage current (see Note 8)	On-channel input at 0 V				-1	μA
		Off-channel inputs at 5 V, T <sub>A</sub> = 25°C				-50	nA
		On-channel input at 0 V				1	μA
		Off-channel inputs at 5 V				50	nA
R <sub>REF</sub>	Input resistance to reference ladder			1.9	2.4		kΩ
C <sub>i</sub>	Input capacitance (logic inputs)	T <sub>A</sub> = 25°C			5		pF
C <sub>o</sub>	Output capacitance	T <sub>A</sub> = 25°C			5		pF
I <sub>CC</sub>	Supply current (see Note 5)	ADC0832 <sup>§</sup>			3	5.2	mA
		ADC0831, ADC0834, ADC0838			1	2.5	
I <sub>+</sub>	Current into V <sub>+</sub> (see Note 5)					10	mA

<sup>†</sup>All parameters are measured under open-loop conditions with zero common-mode input voltage (unless otherwise specified).

<sup>‡</sup>All typical values are at T<sub>A</sub> = 25°C.

<sup>§</sup>Includes ladder current.

NOTES: 4. For I<sub>N-</sub> more positive than I<sub>N+</sub>, the digital output code will be 0000 0000. Connected to each analog input are two on-chip diodes that will conduct forward current for analog input voltages one diode drop below ground or one diode drop above V<sub>CC</sub>. Care must be taken during testing at low V<sub>CC</sub> levels (4.5 V) because high-level analog input (5 V) can, especially at high temperatures, cause this input diode to conduct and cause errors for analog inputs that are near full-scale. As long as the analog input voltage does not exceed the supply voltage by more than 50 mV, the output code will be correct. To achieve an absolute 0-V to 5-V input voltage range requires a minimum V<sub>CC</sub> of 4.950 volts for all variations of temperature and load.

5. An internal zener diode is connected from the V<sub>CC</sub> input to ground and from V<sub>+</sub> to ground. The breakdown voltage of each diode is approximately 7 V. The V<sub>+</sub> diode is a shunt regulator and connects to V<sub>CC</sub> via a diode. When the voltage regulator powers the converter, this diode ensures that the V<sub>CC</sub> input is less than the zener breakdown voltage (6.4 V). A series resistor is recommended to limit the maximum current into the V<sub>+</sub> input.

# TYPES ADC0831, ADC0832, ADC0834, ADC0838 2-, 4-, 8-CHANNEL A/D PERIPHERALS WITH SERIAL CONTROL AND MULTIPLEXER OPTIONS

operating characteristics over recommended operating free-air temperature range,  
 $V_{CC} = V_+ = 5\text{ V}$  ( $V_+$  applies to ADC0834 and ADC0838 only),  $f_{\text{clock}} = 250\text{ kHz}$ ,  $t_r = t_f = 20\text{ ns}$   
(unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Supply-voltage variation error			± 1/16			LSB
Total unadjusted error (see Note 6)		$V_{\text{ref}}$ forced to 5 V			± 1	LSB
Common-Mode error		Differential mode	± 1/16			LSB
$t_{\text{pd}}$	Propagation delay time, clock ↓ to output data (see Note 7)	MSB first	650 1000		ns	
		LSB first	250 600			
$t_{\text{dis}}$	Output disable time from $\overline{\text{CS}} \uparrow$	$C_L = 10\text{ pF}$ , $R_L = 10\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$	125	250		ns
$t_{\text{conv}}$	Conversion time	Not including multiplexer addressing time, $T_A = 25^\circ\text{C}$		8		clock period

- NOTES: 6. Total unadjusted error includes offset, full scale, linearity, and multiplexer errors.  
7. If the MSB from the comparator is used first in the successive approximation loop, then an additional built-in delay will allow for comparator response time.  
8. Leakage current is measured with the clock not switching.

## PARAMETER MEASUREMENT INFORMATION

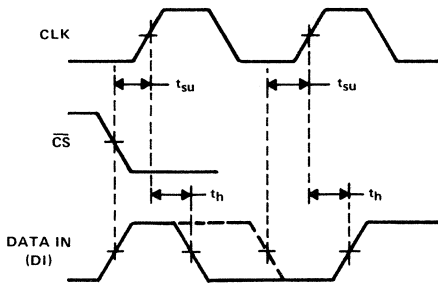


FIGURE 1—DATA INPUT TIMING

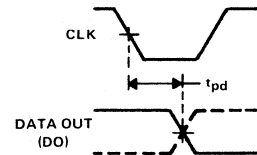


FIGURE 2—DATA OUTPUT TIMING

**TYPES ADC0831, ADC0832, ADC0834, ADC0838**  
**2-, 4-, 8-CHANNEL A/D PERIPHERALS WITH**  
**SERIAL CONTROL AND MULTIPLEXER OPTIONS**

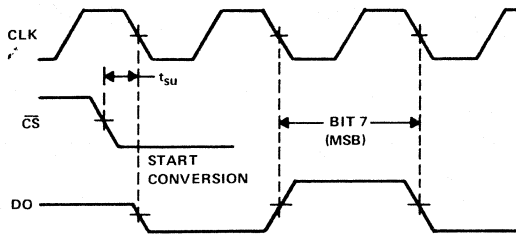


FIGURE 3—CONVERSION TIMING (ADC0831)

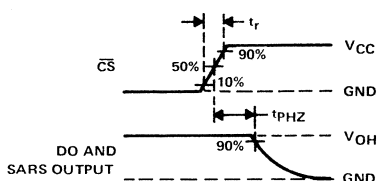


FIGURE 4— $t_{pHZ}$  VOLTAGE WAVEFORMS

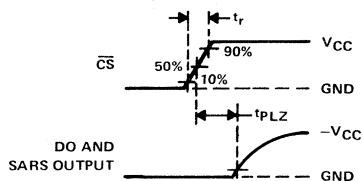
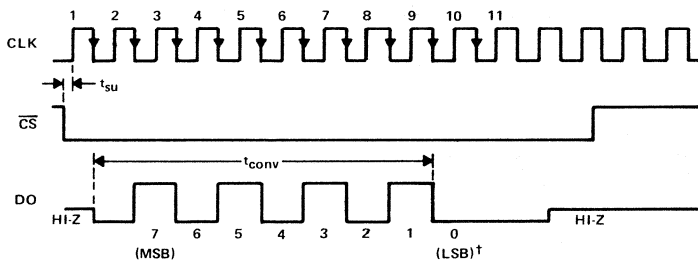


FIGURE 5— $t_{pLZ}$  VOLTAGE WAVEFORMS



<sup>†</sup>LSB first output not available on ADC0831.

FIGURE 6—ADC0831 TIMING DIAGRAM



**TYPES ADC0831, ADC0832, ADC0834, ADC0838**  
**2-, 4-, 8-CHANNEL A/D PERIPHERALS WITH**  
**SERIAL CONTROL AND MULTIPLEXER OPTIONS**

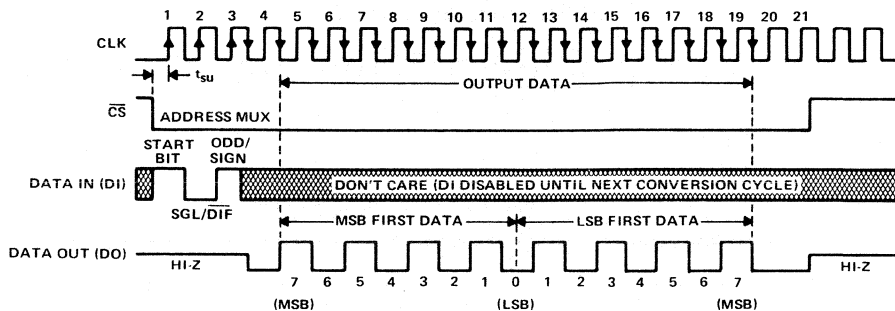


FIGURE 7—ADC0832 TIMING DIAGRAM

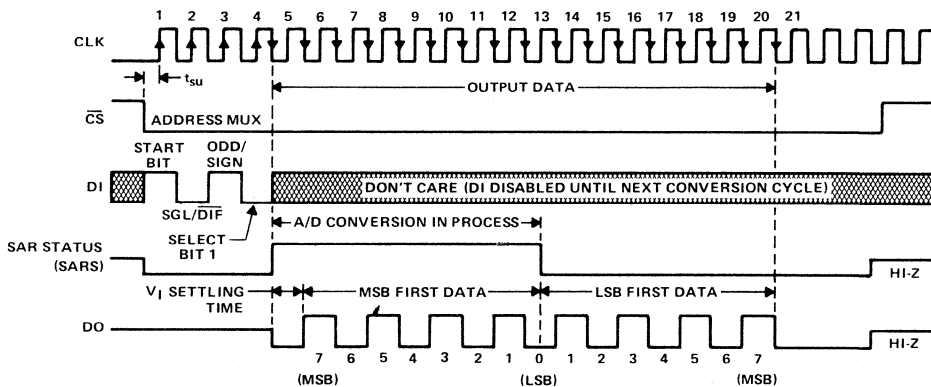
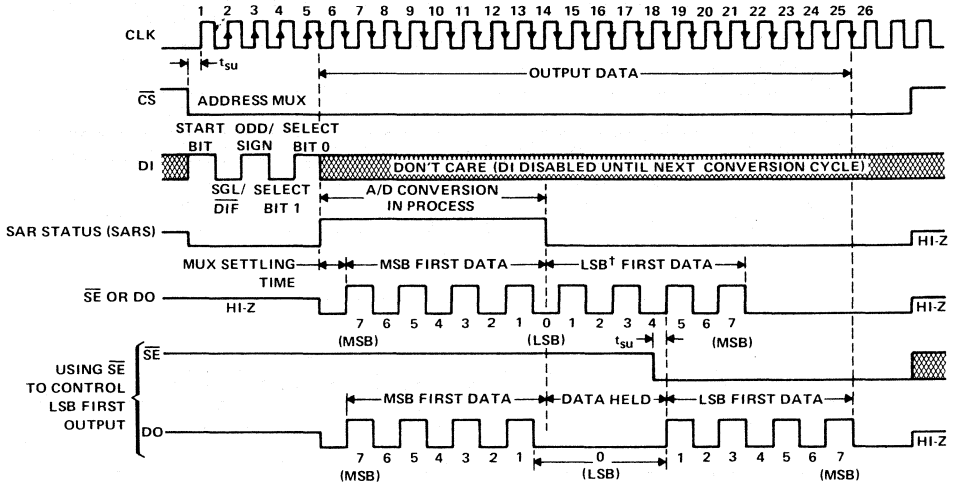


FIGURE 8—ADC0834 TIMING DIAGRAM

**TYPES ADC0831, ADC0832, ADC0834, ADC0838**  
**2-, 4-, 8-CHANNEL A/D PERIPHERALS WITH**  
**SERIAL CONTROL AND MULTIPLEXER OPTIONS**

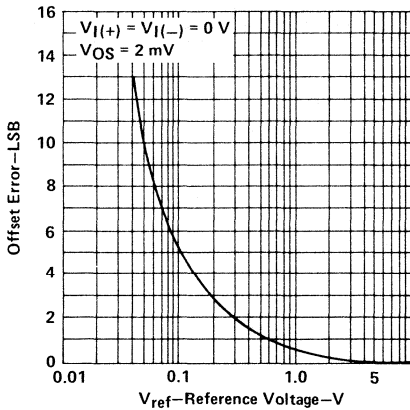
**TYPICAL CHARACTERISTICS**



†Make sure clock edge of 18th clock, clocks in the LSB before  $\overline{SE}$  is taken low.

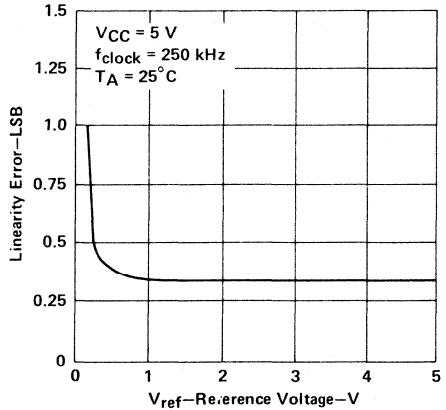
**FIGURE 9—ADC0838 TIMING DIAGRAM**

**UNADJUSTED OFFSET ERROR**  
**vs**  
**REFERENCE VOLTAGE**



**FIGURE 10**

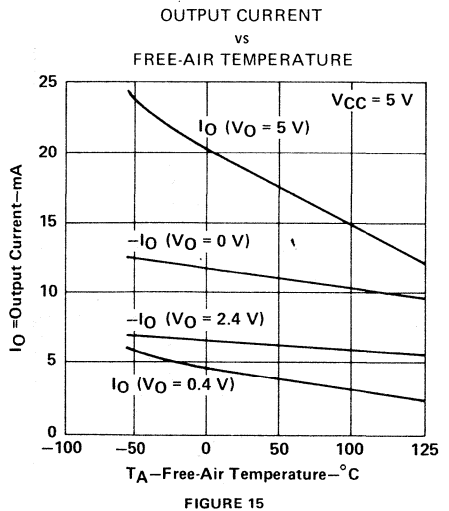
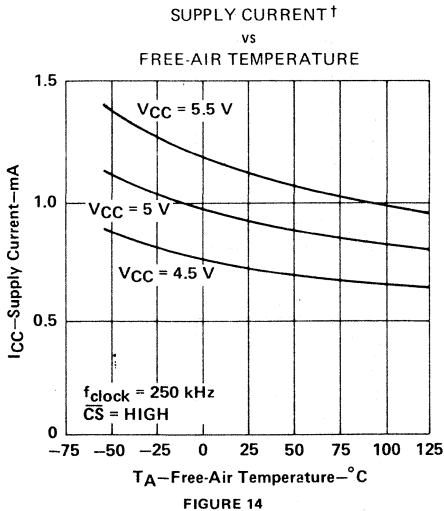
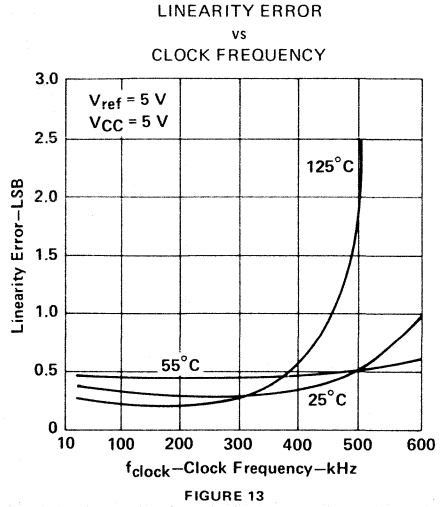
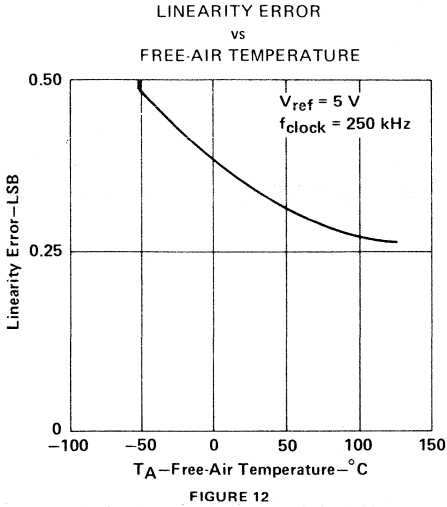
**LINEARITY ERROR**  
**vs**  
**REFERENCE VOLTAGE**



**FIGURE 11**

**TYPES ADC0831, ADC0832, ADC0834, ADC0838**  
**2-, 4-, 8-CHANNEL A/D PERIPHERALS WITH**  
**SERIAL CONTROL AND MULTIPLEXER OPTIONS**

**TYPICAL CHARACTERISTICS**



†For ADC0832, the ladder current  $I_{REF}$  should be added to  $I_{CC}$ .

**TYPES ADC0831, ADC0832, ADC0834, ADC0838**  
**2-, 4-, 8-CHANNEL A/D PERIPHERALS WITH**  
**SERIAL CONTROL AND MULTIPLEXER OPTIONS**

**TYPICAL CHARACTERISTICS**

SUPPLY CURRENT  
 vs  
 CLOCK FREQUENCY

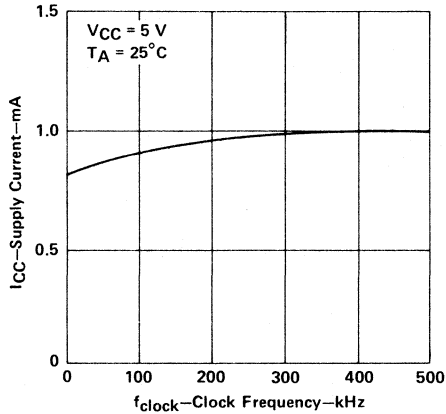


FIGURE 16

**TYPICAL APPLICATION INFORMATION**

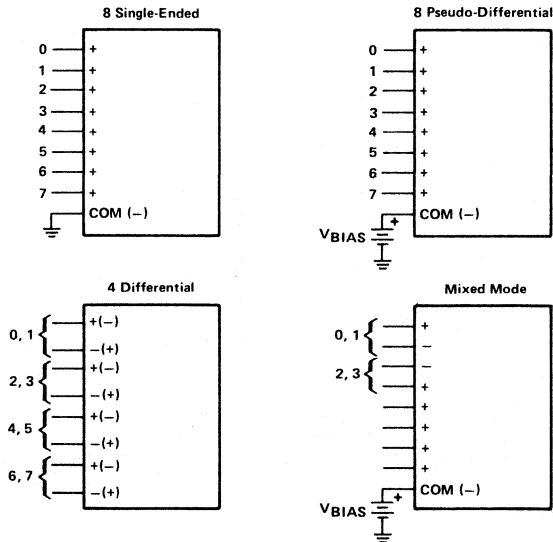


FIGURE 17—ANALOG INPUT MULTIPLEXER OPTIONS FOR THE ADC0838

# TYPES ADC0831, ADC0832, ADC0834, ADC0838 2-, 4-, 8-CHANNEL A/D PERIPHERALS WITH SERIAL CONTROL AND MULTIPLEXER OPTIONS

## ADC0832 MUX ADDRESSING (5-BIT SHIFT REGISTER) (See Note 9)

**TABLE 1. SINGLE ENDED MUX MODE**

MUX ADDRESS		CHANNEL NO.
SGL/DIF	ODD/SIGN	0 1
1	0	+
1	1	+

**TABLE 2. DIFFERENTIAL MUX MODE**

MUX ADDRESS		CHANNEL NO.
SGL/DIF	ODD/SIGN	0 1
0	0	+ -
0	1	- +

NOTE 9: Internally, Select 0 is low, Select 1 is high, COMMON is internally connected to ANLG GND.

## ADC0834 MUX ADDRESSING (5-BIT SHIFT REGISTER) (See Note 10)

**TABLE 3. SINGLE-ENDED MUX MODE**

MUX ADDRESS			CHANNEL NO.			
SGL/DIF	ODD/SIGN	SELECT 1	0	1	2	3
1	0	0	+			
1	0	1			+	
1	1	0		+		
1	1	1				+

**TABLE 4. DIFFERENTIAL MUX MODE**

MUX ADDRESS			CHANNEL NO.			
SGL/DIF	ODD/SIGN	SELECT 1	0	1	2	3
0	0	0	+	-		
0	0	1			+	-
0	1	0	-	+		
0	1	1			-	+

NOTE 10: Internally, Select 0 is high, COMMON is internally connected to ANLG GND.

## ADC0838 MUX ADDRESSING (5-BIT SHIFT REGISTER)

**TABLE 5. SINGLE-ENDED MUX MODE**

MUX ADDRESS			ANALOG SINGLE-ENDED CHANNEL NO.									
SGL/DIF	ODD/SIGN	SELECT		0	1	2	3	4	5	6	7	COM
		1	0									
1	0	0	0	+								-
1	0	0	1			+						-
1	0	1	0					+				-
1	0	1	1							+		-
1	1	0	0		+							-
1	1	0	1				+					-
1	1	1	0						+			-
1	1	1	1								+	-

**TYPES ADC0831, ADC0832, ADC0834, ADC0838**  
**2-, 4-, 8-CHANNEL A/D PERIPHERALS WITH**  
**SERIAL CONTROL AND MULTIPLEXER OPTIONS**

**TABLE 6. DIFFERENTIAL MUX MODE**

MUX ADDRESS		ANALOG DIFFERENTIAL CHANNEL-PAIR NO.									
SGL/DIF	ODD/SIGN	SELECT		0		1		2		3	
		1	0	0	1	2	3	4	5	6	7
0	0	0	0	+	-						
0	0	0	1			+	-				
0	0	1	0					+	-		
0	0	1	1							+	-
0	1	0	0	-	+						
0	1	0	1			-	+				
0	1	1	0					-	+		
0	1	1	1							-	+

**PRINCIPLES OF OPERATION**

The ADC0831, ADC0832, ADC0834, and ADC0838 use a sample data comparator structure that converts differential analog inputs by a successive-approximation routine. The input voltage to be converted is applied to a channel terminal and is compared to ground (single-ended), to an adjacent channel (differential), or to a common terminal (pseudo-differential) that can be an arbitrary voltage. The input terminals are assigned a positive (+) or negative (-) polarity. If the signal input applied to the assigned positive terminal is less than the signal on the negative terminal, the converter output is all zeroes.

Channel selection and input configuration are under software control using a serial data link from the controlling processor. A serial communication format allows more functions to be included in a converter package with no increase in size. In addition, it eliminates the transmission of low-level analog signals by locating the converter at the analog sensor. This process returns noise-free digital data to the processor.

A particular input configuration is assigned during the multiplexer addressing sequence. The multiplexer address is shifted into the converter through the data input (DI) line. The ADC0831 contains only one differential input channel having a fixed polarity assignment and not requiring addressing. The multiplexer address selects the analog inputs to be enabled and determines whether the input is single-ended or differential. When the input is differential, the polarity of the channel input is assigned. Differential inputs are assigned to adjacent channel pairs. For example, channel 0 and channel 1 may be selected as a differential pair. These channels can not act differentially with any other channel. In addition to selecting the differential mode, the polarity may also be selected. Either channel of the channel pair may be designated as negative or positive.

The common input on the ADC0838 can be used for a pseudo-differential input. In this mode, the voltage on the input is negative to any other channel. This voltage can be any reference potential common to all channel inputs. This feature is useful in single-supply applications where all analog circuits are biased to a potential other than ground.

Operation of the ADC0831, ADC0832, ADC0834, and ADC0838 is similar with the exception of multiplexer addressing. The ADC0838 has all the features of the other converts and is used for the functional block diagram.

A conversion is initiated by setting the chip select ( $\overline{CS}$ ) input low. This enables all logic circuits. The  $\overline{CS}$  input must be held low for the complete conversion process. A clock input is received from the processor. On each low-to-high transition of the clock input, the data on the DI input is clocked into the multiplexer address shift register. The first logic high on the input is the start bit. A 2- to 4-bit assignment word follows the start bit. On each successive low-to-high transition of the clock input, the start bit and assignment word are shifted through the shift register. When the start bit has been shifted into the start location of the multiplexer register, the input channel has been selected and conversion starts. The SAR status output (SARS) goes high to indicate that a conversion is in progress and the DI input to the multiplexer shift register is disabled for the duration of the conversion.

## TYPES ADC0831, ADC0832, ADC0834, ADC0838 2-, 4-, 8-CHANNEL A/D PERIPHERALS WITH SERIAL CONTROL AND MULTIPLEXER OPTIONS

---

An interval of one clock period is automatically inserted to allow for the selected multiplexer channel to settle. The data output DO comes out of the high-impedance state and provides a leading low for this one clock period of multiplexer settling time. The SAR comparator compares successive outputs from the resistive ladder with the incoming analog signal. The comparator output indicates whether the analog input is greater than or less than resistive ladder output. This data is parallel loaded into a 9-bit shift register which immediately outputs an 8-bit serial data word. This output is sent to the DO output with the most-significant bit (MSB) first. After eight clock periods the conversion is complete and the SAR status (SARS) output goes low. When  $\overline{CS}$  goes high, all internal registers are cleared. At this time the output circuits go to three-state. If another conversion is desired, the  $\overline{CS}$  line must make a high-to-low transition followed by address information.

In the ADC0831, only the MSB data is output first. The ADC0832 and ADC0834 output the LSB data first after the MSB first data stream is output. In the ADC0838, the programmer has the option of selecting MSB first or LSB first. To output LSB first, the shift enable ( $\overline{SE}$ ) control input must go low. Data stored in the 9-bit shift register is now output with LSB first. The ADC0831 data is only output in MSB-first format.

The DI and DO pins can be tied together and controlled by a bi-directional processor I/O bit received on a single wire. This is possible because the DI input is only examined during the multiplexer addressing interval and the DO output is still in a high-impedance state.





- Functionally Interchangeable with Siliconix DG182, DG185, DG188, and DG191 with Same Terminal Assignments
- Monolithic Construction
- Adjustable Reference Voltage
- JFET Inputs

- Uniform On-State Resistance for Minimum Signal Distortion
- ±10-V Analog Voltage Range
- TTL, MOS, and CMOS Logic Control Compatibility

**description**

The TL182, TL185, TL188, and TL191 are monolithic high-speed analog switches using BI-MOS technology. They comprise JFET-input buffers, level translators, and output JFET switches. The TL182 switches are SPST; the TL185 switches are SPDT. The TL188 is a pair of complementary SPST switches as is each half of the TL191.

A high level at a control input of the TL182 turns the associated switch off. A high level at a control input of the TL185 turns the associated switch on. For the TL188, a high level at the control input turns the associated switches S1 on and S2 off.

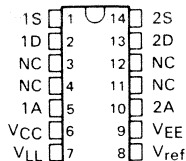
The threshold of the input buffer is determined by the voltage applied to the reference input ( $V_{ref}$ ). The input threshold is related to the reference input by the equation  $V_{th} = V_{ref} + 1.4 V$ . Thus, for TTL compatibility, the  $V_{ref}$  input is connected to ground. The JFET input makes the device compatible with bipolar, MOS and CMOS logic families. Threshold compatibility may, again, be determined by  $V_{th} = V_{ref} + 1.4 V$ .

The output switches are junction field-effect transistors featuring low on-state resistance and high off-state resistance. The monolithic structure ensures uniform matching.

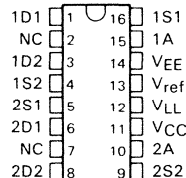
BI-MOS technology is a major breakthrough in linear integrated circuit processing. BI-MOS can have ion-implanted JFETs, p-channel MOS-FETs, plus the usual bipolar components all on the same chip. BI-MOS allows circuit designs that previously have been available only as expensive hybrids to be monolithic.

Devices with an "M" suffix are characterized for operation over the full military temperature range of -55°C to 125°C, those with an "I" suffix are characterized for operation from -25°C to 85°C, and those with a "C" suffix are characterized for operation from 0°C to 70°C.

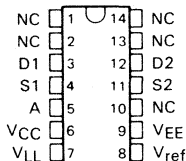
**TL182**  
J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



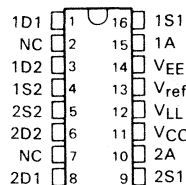
**TL185**  
J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**TL188**  
J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**TL191**  
J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)

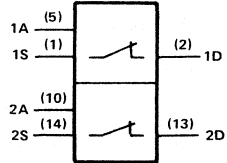
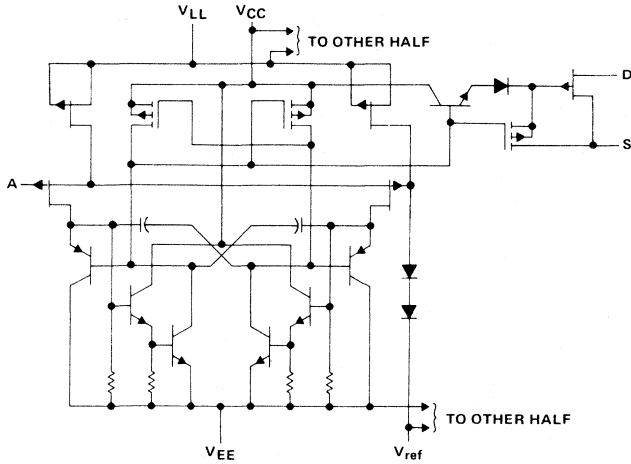


NC—No internal connection

**TYPES TL182, TL185  
BI-MOS SWITCHES**

**TL182 TWIN SPST SWITCH**

schematic (each channel)

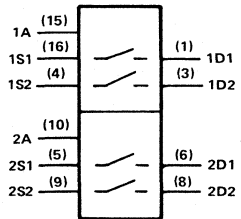
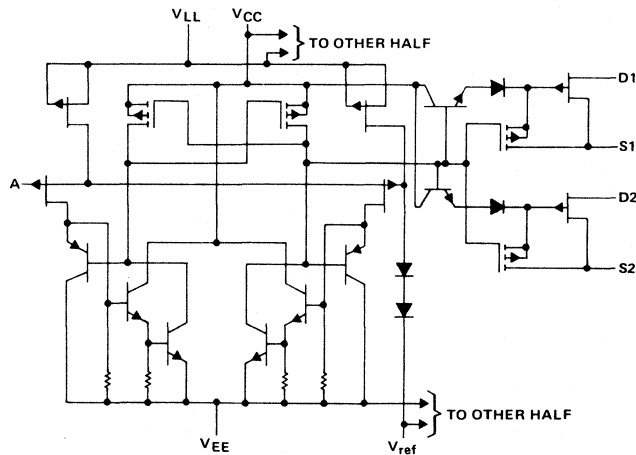


**FUNCTION TABLE  
(EACH HALF)**

INPUT	SWITCH
A	S
L	ON (CLOSED)
H	OFF (OPEN)

**TL185 TWIN DPST SWITCH**

schematic (each channel)



**FUNCTION TABLE  
(EACH HALF)**

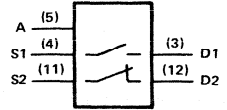
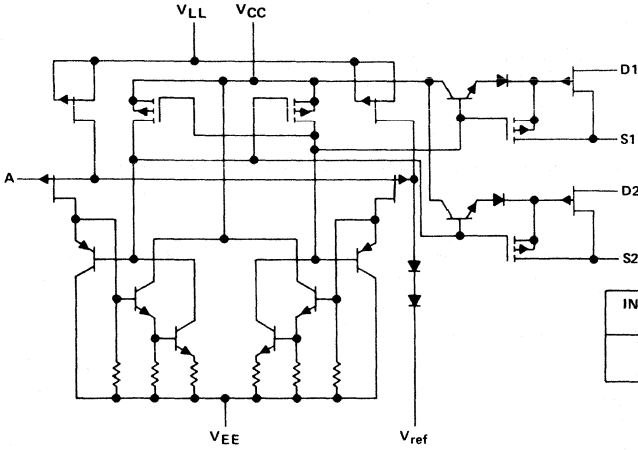
INPUT	SWITCHES
A	SW1 AND SW2
L	OFF (OPEN)
H	ON (CLOSED)

Data Acquisition

7

TL188 DUAL COMPLEMENTARY SPST SWITCH

schematic

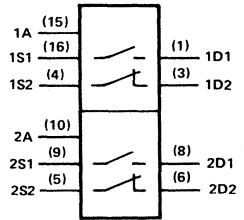
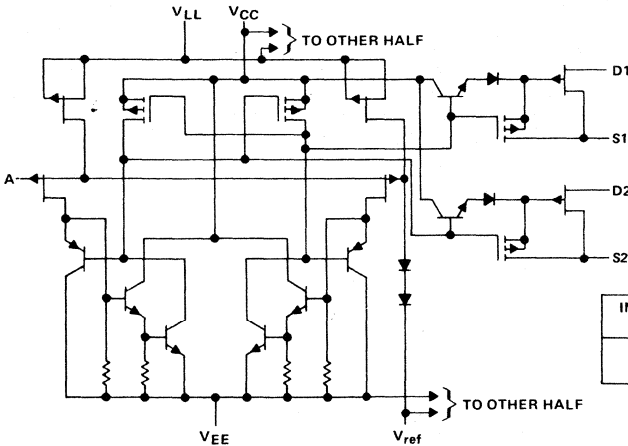


FUNCTION TABLE

INPUT A	SWITCHES	
	SW1	SW2
L	OFF (OPEN)	ON (CLOSED)
H	ON (CLOSED)	OFF (OPEN)

TL191 TWIN DUAL COMPLEMENTARY SPST SWITCH

schematic (each channel)



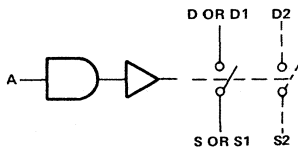
FUNCTION TABLE

INPUT A	SWITCHES	
	SW1	SW2
L	OFF (OPEN)	ON (CLOSED)
H	ON (CLOSED)	OFF (OPEN)

# TYPES TL182, TL185, TL188, TL191

## BI-MOS SWITCHES

### functional block diagram



See the preceding two pages for operation of the switches.

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Positive supply to negative supply voltage, $V_{CC} - V_{EE}$ .....	36 V
Positive supply voltage to either drain, $V_{CC} - V_D$ .....	33 V
Drain to negative supply voltage, $V_D - V_{EE}$ .....	33 V
Drain to source voltage, $V_D - V_S$ .....	$\pm 22$ V
Logic supply to negative supply voltage, $V_{LL} - V_{EE}$ .....	36 V
Logic supply to logic input voltage, $V_{LL} - V_I$ .....	33 V
Logic supply to reference voltage, $V_{LL} - V_{ref}$ .....	33 V
Logic input to reference voltage, $V_I - V_{ref}$ .....	33 V
Reference to negative supply voltage, $V_{ref} - V_{EE}$ .....	27 V
Reference to logic input voltage, $V_{ref} - V_I$ .....	2 V
Current (any terminal) .....	30 mA
Continuous dissipation at (or below) 25°C free-air temperature (see Note 1):	
TL182MJ, TL185MJ, TL188MJ, TL191MJ .....	1375 mW
TL182IJ, TL182CJ, TL185IJ, TL185CJ, TL188IJ, TL188CJ, TL191IJ, TL191CJ .....	1025 mW
N package .....	875 mW
Operating free-air temperature range: TL182M, TL185M, TL188M, TL191M .....	-55°C to 125°C
TL182I, TL185I, TL188I, TL191I .....	-25°C to 85°C
TL182C, TL185C, TL188C, TL191C .....	0°C to 70°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package .....	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N package .....	260°C

NOTE 1: For operation above 25°C free-air temperature, see Dissipation Derating Curves, Section 2. In the J package, "M" suffix chips are alloy mounted, "I" and "C" suffix chips are glass mounted.

electrical characteristics.  $V_{CC} = 15\text{ V}$ ,  $V_{EE} = -15\text{ V}$ ,  $V_{LL} = -15\text{ V}$ ,  $V_{VLL} = 5\text{ V}$ ,  $V_{ref} = 0\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	TL1_M		TL1_I		TL1_C		UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	
$V_{IH}$	High-level control input voltage	$V_{ref} + 2$		$V_{ref} + 2$		$V_{ref} + 2$		V
$V_{IL}$	Low-level control input voltage	$V_{ref} + 0.8$		$V_{ref} + 0.8$		$V_{ref} + 0.8$		V
$I_{IH}$	High-level control input current	$V_1 = 5\text{ V}$		10		20		$\mu\text{A}$
$I_{IL}$	Low-level control input current	$V_1 = 0$		20		20		$\mu\text{A}$
$I_{D(off)}$	Off-state drain current	$V_D = 10\text{ V}$ , $V_S = -10\text{ V}$ , $V_{IH} = 2\text{ V}$ , $V_{IL} = 0.8\text{ V}$		$T_A = 25^\circ\text{C}$		5		nA
$I_{S(off)}$	Off-state source current	$V_D = -10\text{ V}$ , $V_S = 10\text{ V}$ , $V_{IH} = 2\text{ V}$ , $V_{IL} = 0.8\text{ V}$		$T_A = 25^\circ\text{C}$		5		nA
$I_{D(on)} + I_{S(on)}$	On-state channel leakage current	$V_D = -10\text{ V}$ , $V_S = -10\text{ V}$ , $V_{IH} = 2\text{ V}$ , $V_{IL} = 0.8\text{ V}$		$T_A = 25^\circ\text{C}$		-10		nA
$r_{DS(on)}$	Drain-to-source on-state resistance	TL182, $V_D = -10\text{ V}$ , $I_S = 1\text{ mA}$ , $T_A = \text{MAX}$		75		100		$\Omega$
		TL188, $V_D = -10\text{ V}$ , $V_{IL} = 0.8\text{ V}$ , $T_A = \text{MAX}$		100		150		
$I_{CC}$	Supply current from $V_{CC}$	TL185, $V_D = 2\text{ V}$ , $V_{IL} = 0.8\text{ V}$ , $T_A = \text{MIN to } 25^\circ\text{C}$		125		150		
		TL191, $V_D = 2\text{ V}$ , $V_{IL} = 0.8\text{ V}$ , $T_A = \text{MAX}$		250		300		
$I_{EE}$	Supply current from $V_{EE}$	Both control inputs at 0 V		-5		-5		mA
$I_{LL}$	Supply current from $V_{LL}$	Both control inputs at 0 V		4.5		4.5		
$I_{ref}$	Reference current	Both control inputs at 0 V		-2		-2		
$I_{CC}$	Supply current from $V_{CC}$	Both control inputs at 5 V		1.5		1.5		
$I_{EE}$	Supply current from $V_{EE}$	Both control inputs at 5 V		-5		-5		
$I_{LL}$	Supply current from $V_{LL}$	Both control inputs at 5 V		4.5		4.5		
$I_{ref}$	Reference current	Both control inputs at 5 V		-2		-2		

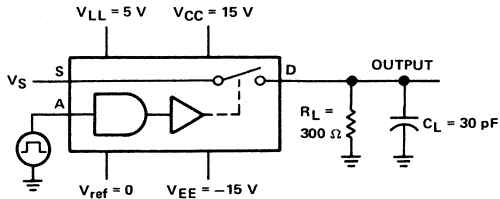
switching characteristics,  $V_{CC} = 10\text{ V}$ ,  $V_{EE} = -20\text{ V}$ ,  $V_{LL} = -20\text{ V}$ ,  $V_{VLL} = 5\text{ V}$ ,  $V_{ref} = 0\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL1_M		TL1_I		TL1_C		UNIT
		TYP		TYP		TYP		
$t_{on}$	Turn-on time	175		175		175		ns
$t_{off}$	Turn-off time	350		350		350		ns

$R_L = 300\ \Omega$ ,  $C_L = 30\text{ pF}$ , Figure 1

**TYPES TL182, TL185, TL188, TL191  
BI-MOS SWITCHES**

**PARAMETER MEASUREMENT INFORMATION**

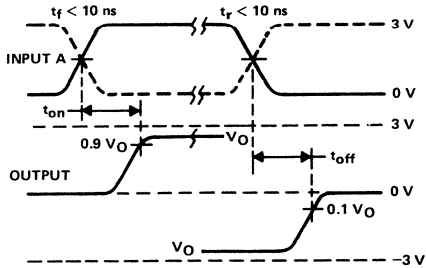


$C_L$  includes probe and jig capacitance.

$V_S = 3\text{ V}$  for  $t_{on}$  and  $-3\text{ V}$  for  $t_{off}$ .

$$V_O = V_S \frac{R_L}{R_L + r_{DS(on)}}$$

**TEST CIRCUIT**



- NOTE: A. The solid waveform applies for TL185 and SW1 of TL185 and TL191; the dashed waveform applies for TL182 and SW2 of TL185 and TL191.  
B.  $V_O$  is the steady-state output with the switch on. Feed through via the gate capacitance may result in spikes (not shown) at the leading and trailing edges of the output waveform.

**FIGURE 1—VOLTAGE WAVEFORMS**

**TL500C/TL501C  
ANALOG PROCESSORS**

- True Differential Inputs
- Automatic Zero
- Automatic Polarity
- High Input Impedance . . . 10<sup>9</sup> Ohms Typically

**TL500C CAPABILITIES**

- Resolution . . . 14 Bits (with TL502C)
- Linearity Error . . . 0.001%
- 4 1/2-Digit Readout Accuracy with External Precision Reference

**TL501C CAPABILITIES**

- Resolution . . . 10-13 Bits (with TL502C)
- Linearity Error . . . 0.01%
- 3 1/2-Digit Readout Accuracy

**TL502C/TL503C  
DIGITAL PROCESSORS**

- Fast Display Scan Rates
- Internal Oscillator May Be Driven or Free-Running
- Interdigit Blanking
- Over-Range Blanking
- Display Test
- 4 1/2-Digit Display Circuitry
- High-Sink-Current Digit Driver for Large Displays

**TL502C CAPABILITIES**

- Compatible with Popular Seven-Segment Common-Anode Displays
- High-Sink-Current Segment Driver For Large Displays

**TL503C CAPABILITIES**

- Multiplexed BCD Outputs
- High-Sink-Current BCD Outputs



Caution. These devices have limited built-in gate protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

The TL500C and TL501C analog processors and TL502C and TL503C digital processors provide the basic functions for a dual-slope-integrating analog-to-digital converter.

The TL500C and TL501C contain the necessary analog switches and decoding circuits, reference voltage generator, buffer, integrator, and comparator. These devices may be controlled by the TL502C, TL503C, by discrete logic, or by a software routine in a microprocessor.

The TL502C and TL503C each includes oscillator, counter, control logic, and digit enable circuits. The TL502C provides multiplexed outputs for seven-segment displays, while the TL503C has multiplexed BCD outputs.

When used in complementary fashion, these devices form a system that features automatic zero-offset compensation, true differential inputs, high input impedance, and capability for 4 1/2-digit accuracy. Applications include the conversion of analog data from high-impedance sensors of pressure, temperature, light, moisture, and position. Analog-to-digital-logic conversion provides display and control signals for weight scales, industrial controllers, thermometers, light-level indicators, and many other applications.

# TYPES TL500C THRU TL503C ANALOG-TO-DIGITAL-CONVERTER BUILDING BLOCKS

## principles of operation

The basic principle of dual-slope-integrating converters is relatively simple. A capacitor,  $C_X$ , is charged through the integrator from  $V_{CT}$  for a fixed period of time at a rate determined by the value of the unknown voltage input. Then the capacitor is discharged at a fixed rate (determined by the reference voltage) back to  $V_{CT}$  where the discharge time is measured precisely. The relationship of the charge and discharge values are shown below (see Figure 1).

$$V_{CX} = V_{CT} - \frac{V_I t_1}{R_X C_X} \quad \text{Charge} \quad (1)$$

$$V_{CT} = V_{CX} - \frac{V_{ref} t_2}{R_X C_X} \quad \text{Discharge} \quad (2)$$

Combining equations 1 and 2 results in:

$$\frac{V_I}{V_{ref}} = - \frac{t_2}{t_1} \quad (3)$$

where:

$V_{CT}$  = Comparator (offset) threshold voltage

$V_{CX}$  = Voltage change across  $C_X$  during  $t_1$  and during  $t_2$  (equal in magnitude)

$V_I$  = Average value of input voltage during  $t_1$

$t_1$  = Time period over which unknown voltage is integrated

$t_2$  = Unknown time period over which a known reference voltage is integrated.

Equation (3) illustrates the major advantages of a dual-slop converter:

- a. Accuracy is not dependent on absolute values of  $t_1$  and  $t_2$ , but is dependent on their ratios. Long-term clock frequency variations will not affect the accuracy.
- b. Offset values,  $V_{CT}$ , are not important.

The BCD counter in the digital processor (see Figure 2) and the control logic divide each measurement cycle into three phases. The BCD counter changes at a rate equal to one-half the oscillator frequency.

### auto-zero phase

The cycle begins at the end of the integrate-reference phase when the digital processor applies low levels to inputs A and B of the analog processor. If the trigger input is at a high level, a free-running condition exists and continuous conversions are made. However, if the trigger input is low, the digital processor stops the counter at 20,000, entering a hold mode. In this mode, the processor samples the trigger input every 4000 oscillator pulses until a high level is detected. When this occurs, the counter is started again and is carried to completion at 30,000. The reference voltage is stored on reference capacitor  $C_{ref}$ , comparator offset voltage is stored on integration capacitor  $C_X$ , and the sum of the buffer and integrator offset voltages is stored on zero capacitor  $C_Z$ . During the auto-zero phase, the comparator output is characterized by an oscillation (limit cycle) of indeterminate waveform and frequency that is filtered and d-c shifted by the level shifter.

### integrate-input phase

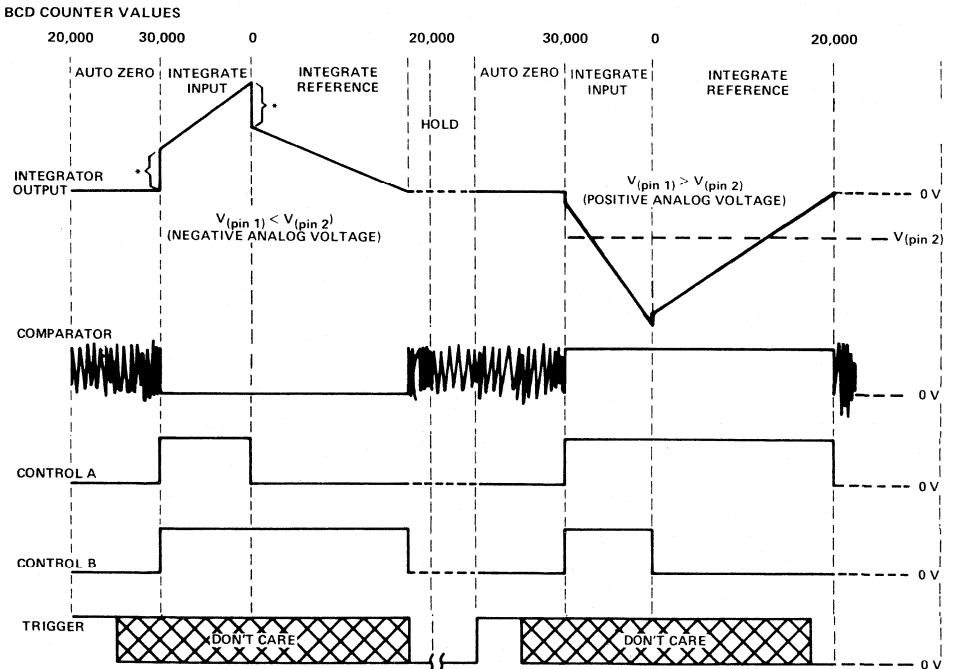
The auto-zero phase is completed at a BCD count of 30,000, and high levels are applied to both control inputs to initiate the integrate-input phase. The integrator charges  $C_X$  for a fixed time of 10,000 BCD counts at a rate determined by the input voltage. Note that during this phase, the analog inputs see only the high impedance of the noninverting operational amplifier input. Therefore, the integrator responds only to the difference between the analog input terminals, thus providing true differential inputs.



**integrate-reference phase**

At a BCD count of  $39,999 + 1 = 40,000$  or 0, the integrate-input phase is terminated and the integrate-reference phase is begun by sampling the comparator output. If the comparator output is low corresponding to a negative average analog input voltage, the digital processor applies a low and a high to inputs A and B, respectively, to apply the reference voltage stored on  $C_{ref}$  to the buffer. If the comparator output is high corresponding to a positive input, inputs A and B are made high and low, respectively, and the negative of the stored reference voltage is applied to the buffer. In either case, the processor automatically selects the proper logic state to cause the integrator to ramp back toward zero at a rate proportional to the reference voltage. The time required to return to zero is measured by the counter in the digital processor. The phase is terminated when the integrator output crosses zero and the counter contents are transferred to the register, or when the BCD counter reaches 20,000 and the over-range indication is activated. When activated, the over-range indication blands all but the most significant digit and sign.

Seventeen parallel bits (4-1/2 digits) of information are strobed into the buffer register at the end of the integration phase. Information for each digit is multiplexed out to the BCD outputs (TL503C) or the seven-segment drivers (TL502C) at a rate equal to the oscillator frequency divided by 400.



\*This step is the voltage at pin 2 with respect to analog ground.

**FIGURE 1—VOLTAGE WAVEFORMS AND TIMING DIAGRAM**

# TYPES TL500C THRU TL503C ANALOG-TO-DIGITAL-CONVERTER BUILDING BLOCKS

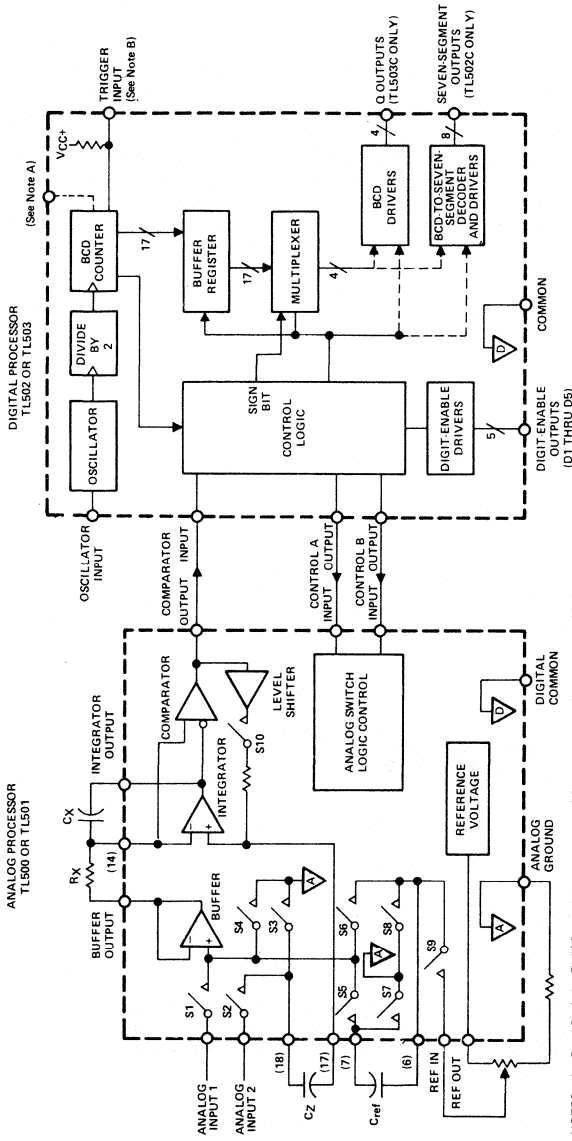


FIGURE 2—BLOCK DIAGRAM OF BASIC ANALOG-TO-DIGITAL CONVERTER USING TL500C OR TL501C AND TL502C OR TL503C

NOTES: A. Pin 18 of the TL502 provides an output of  $f_{osc}$  (oscillator frequency)  $\approx 20,000$ .  
 B. The trigger input assumes a high level if not externally connected.

MODE	ANALOG INPUT	COMPARATOR	CONTROLS A AND B	ANALOG SWITCHES
Auto Zero	X	Oscillation	L L	S3, S4, S7, S9, S10
Hold†				
Integrate	Positive	H	H H	S1, S2
	Negative	L		
Integrate Reference	X	H†	H L	S3, S6, S7
		L†	L H	S3, S5, S8

H  $\equiv$  High, L  $\equiv$  Low, X  $\equiv$  Irrelevant

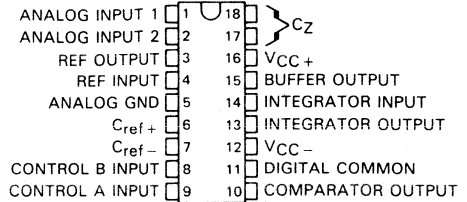
† If the trigger input is low at the beginning of the auto-zero cycle, the system will enter the hold mode. A high level (or open circuit) will signal the digital processor to continue or resume normal operation.  
 ‡ This is the state of the comparator output as determined by the polarity of the analog input during the integrate input phase.

# TYPES TL500C, TL501C ANALOG PROCESSORS

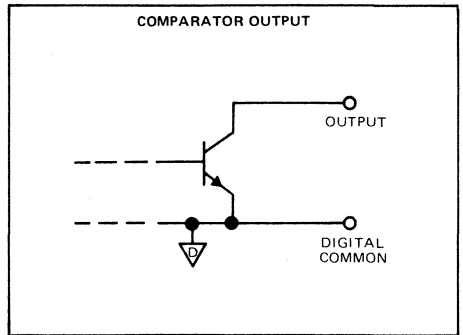
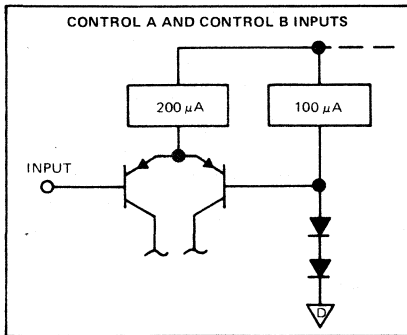
## description of analog processors

The TL500C and TL501C analog processors are designed to automatically compensate for internal zero offsets, integrate a differential voltage at the analog inputs, integrate a voltage at the reference input in the opposite direction, and provide an indication of zero-voltage crossing. The external control mechanism may be a microcomputer and software routine, discrete logic, or a TL502C or TL503C controller. The TL500C and TL501C are designed primarily for simple, cost-effective, dual-slope analog-to-digital converters. Both devices feature true differential analog inputs, high input impedance, and an internal reference-voltage source. The TL500C provides 4-1/2-digit readout accuracy when used with a precision external reference voltage. The TL501C provides 100-ppm linearity error and 3-1/2-digit accuracy capability. These devices are manufactured using TI's advanced technology to produce JFET, MOSFET, and bipolar devices on the same chip. The TL500C and TL501C are intended for operation over the temperature range of 0°C to 70°C.

N DUAL-IN-LINE PACKAGE  
(TOP VIEW)



## schematics of inputs and outputs



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Positive supply voltage, V <sub>CC+</sub> (see Note 1)	+18 V
Negative supply voltage, V <sub>CC-</sub>	-18 V
Input voltage, V <sub>I</sub>	±V <sub>CC</sub>
Comparator output voltage range (see Note 2)	0 V to V <sub>CC+</sub>
Comparator output sink current (see Note 2)	20 mA
Buffer, reference, or integrator output source current (see Note 2)	10 mA
Total dissipation at (or below) 25°C free-air temperature (see Note 3)	875 mW
Operating free-air temperature range	-0°C to 70°C
Storage temperature range	-65°C to 125°C

- NOTES: 1. Voltage values, except differential voltages, are with respect to the analog ground common pin tied together.  
 2. Buffer, integrator, and comparator outputs are not short-circuit protected.  
 3. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2.

# TYPES TL500C, TL501C ANALOG PROCESSORS

## recommended operating conditions

		MIN	NOM	MAX	UNIT
Positive supply voltage, $V_{CC+}$		7	12	15	v
Negative supply voltage, $V_{CC-}$		-9	-12	-15	V
Reference input voltage, $V_{ref(I)}$		0.1		5	V
Analog input voltage, $V_I$				±5	V
Differential analog input voltage, $V_{ID}$				10	V
High-level input voltage, $V_{IH}$	Control inputs	2			V
Low-level input voltage, $V_{IL}$	Control inputs			0.8	V
Peak positive integrator output voltage, $V_{OM+}$		+9			V
Peak negative integrator output voltage, $V_{OM-}$		-5			V
Full scale input voltage				2 $V_{ref}$	
Autozero and reference capacitors, $C_Z$ and $C_{ref}$		0.2			$\mu F$
Integrator capacitor, $C_X$		0.2			$\mu F$
Integrator resistor, $R_X$		15		100	k $\Omega$
Integrator time constant, $R_X C_X$		See Note 4			
Free-air operating temperature, $T_A$		0		70	$^{\circ}C$
Maximum conversion rate with TL502 or TL503		3		12.5	conv/sec

system electrical characteristics at  $V_{CC} = \pm 12 V$ ,  $V_{ref} = 1,000 \pm 0.03 mV$ ,  $T_A = 25^{\circ}C$   
(unless otherwise noted) (see Figure 3)

PARAMETER	TEST CONDITIONS	TL501C			TL500C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Zero error		50	300		10	30	$\mu V$	
Linearity error relative to full scale	$V_I = -2 V$ to $2 V$	0.005	0.05		0.001	0.005	%FS	
Full scale temperature coefficient	$T_A = 0^{\circ}C$ to $70^{\circ}C$	6			6			ppm/ $^{\circ}C$
Temperature coefficient of zero error	$T_A = 0^{\circ}C$ to $70^{\circ}C$	4			1			$\mu V/^{\circ}C$
Rollover error <sup>†</sup>		200 500		30 100			$\mu V$	
Equivalent peak-to-peak input noise voltage		20			20			$\mu V$
Analog input resistance	Pin 1 or 2	10 <sup>9</sup>			10 <sup>9</sup>			$\Omega$
Common-mode rejection ratio	$V_{IC} = -1 V$ to $+1 V$	86			90			dB
Current into analog input	$V_I = \pm 5 V$	50			50			pA
Supply voltage rejection ratio		90			90			dB

<sup>†</sup> Rollover error is the voltage difference between the conversion results of the full-scale positive 2 volts and the full-scale negative 2 volts.

NOTE 4. The minimum integrator time constant may be found by use of the following formula:

$$\text{Minimum } R_X C_X = \frac{V_{ID} \text{ (full scale)} t_1}{|V_{OM-}| - V_I(\text{pin 2})}$$

where

$V_{ID}$  = voltage at pin with respect to pin 2

$V_I(\text{pin 2})$  = voltage at pin 2 with respect to analog ground

$t_1$  = input integration time seconds

electrical characteristics at  $V_{CC} = \pm 12\text{ V}$ ,  $V_{ref} = 1\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (see Figure 3)

**integrator and buffer operational amplifiers**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
$V_{IO}$	Input offset voltage		15		mV
$I_{IB}$	Input bias current		50		pA
$V_{OM+}$	Positive output voltage swing	9	11		V
$V_{OM-}$	Negative output voltage swing	-5	-7		V
$A_{VD}$	Voltage amplification		110		dB
$B_1$	Unity-gain bandwidth		3		MHZ
CMRR	Common mode rejection	$V_{IC} = -1\text{ V to }+1\text{ V}$		100	dB
SR	Output slew rate		5		V/ $\mu\text{s}$

**comparator**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS	
$V_{IO}$	Input offset voltage		15		mV	
$I_{IB}$	Input bias current		50		pA	
$A_{VD}$	Voltage amplification		100		dB	
$V_{OL}$	Low-level output voltage	$I_{OL} = 1.6\text{ mA}$		200	400	mV
$I_{OH}$	High-level output current	$V_{OH} = 3\text{ V}$		5	20	nA

**voltage reference output**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
$V_{ref(0)}$	Reference voltage	1.12	1.22	1.32	V
$\alpha_{Vref}$	Reference-voltage temperature coefficient	$T_A = 0^\circ\text{C to }70^\circ\text{C}$		80	ppm/ $^\circ\text{C}$
$r_o$	Reference output resistance		3		$\Omega$

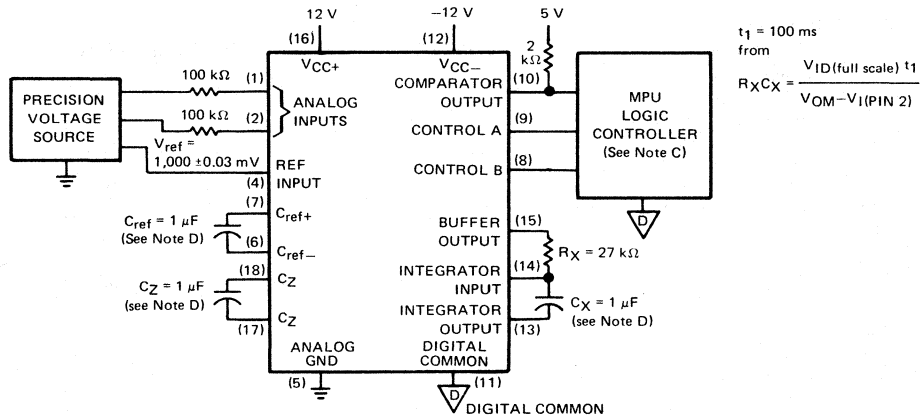
**logic control section**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS	
$I_{IH}$	High-level input current	$V_{IH} = 2\text{ V}$		1	10	$\mu\text{A}$
$I_{IL}$	Low-level input current	$V_{IL} = 0.8\text{ V}$		-40	-300	$\mu\text{A}$

**total device**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
$I_{CC+}$	Positive supply current		15	20	mA
$I_{CC-}$	Negative supply current		12	18	mA

**PARAMETER MEASUREMENT INFORMATION**



NOTES: C. Tests are started approximately 5 seconds after power-on.

D. Capacitors used are TRW's X363UW poly propylene or equivalent for  $C_X$ ,  $C_{ref}$ , and  $C_Z$ ; however for  $C_{ref}$  and  $C_Z$ , film-dielectric capacitors may be substituted.

**FIGURE 3—TEST CIRCUIT CONFIGURATION**

**external-component selection guide**

The autozero capacitor  $C_Z$  and reference capacitor  $C_{ref}$  should be within the recommended range of operating conditions and should have low leakage characteristics. Most film-dielectric capacitors and some tantalum capacitors provide acceptable results. Ceramic and aluminum capacitors are not recommended because of their relatively high leakage characteristics.

The integrator capacitor  $C_X$  should also be within the recommended range and must have good voltage linearity and low dielectric absorption. A polypropylene-dielectric capacitor similar to TRW's X363UW is recommended for 4-1/2-digit accuracy. For 3-1/2-digit applications, polyester, polycarbonate, and other film dielectrics are usually suitable. Ceramic and electrolytic capacitors are not recommended.

Stray coupling from the comparator output to any analog pin (in order of importance 17, 18, 14, 7, 6, 13, 1, 2, 15) must be minimized to avoid oscillations. In addition, all power supply pins should be bypassed at the package, for example, by a 0.01- $\mu\text{F}$  ceramic capacitor.

Analog and digital common are internally isolated and may be a different potentials. Digital common can be within 4 volts of positive or negative supply with the logic decode still functioning properly.

The time constant  $R_X C_X$  should be kept as near the minimum value as possible and is given by the formula:

$$\text{Minimum } R_X C_X = \frac{V_{ID}(\text{full scale}) t_1}{|V_{OM}| - V_I(\text{pin 2})}$$

where:

$V_{ID}(\text{full scale})$  = Voltage on pin 1 with respect to pin 2

$t_1$  = Input integration time in seconds

$V_I(\text{pin 2})$  = Voltage on pin 2 with respect to analog ground

**description of digital processors**

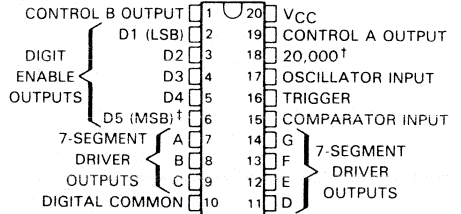
The TL502C and TL503C are control logic devices designed to complement the TL500C and TL501C analog processors. They feature interdigit blanking, over-range blanking, an internal oscillator, and a fast display scan rate. The internal-oscillator input is a Schmitt trigger circuit that can be driven by an external clock pulse or provide its own time base with the addition of a capacitor. The typical oscillator frequency is 120 kHz with a 470-picofarad capacitor connected between the oscillator input and ground.

The TL502C provides seven-segment-display output drivers capable of sinking 100 milliamperes and compatible with popular common-anode displays. The TL503C has four BCD output drivers capable of 100-milliampere sink currents. The code (see next page and Figure 4) for each digit is multiplexed to the output drivers in phase with a pulse on the appropriate digit-enable line at a digit rate equal to  $f_{osc}$  divided by 200. Each digit-enable output is capable of sinking 20 milliamperes.

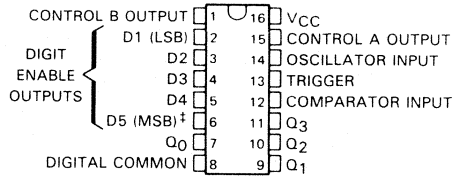
The comparator input of each device, in addition to monitoring the output of the zero-crossing detector in the analog processor, may be used in the display test mode to check for wiring and display faults. A high logic level (2 to 6.5 volts) at the trigger input with the comparator input at or below 6.5 volts starts the integrate-input phase. Voltage levels equal to or greater than 7.9 volts on both the trigger and comparator inputs clear the system and set the BCD counter to 20,000. When normal operation resumes, the conversion cycle is restarted at the auto zero phase.

These devices are manufactured using I<sup>2</sup>L and bipolar techniques. The TL502C and TL503C are intended for operation from 0°C to 70°C.

**TL502 ... N DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



**TL503 ... N DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



<sup>†</sup> Pin 18 of TL502 provides an output of  $f_{osc}$  (oscillator frequencies) = 20,000.

<sup>‡</sup> D5, the most significant bit, is also the sign bit.

**TABLE OF SPECIAL FUNCTIONS**

VCC = 5 V ± 10%

TRIGGER INPUT	COMPARATOR INPUT	FUNCTION
$V_I \leq 0.8 \text{ V}$	$V_I \leq 6.5 \text{ V}$	Hold at auto-zero cycle after completion of conversion
$2 \text{ V} \leq V_I \leq 6.5 \text{ V}$	$V_I \leq 6.5 \text{ V}$	Normal operation (continuous conversion)
$V_I \leq 6.5 \text{ V}$	$V_I \geq 7.9 \text{ V}$	Display Test: All BCD outputs high
$V_I \geq 7.9 \text{ V}$	$V_I \leq 6.5 \text{ V}$	Internal Test
Both inputs go to $V_I \geq 7.9 \text{ V}$ simultaneously		System clear: Sets BCD counter to 20,000. When normal operation is resumed, cycle begins with Auto Zero.

# TYPES TL502C, TL503C DIGITAL PROCESSORS

DIGIT 5 (MOST SIGNIFICANT DIGIT) CHARACTER CODES

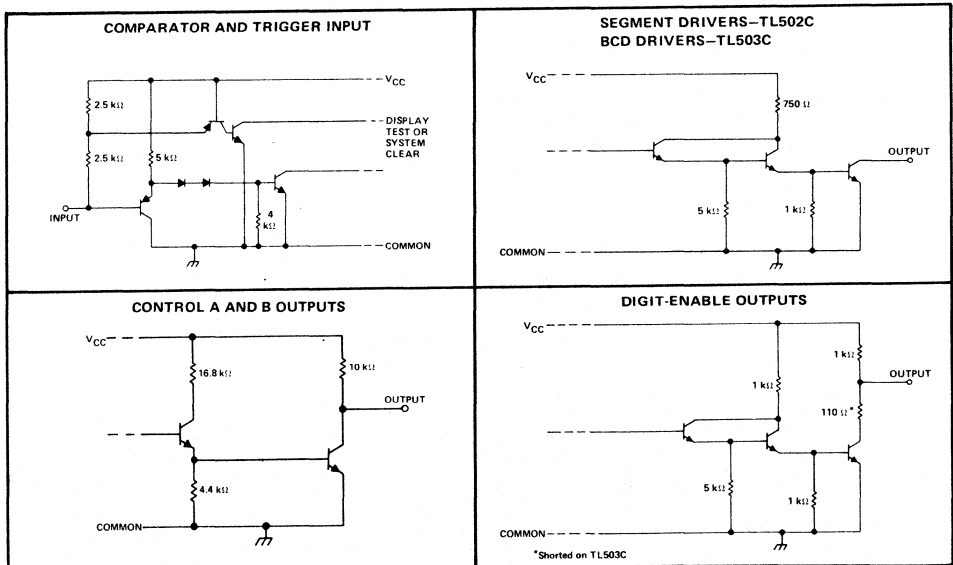
CHARACTER	TL502C SEVEN-SEGMENT LINES							TL503C BCD OUTPUT LINES			
	A	B	C	D	E	F	G	Q3 8	Q2 4	Q1 2	Q0 1
+	H	H	H	H	L	L	L	H	L	H	L
+1	H	L	L	H	L	L	L	H	H	H	L
-	L	H	H	L	H	H	L	H	L	H	H
-1	L	L	L	L	H	H	L	H	H	H	H

DIGITS 1 THRU 4 NUMERIC CODE (See Figure 4)

NUMBER	TL502C SEVEN-SEGMENT LINES							TL503C BCD OUTPUT LINES			
	A	B	C	D	E	F	G	Q3 8	Q2 4	Q1 2	Q0 1
0	L	L	L	L	L	L	H	L	L	L	L
1	H	L	L	H	H	H	H	L	L	L	H
2	L	L	H	L	L	H	L	L	L	H	L
3	L	L	L	L	H	H	L	L	L	H	H
4	H	L	L	H	H	L	L	L	H	L	L
5	L	H	L	L	H	L	L	L	H	L	H
6	L	H	L	L	L	L	L	L	H	H	L
7	L	L	L	H	H	H	H	L	H	H	H
8	L	L	L	L	L	L	L	H	L	L	L
9	L	L	L	L	H	L	L	H	L	L	H

H = high level, L = low level

schematics of inputs and outputs



Data Acquisition 7



**absolute maximum ratings**

Supply voltage, $V_{CC}$ (see Note 5)		7	V
Input voltage, $V_I$	Oscillator	5.5	V
	Comparator or Trigger	9	
Output current	BCD or Segment drivers	120	mA
	Digit-enable outputs	40	
	Pin 18 (TLC502 only)	20	
Total power dissipation at (or below) 30°C free-air temperature (see Note 6)		875	mW
Operating free-air temperature range		0 to 70	°C
Storage temperature range		-65 to 150	°C

NOTES: 5. Voltage values are with respect to the network ground terminal.  
6. For operation above 30°C free-air temperature, derate linearly at the rate of 9.2 mW/°C.

**recommended operating conditions**

		MIN	NOM	MAX	UNIT	
Supply voltage, $V_{CC}$		4.5	5	5.5	V	
High-level input voltage, $V_{IH}$	Comparator and trigger inputs	2			V	
Low-level input voltage, $V_{IL}$	Comparator and trigger inputs	0.8			V	
Operating free-air temperature		0			70	°C

**TYPES TL502C, TL503C  
DIGITAL PROCESSORS**

**electrical characteristics at 25 °C free-air temperature**

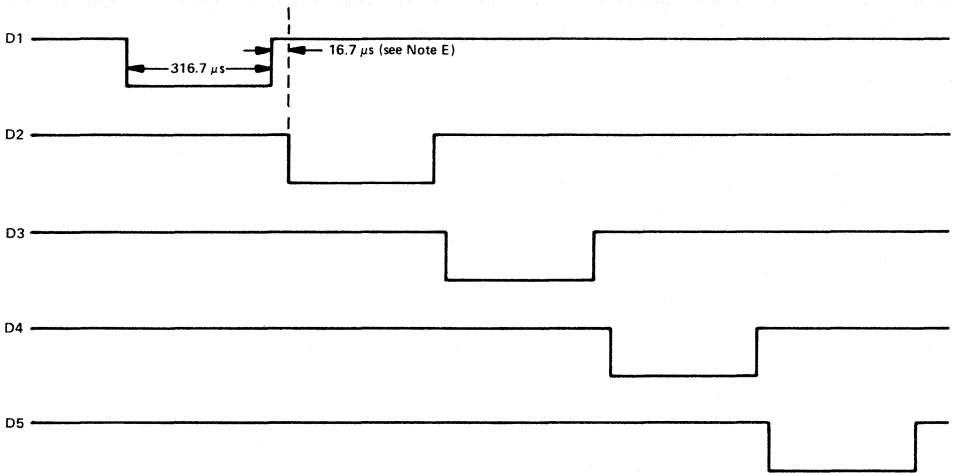
PARAMETER	TERMINAL	TEST CONDITIONS	TL502C			TL503C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V <sub>IK</sub>	All inputs	V <sub>CC</sub> = 4.5 V, I <sub>I</sub> = -12 mA	-0.8	-1.5	-0.8	-1.5	-0.8	-1.5	V
V <sub>T+</sub>	Oscillator	V <sub>CC</sub> = 5 V	1.5		1.5		1.5		V
V <sub>T-</sub>	Oscillator	V <sub>CC</sub> = 5 V	0.9		0.9		0.9		V
V <sub>T+</sub> - V <sub>T-</sub>	Oscillator	V <sub>CC</sub> = 5 V	0.4	0.6	0.8	0.4	0.6	0.8	
I <sub>T+</sub>	Oscillator	V <sub>CC</sub> = 5 V	-40	-94	-170	-40	-94	-170	µA
I <sub>T-</sub>	Oscillator	V <sub>CC</sub> = 5 V	40	117	170	40	117	170	µA
V <sub>OH</sub>	Digit enable Pin 18 (TL502C only)	V <sub>CC</sub> = 4.5 V, I <sub>OL</sub> = 0	4.15	4.4	4.15	4.4	4.15	4.4	V
V <sub>OL</sub>	Control A and B		4.25	4.4	4.25	4.4	4.25	4.4	
	Digit enable	I <sub>OL</sub> = 20 mA					0.2	0.5	
	Pin 18 (TL502C only)	I <sub>OL</sub> = 10 mA			0.15	0.4			
	Control A and B	V <sub>CC</sub> = 4.5 V			0.088	0.4		0.088	0.4
I <sub>I</sub>	Segment drivers	I <sub>OL</sub> = 100 mA			0.17	0.3			
	BCD drivers	I <sub>OL</sub> = 100 mA					0.17	0.3	
I <sub>I</sub>	Comparator, Trigger	V <sub>CC</sub> = 5.5 V, V <sub>I</sub> = 5.5 V	65	100	65	100	65	100	µA
I <sub>IH</sub>	Comparator, Trigger	V <sub>CC</sub> = 5.5 V, V <sub>I</sub> = 2.4 V	-0.6	-1	-0.6	-1	-0.6	-1	mA
I <sub>IL</sub>	Oscillator	V <sub>CC</sub> = 5.5 V, V <sub>I</sub> = 0.4 V	-0.1	-0.17	-0.1	-0.17	-0.1	-0.17	mA
I <sub>OH</sub>	Comparator, Trigger		-1	-1.6	-1	-1.6	-1	-1.6	
	Digit enable	V <sub>O</sub> = 0.5 V	-2.5	-4	-2.5	-4	-2.5	-4	
	Pin 18 (TL502C only)	V <sub>O</sub> = 0.5 V	-0.5	-0.9	-0.5	-0.9	-0.5	-0.9	
	Control A and B	V <sub>CC</sub> = 4.5 V	-0.25	-0.4	-0.25	-0.4	-0.25	-0.4	mA
I <sub>OL</sub>	Segment drivers	V <sub>O</sub> = 5.5 V			0.25				
	BCD drivers	V <sub>O</sub> = 5.5 V						0.25	
I <sub>CC</sub>	Digit enable (Output transistor on)	V <sub>CC</sub> = 4.5 V, V <sub>O</sub> = 3.55 V	18	23	18	23	18	23	mA
	V <sub>CC</sub>	V <sub>CC</sub> = 5.5 V	73	110	73	110	73	110	mA

**special functions<sup>†</sup> operating characteristics at 25°C free-air temperature**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{ij}$ Input current into comparator or trigger inputs	$V_{CC} = 5.5 \text{ V}, V_I = 8.55 \text{ V}$		1.2	1.8	mA
	$V_{CC} = 5.5 \text{ V}, V_I = 6.25 \text{ V}$			0.5	mA

<sup>†</sup>The comparator and trigger inputs may be used in the normal mode or to perform special functions. See the Table of Special Functions.

**TYPICAL APPLICATION DATA**



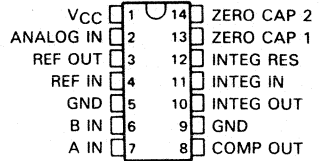
NOTE E. The BCD or seven-segment driver outputs are present for a particular digit slightly before the falling edge of that digit enable.

**FIGURE 4—TL502C, TL503C DIGIT TIMING WITH 120-kHz CLOCK SIGNAL AT OSCILLATOR INPUT**



- 3-Digit Accuracy (0.1%)
- 10-Bit Resolution
- Automatic Zero
- Internal Reference Voltage
- Single-Supply Operation
- High-Impedance MOS Input
- Designed for use with TMS 1000 Type Microprocessors for Cost-Effective High-Volume Applications
- BI-MOS Technology
- Only 40 mW Typical Power Consumption

**N DUAL-IN-LINE PACKAGE (TOP VIEW)**



Caution. This device has limited built-in gate protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

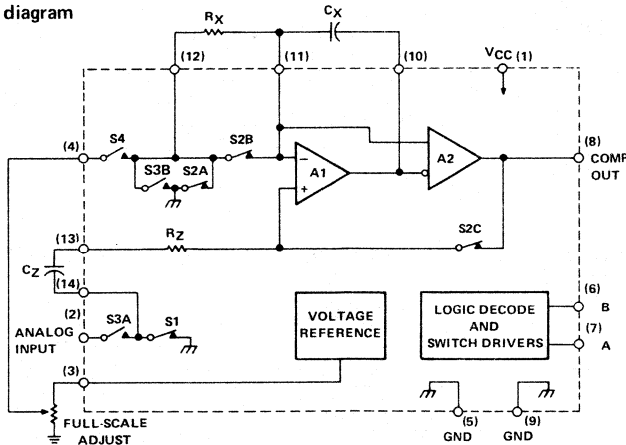
**description**

The TL505C is an analog-to-digital converter building block designed for use with TMS 1000 type microprocessors. It contains the analog elements (operational amplifier, comparator, voltage reference, analog switches, and switch drivers) necessary for a unipolar automatic-zeroing dual-slope converter. The logic for the dual-slope conversion can be performed by the associated MPU as a software routine or it can be implemented with other components such as the TL502 logic-control device.

The high-impedance MOS inputs permit the use of less expensive, lower value capacitors for the integration and offset capacitors and permit conversion speeds from 20 per second to 0.05 per second.

The TL505C is a product of TI's BI-MOS process, which incorporates bipolar and MOSFET transistors on the same monolithic integrated circuit. The TL505C is characterized for operation from 0°C to 70°C.

**functional block diagram**



NOTE: Analog and digital GND are internally connected together.

# TYPE TL505C

## ANALOG-TO-DIGITAL CONVERTER

### absolute maximum ratings over operating temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	18 V
Input voltage, pins 2, 4, 6, and 7	$V_{CC}$
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	875 mW
Operating free-air temperature range	0°C to 70°C
Storage temperature range	-65°C to 150°C

- NOTES: 1. Voltage values are with respect to the two ground terminals connected together.  
 2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2.

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	7	9	15	V
Analog input voltage, $V_I$	0		4	V
Reference input voltage, $V_{ref(I)}$	0.5		3	V
High-level input voltage at A or B, $V_{IH}$	3.6		$V_{CC} + 1$	V
Low-level input voltage at A or B, $V_{IL}$	0.2		1.8	V
Integrator capacitor, $C_X$	See "component selection"			
Integrator resistor, $R_X$	0.5		2	M $\Omega$
Integration time, $t_1$	16.6		500	ms
Operating free-air temperature, $T_A$	0		70	°C

### electrical characteristics, $V_{CC} = 9\text{ V}$ , $V_{ref(I)} = 1\text{ V}$ , $T_A = 25^\circ\text{C}$ , connected as shown in Figure 1 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{OH}$	High-level output voltage at pin 8 $I_{OH} = 0$	7.5	8.5		V
$I_{OH}$	High-level output current at pin 8 $V_{OH} = 7.5\text{ V}$		-100		$\mu\text{A}$
$V_{OL}$	Low-level output voltage at pin 8 $I_{OL} = 1.6\text{ mA}$		200	400	mV
$V_{OM}$	Maximum peak output voltage swing at integrator output $R_X \geq 500\text{ k}\Omega$	$V_{CC} - 2$	$V_{CC} - 1$		V
$V_{ref(O)}$	Reference output voltage $I_{ref} = -100\text{ }\mu\text{A}$	1.15	1.22	1.35	V
$\alpha_{Vref}$	Temperature coefficient of reference output voltage $T_A = 0^\circ\text{C to } 70^\circ\text{C}$		$\pm 100$		ppm/°C
$I_{IH}$	High-level input current into A or B $V_I = 9\text{ V}$		1	10	$\mu\text{A}$
$I_{IL}$	Low-level input current into A or B $V_I = 1\text{ V}$		10	200	$\mu\text{A}$
$I_I$	Current into analog input $V_I = 0\text{ to } 4\text{ V}$ , A input at 0 V		$\pm 10$	$\pm 200$	$\mu\text{A}$
$I_B$	Total integrator input bias current		$\pm 10$		$\mu\text{A}$
$I_{CC}$	Supply current No load		4.5	8	mA

### system electrical characteristics, $V_{CC} = 9\text{ V}$ , $V_{ref(I)} = 1\text{ V}$ , $T_A = 25^\circ\text{C}$ , connected as shown in Figure 1 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Zero error	$V_I = 0$		0.1	0.4	mV
Linearity error	$V_I = 0\text{ to } 4\text{ V}$		0.02	0.1	%FS
Ratiometric reading	$V_I = V_{ref(I)} \approx 1\text{ V}$	0.998	1.000	1.002	
Temperature coefficient of ratiometric reading	$V_{ref(I)}$ constant and $\approx 1\text{ V}$ , $T_A = 0^\circ\text{C to } 70^\circ\text{C}$		$\pm 10$		ppm/°C

DEFINITION OF TERMS

Zero Error

The intercept (b) of the analog-to-digital converter system transfer function  $y = mx + b$ , where y is the digital output, x is the analog input, and m is the slope of the transfer function, which is approximated by the ratiometric reading.

Linearity Error

The maximum magnitude of the deviation from a straight line between the end points of the transfer function.

Ratiometric Reading

The ratio of negative integration time ( $t_2$ ) to positive integration time ( $t_1$ ).

PRINCIPLES OF OPERATION

A block diagram of an MPU system utilizing the TL505C is shown in Figure 1. The TL505C operates in a modified positive-integration three-step dual-slope conversion mode. The A/D converter waveforms during the conversion process are illustrated in Figure 2.

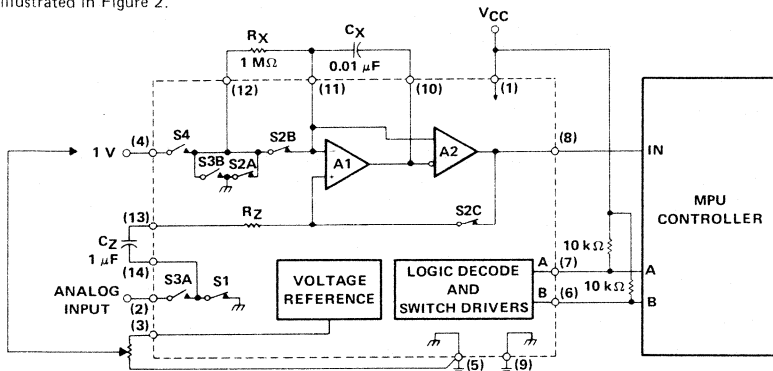


FIGURE 1—FUNCTIONAL BLOCK DIAGRAM OF TL505C INTERFACE WITH A MICROPROCESSOR SYSTEM

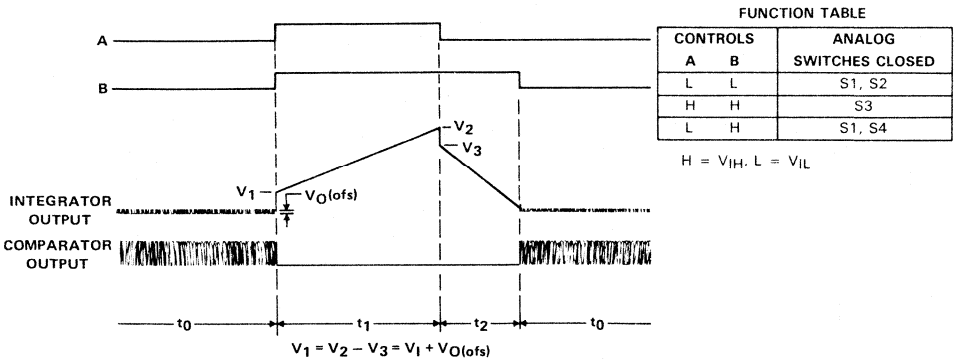


FIGURE 2—CONVERSION PROCESS TIMING DIAGRAMS

# TYPE TL505C ANALOG-TO-DIGITAL CONVERTER

## PRINCIPLES OF OPERATION

The first step of the conversion cycle is the auto-zero period  $t_0$  during which the integrator offset is stored in the auto-zero capacitor and the offset of the comparator is stored in the integrator capacitor. To accomplish this, the MPU takes the A and B inputs both low. This is decoded by the switch drivers, which close S1 and S2. The output of the comparator is connected to the input of the integrator through the low-pass filter consisting of  $R_Z$  and  $C_Z$ . The closed loop of A1 and A2 will seek a null condition where the offsets of the integrator and comparator are stored in  $C_Z$  and  $C_X$ , respectively. This null condition is characterized by a high-frequency oscillation at the output of the comparator. The purpose of S2B is to shorten the amount of time required to reach the null condition.

At the conclusion of  $t_0$ , the MPU takes the A and B inputs both high. This closes S3 and turns all other switches off. The input signal  $V_I$  is applied to the noninverting input of A1 through  $C_Z$ .  $V_I$  is then positively integrated by A1. Since the offset of A1 is stored in  $C_Z$ , the change in voltage across  $C_X$  will be due to only the input voltage. It should be noted that since the input is integrated in a positive integration during  $t_1$ , the output of A1 will be the sum of the input voltage, the integral of the input voltage, and the comparator offset, as shown in Figure 2. The change in voltage across capacitor  $C_X$  ( $V_{CX}$ ) during  $t_1$  is given by

$$\Delta V_{CX}(1) = \frac{V_I t_1}{R_1 C_X} \quad (1)$$

where  $R_1 = R_X + R_{S3B}$  and

$R_{S3B}$  is the resistance of switch S3B.

At the end of  $t_1$  the MPU takes the A input low and the B input high. This turns on S1 and S4; all other switches are turned off. In this state the reference is integrated by A1 in a negative sense until the integrator output reaches the comparator threshold. At this point the comparator output goes high. This change in state is sensed by the MPU, which terminates  $t_2$  by again taking the A and B inputs both low. During  $t_2$  the change in voltage across  $C_X$  is given by

$$\Delta V_{CX}(2) = \frac{V_{ref} t_2}{R_2 C_X} \quad (2)$$

where  $R_2 = R_X + R_{S4} + R_{ref}$  and

$R_{ref}$  is the equivalent resistance of the reference divider.

Since  $\Delta V_{CX1} = -\Delta V_{CX2}$ , equations (1) and (2) can be combined to give

$$V_I = V_{ref} \frac{R_1 \cdot t_2}{R_2 \cdot t_1} \quad (3)$$

This equation is a variation on the ideal dual-slope equation, which is

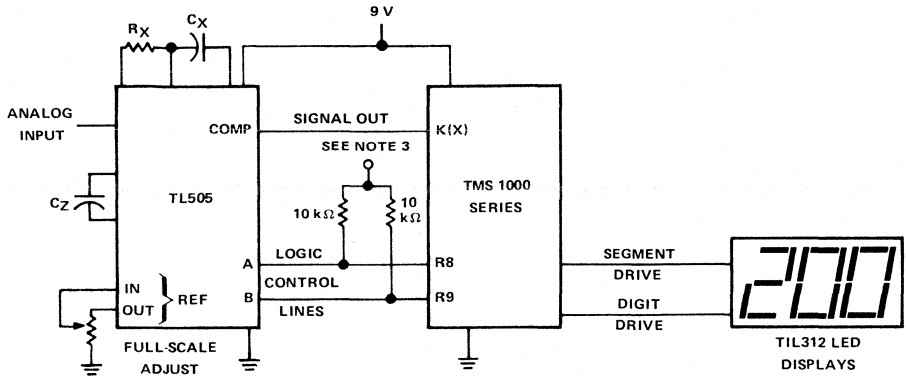
$$V_I = V_{ref} \frac{t_2}{t_1} \quad (4)$$

Ideally then, the ratio of  $R_1/R_2$  would be exactly equal to one. In a typical TL505C system where  $R_X = 1 \text{ M}\Omega$ , the scaling error introduced by the difference in  $R_1$  and  $R_2$  is so small that it can be neglected, and equation (3) reduces to (4).



# TYPE TL505C ANALOG-TO-DIGITAL CONVERTER

## TYPICAL APPLICATION DATA



NOTE 3: Connect to either +9 V or 0 V depending on which device in the TMS 1000 series is used and how it is programmed.

FIGURE 5—TL505C IN CONJUNCTION WITH A TMS 1000 SERIES MICROPROCESSOR FOR A 3-DIGIT DIGITAL PANEL METER APPLICATION

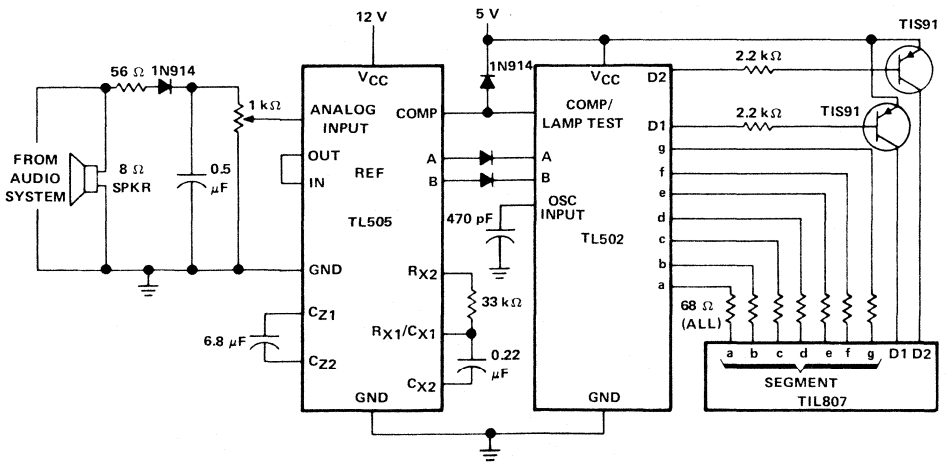
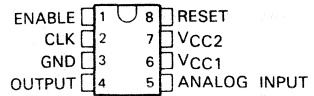


FIGURE 6—AUDIO PEAK POWER METER



- Low Cost
- 7-Bit Resolution
- Guaranteed Monotonicity
- Ratiometric Conversion
- Conversion Speed . . . approximately 1 ms
- Single-Supply Operation . . . Either Unregulated 8-V to 18-V ( $V_{CC2}$  Input), or Regulated 3.5-V to 6-V ( $V_{CC1}$  Input)
- $i^2L$  Technology
- Power Consumption at 5 V . . . 25 mW Typ
- Regulated 5.5-V Output ( $\leq 1$  mA)

**P DUAL-IN-LINE PACKAGE (TOP VIEW)**



**FUNCTION TABLE**

ANALOG INPUT CONDITION	ENABLE	OUTPUT
X	L <sup>†</sup>	H
$V_I < 200$ mV	H	L
$V_{ramp} > V_I > 200$ mV	H	H
$V_I > V_{ramp}$	H	L

<sup>†</sup>Low level on enable also inhibits the reset function.  
H = high level, L = low level, X = irrelevant

A high level on the reset pin clears the counter to zero, which sets the internal ramp to  $0.75 V_{CC}$ . Internal pull-down resistors keep the reset and enable pins low when not connected.

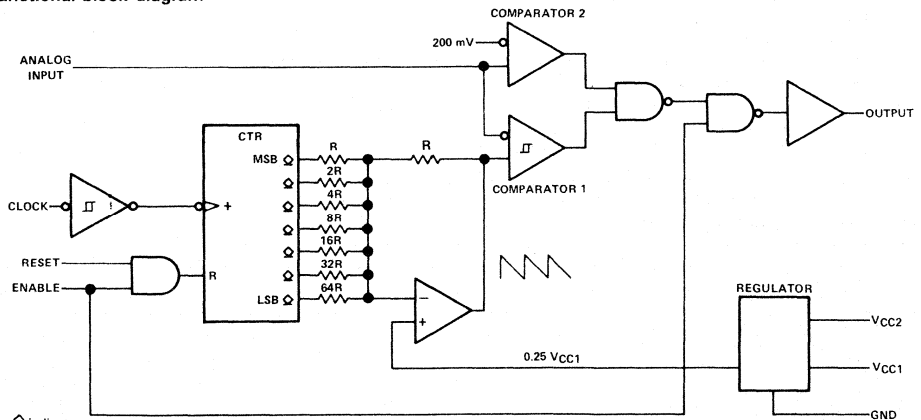
**description**

The TL507 is a low-cost single-slope analog-to-digital converter designed to convert analog input voltages between  $0.25 V_{CC1}$  and  $0.75 V_{CC1}$  into a pulse-width-modulated output code. It contains a 7-bit synchronous counter, a binary-weighted resistor ladder network, an operational amplifier, two comparators, a buffer amplifier, an internal regulator, and necessary logic circuitry. Integrated-injection logic ( $i^2L$ ) technology makes it possible to offer this complex circuit at low cost in a small dual-in-line 8-pin package.

In continuous operation, it is possible to obtain conversion speeds up to 1000 per second. The TL507 requires external signals for clock, reset, and enable. Versatility and simplicity of operation coupled with low cost, makes this converter especially useful for a wide variety of applications.

The TL507C is characterized for operation from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ , and the TL507I is characterized for operation from  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ .

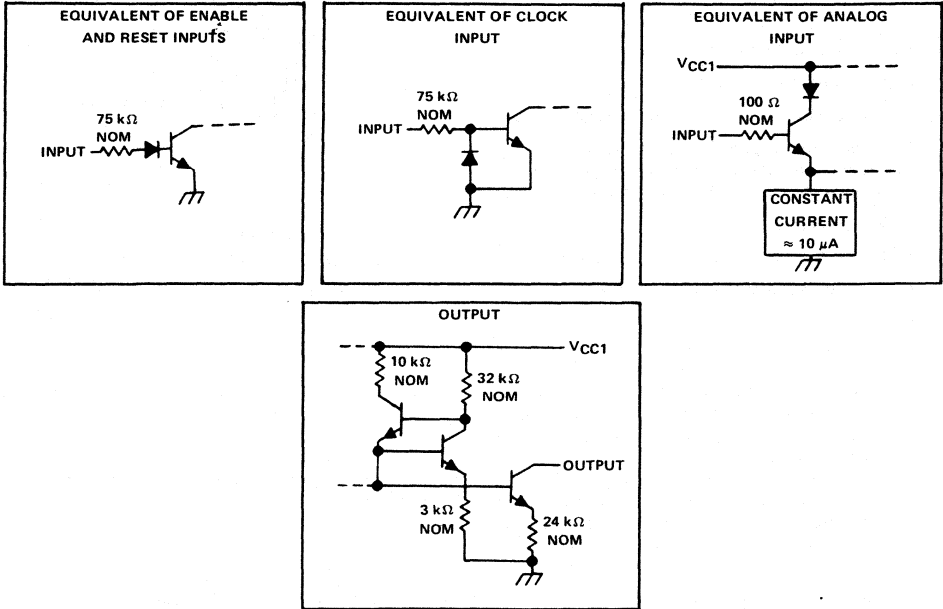
**functional block diagram**



⊗ Indicates an n-p-n open-collector output.

# TYPES TL507I, TL507C ANALOG-TO-DIGITAL CONVERTER

## schematics of inputs and outputs



### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC1}$ (see Note 1)	6.5 V
Supply voltage, $V_{CC2}$	20 V
Input voltage at analog input	6.5 V
Input voltage at enable, clock, and reset inputs	$\pm 20$ V
On-state output voltage	6 V
Off-state output voltage	20 V
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	725 mW
Operating free-air temperature range: TL507I	-40°C to 85°C
TL507C	-0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	260°C

- NOTES: 1. Voltage values are with respect to network ground terminal unless otherwise noted.  
2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2.

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC1}$	3.5	5	6	V
Supply voltage, $V_{CC2}$	8	15	18	V
Input voltage at analog input	0		5.5	V
Input voltage at chip enable, clock, and reset inputs			$\pm 18$	V
On-state output voltage			5.5	V
Off-state output voltage			18	V
Clock frequency, $f_{clock}$		125	150	kHz

**electrical characteristics over recommended operating free-air temperature range,  $V_{CC1} = V_{CC2} = 5\text{ V}$  (unless otherwise noted)**

**regulator section**

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
$V_{CC1}$	Supply voltage (output)	$V_{CC2} = 10\text{ to }18\text{ V}$ , $I_{CC1} = 0\text{ to }-1\text{ mA}$	5	5.5	6	V
$I_{CC1}$	Supply current	$V_{CC1} = 5\text{ V}$ , $V_{CC2}$ open		5	8	mA
$I_{CC2}$	Supply current	$V_{CC2} = 15\text{ V}$ , $V_{CC1}$ open		7	10	mA

**inputs**

PARAMETER			TEST CONDITIONS			MIN	TYP <sup>†</sup>	MAX	UNIT
$V_{IH}$	High-level input voltage	Reset and Enable				2			V
$V_{IL}$	Low-level input voltage							0.8	V
$V_{T+}$	Positive-going threshold voltage <sup>‡</sup>	Clock Input				4.5			V
$V_{T-}$	Negative-going threshold voltage <sup>‡</sup>							0.4	V
$V_{T+} - V_{T-}$	Hysteresis		2	2.6	4			V	
$I_{IH}$	High-level input current	Reset, Enable, and Clock	$V_I = 2.4\text{ V}$			17	35		$\mu\text{A}$
			$V_I = 18\text{ V}$			130	220	320	
$I_{IL}$	Low-level input current		$V_I = 0$					$\pm 10$	$\mu\text{A}$
$I_I$	Analog input current		$V_I = 4\text{ V}$			10	300		nA

**output section**

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
$I_{OH}$	High-level output current	$V_{OH} = 18\text{ V}$		0.1	100	$\mu\text{A}$
$I_{OL}$	Low-level output current	$V_{OL} = 5.5\text{ V}$	5	10	15	mA
$V_{OL}$	Low-level output voltage	$I_{OL} = 1.6\text{ mA}$		80	400	mV

**operating characteristics over recommended operating free-air temperature range,  $V_{CC1} = V_{CC2} = 5.12\text{ V}$**

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
Overall error					$\pm 80$	mV
Differential nonlinearity		See Figure 1			$\pm 1$	LSB
Zero error <sup>‡</sup>		Binary count = 0	1.20	1.28	1.36	V
Scale error		Binary count = 127			$\pm 80$	mV
Full scale input voltage <sup>‡</sup>		Binary count = 127	3.74	3.82	3.9	V
Propagation delay time from reset or enable				2		$\mu\text{s}$

<sup>†</sup>All typical values are at  $T_A = 25^\circ\text{C}$ .

<sup>‡</sup>These parameters are linear functions of  $V_{CC1}$ .

**definitions**

**zero error**

The intercept (b) of the analog-to-digital converter-system transfer function  $y = mx + b$ , where y is the digital output, x is the analog input, and m is the slope of the transfer function.

**overall error**

The magnitude of the deviation from a straight line between the endpoints of the transfer function.

**differential nonlinearity**

Maximum deviation of an analog-value change that is associated with a 1-bit code change (1 clock pulse) from its theoretical value of 1 LSB.

# TYPES TL507I, TL507C ANALOG-TO-DIGITAL CONVERTER

## PARAMETER MEASUREMENT INFORMATION

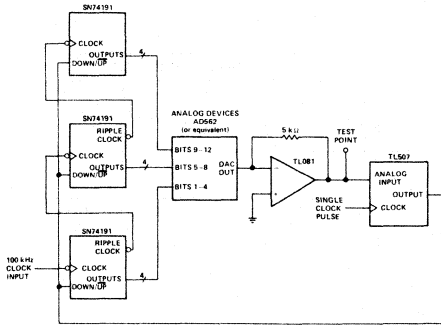


FIGURE 1—MONOTONICITY AND NONLINEARITY TEST CIRCUIT

## PRINCIPLES OF OPERATION

The TL507 is a single-slope analog-to-digital converter. All single-slope converters are basically voltage-time or current-to-time converters. A study of the functional block diagram shows the versatility of the TL507.

An external clock signal is applied through a buffer to a negative-edge-triggered synchronous counter. Binary-weighted resistors from the counter are connected to an operational amplifier used as an adder. The operational amplifier generates a signal that ramps from  $0.75 \cdot V_{CC1}$  down to  $0.25 \cdot V_{CC1}$ . Comparator 1 compares the ramp signal to the analog input signal. Comparator 2 functions as a fault defector. With the analog input voltage in the range  $0.25 \cdot V_{CC1}$  to  $0.75 \cdot V_{CC1}$ , the duty cycle of the output signal is determined by the unknown analog input as shown in Figure 2 and the Function Table.

For illustration assume  $V_{CC1} = 5.12 \text{ V}$ ,

$$0.25 \cdot V_{CC1} = 1.28 \text{ V}$$

$$1 \text{ binary count} = \frac{(0.75 - 0.25) V_{CC1}}{128} = 20 \text{ mV}$$

$$0.75 \cdot V_{CC1} - 1 \text{ count} = 3.82 \text{ V}$$

The output is an open-collector n-p-n transistor capable of withstanding up to 18 volts in the off state. The output is current limited to the 8- to 12-milliampere range; however, care must be taken to ensure that the output does not exceed 5.5 volts in the on state.

The voltage regulator section allows operation from either an unregulated 8- to 18-volt  $V_{CC2}$  source or a regulated 3.5- to 6-volt  $V_{CC1}$  source. Regardless of which external power source is used, the internal circuitry operates at  $V_{CC1}$ . When operating from a  $V_{CC1}$  source,  $V_{CC2}$  may be connected to  $V_{CC1}$  or left open. When operating from a  $V_{CC2}$  source,  $V_{CC1}$  can be used as a reference voltage output.

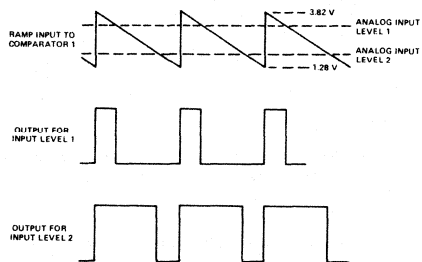
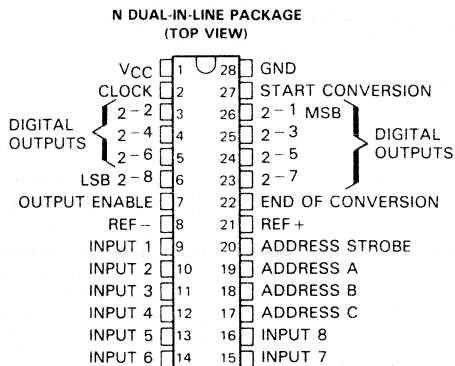


FIGURE 2

- **Total Unadjusted Error at 85°C:**  
 TL520 . . .  $\pm 3/4$  LSB MAX  
 TL521 . . .  $\pm 1$  LSB MAX  
 TL522 . . .  $\pm 1/2$  LSB MAX
- **8-Bit Resolution**
- **Built-in 8-Input Analog Multiplexer**
- **Minimum Conversion Time:**  
 TL520 . . . 70  $\mu$ s  
 TL521 . . . 100  $\mu$ s  
 TL522 . . . 200  $\mu$ s
- **Ratiometric Conversion**
- **Guaranteed Monotonicity**
- **No Missing Codes**
- **Easy Interface with Microprocessors**
- **Latched 3-State Outputs**
- **Latched Address Inputs**
- **Single-Supply Operation**  
 TL520, TL521 . . . 5 V  
 TL522 . . . 3 V
- **Low Power Consumption**  
 TL520, TL521 . . . 2.5 mW Typical  
 TL522 . . . 0.3 mW Typical



**description**

The TL520, TL521, and TL522 are monolithic CMOS devices each with an 8-channel multiplexer, and 8-bit analog-to-digital (A/D) converter, and microprocessor-compatible control logic. The 8-channel multiplexer can be controlled by a microprocessor through a 3-bit address decoder with address load to select any one of eight single-ended analog switches connected directly to a comparator. The 8-bit A/D converter uses a binary-weighted capacitor array to implement the high-speed, successive-approximation conversion technique.

The comparison and conversion methods used eliminate the possibility of missing codes, nonmonotonicity, and the need for zero or full-scale adjustment. Also featured are latched 3-state outputs and latched inputs to the multiplexer address decoder. The single 5-volt supply and low power requirements make the TL520 and TL521 especially useful for a wide variety of applications. The 3-volt and low power requirements make the TL522 especially useful for battery and LCD applications. Ratiometric conversion is made possible by access to the reference voltage input terminals.

The TL520, TL521, and TL522 are characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)**

Supply voltage, $V_{CC}$ (see Note 1)	6.5 V
Positive reference input voltage range, $V_{REF+}$	$V_{REF-}$ to $V_{CC} + 0.3$ V
Negative reference input voltage range, $V_{REF-}$ (see Note 1)	$-0.3$ V to $V_{REF+}$
Input voltage range: all other inputs	$-0.3$ V to $V_{CC} + 0.3$ V
Continuous total dissipation at $25^{\circ}\text{C}$ free-air temperature (see Note 2)	1250 mW
Operating free-air temperature range	$-40^{\circ}\text{C}$ to $85^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds	$260^{\circ}\text{C}$

NOTES: 1. All voltage values are with respect to network ground terminal.  
 2. For operation above  $25^{\circ}\text{C}$  free-air temperature, refer to Dissipation Derating Curves, Section 2.

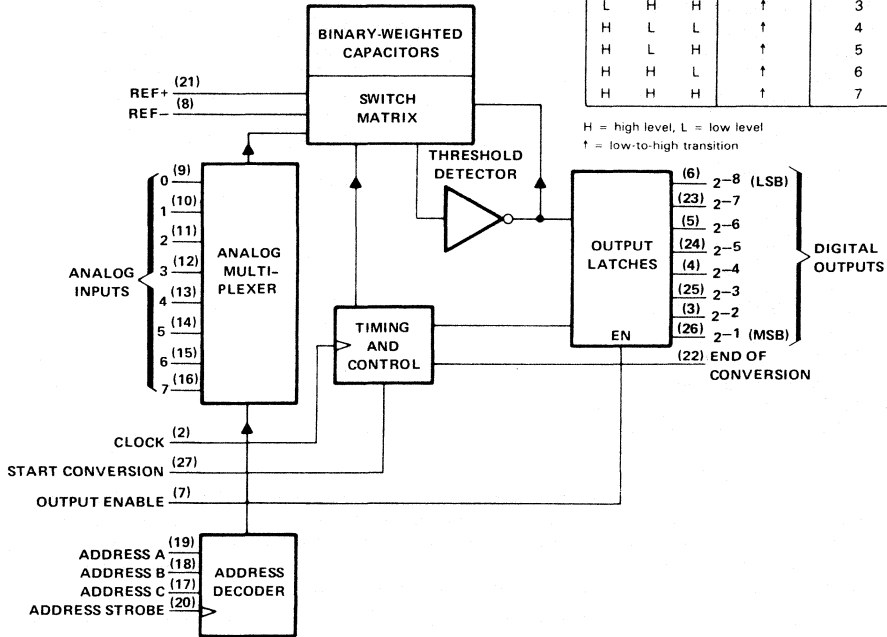
# TYPES TL520, TL521, TL522 CMOS ANALOG-TO-DIGITAL CONVERTERS WITH 8-CHANNEL MULTIPLEXERS

functional block diagram (positive logic)

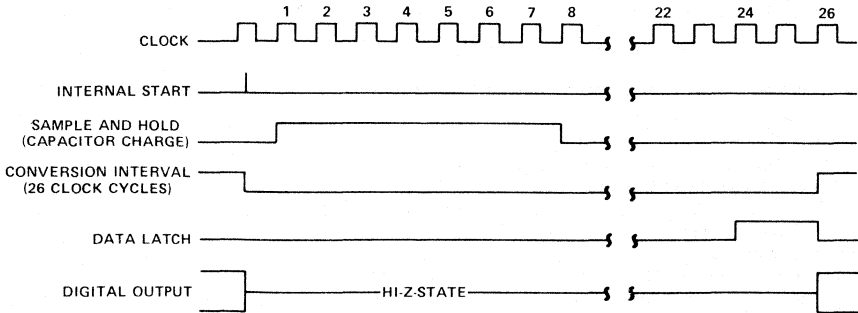
MULTIPLEXER FUNCTION TABLE

INPUTS			ADDRESS STROBE	SELECTED ANALOG CHANNEL
ADDRESS C	ADDRESS B	ADDRESS A		
L	L	L	↑	0
L	L	H	↑	1
L	H	L	↑	2
L	H	H	↑	3
H	L	L	↑	4
H	L	H	↑	5
H	H	L	↑	6
H	H	H	↑	7

H = high level, L = low level  
↑ = low-to-high transition



## internal timing sequence





# TYPES TL520, TL521, TL522 CMOS ANALOG-TO-DIGITAL CONVERTERS WITH 8-CHANNEL MULTIPLEXERS

## TL520, TL521 recommended operating conditions

	TL520			TL521				UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	MAX	
Supply voltage, $V_{CC}$	3	5	5.5	3	5	5.5		V
Positive reference voltage, $V_{REF+}$	3		$V_{CC}$	3		$V_{CC}$		V
Negative reference voltage, $V_{REF-}$	0		0.3	0		0.3		V
Supply voltage relative to $V_{REF+}$ ( $V_{CC} - V_{REF+}$ )	0		1	0		1		V
Analog input voltage (see Note 3)			$V_{REF-}$	$V_{REF+}$		$V_{REF-}$	$V_{REF+}$	V
High-level control input voltage, $V_{IH}$	$V_{CC} \geq 4.75$ V		$V_{CC} - 1.5$		$V_{CC} - 1.5$			
Low-level control input voltage, $V_{IL}$	$V_{CC} \geq 4.75$ V				1.5			V
Clock frequency, $f_{clock}$	$V_{REF+} = 5$ V		260	370	200		260	kHz
	$V_{REF+} = 3$ V		100		100			
Conversion time, $t_{conv}$	$V_{CC} = V_{REF+} = 5$ V		70		100			$\mu$ s
Duration of start pulse, $t_w(S)$			100		100			ns
Duration of address strobe pulse, $t_w(AS)$			200		200			ns
Address setup time, $t_{su}$			50		50			ns
Address hold time, $t_h$			50		50			ns
Input voltage hold time			8		8			clock periods
Operating free-air temperature, $T_A$			-40	85	-40	85		$^{\circ}$ C

## TL522 recommended operating conditions

		MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$ (see Note 4)	$T_A = 0^{\circ}$ C to $85^{\circ}$ C	2.75	3	5.5	V
	$T_A = -40^{\circ}$ C to $0^{\circ}$ C	3		5.5	
Positive reference voltage, $V_{REF+}$ (see Notes 3 and 4)		2.75		$V_{CC}$	V
Negative reference voltage, $V_{REF-}$ (see Note 3)		0		0.3	V
Supply voltage relative to $V_{REF+}$ , $V_{CC} - V_{REF+}$		0		1	V
Analog input voltage (see Note 3)		$V_{REF-}$		$V_{REF+}$	V
High-level control input voltage, $V_{IH}$		$0.7V_{CC}$			V
Low-level control input voltage, $V_{IL}$				$0.3V_{CC}$	V
Clock frequency, $f_{clock}$	$V_{REF+} = 5$ V		100	260	kHz
	$V_{REF+} = 2.75$ V (see Note 4)		100	130	
Conversion time, $t_{conv}$ (see Note 5)		200			$\mu$ s
Duration of start pulse, $t_w(S)$		600			ns
Duration of address strobe pulse, $t_w(AS)$		600			ns
Address setup time, $t_{su}$		200			ns
Address hold time, $t_h$		150			ns
Input voltage hold time		8			clock periods
Operating free-air temperature, $T_A$ (see Note 4)		-40		85	$^{\circ}$ C

NOTES: 3. Analog input voltage greater than  $V_{REF+}$  converts as all highs and less than  $V_{REF-}$  converts as all lows.

4. For proper operation of TL522 at free-air temperatures below  $0^{\circ}$ C,  $V_{CC}$  and differential reference voltage ( $V_{REF+} - V_{REF-}$ ) must never be less than 3 volts.

5. Conversion time is a function of clock frequency, with 200  $\mu$ s corresponding to a maximum clock frequency of 130 kHz.

# TYPES TL520, TL521

## CMOS ANALOG-TO-DIGITAL CONVERTERS

### WITH 8-CHANNEL MULTIPLEXERS

TL520, TL521 electrical characteristics over recommended operating free-air temperature range,  
 $V_{CC} = 4.5\text{ V to }5.25\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
$V_{OH}$	High-level output voltage	$I_O = -360\ \mu\text{A}$			V
$V_{OL}$	Low-level output voltage	$I_O = 1.6\ \text{mA}$			V
$I_{OZ}$	Off-state (high-impedance state) output current	$V_O = 5\ \text{V}$			1
		$V_O = 0$			-1
$I_{IH}$	High-level control input current	$V_I = V_{CC} + 0.3\ \text{V}$			$\mu\text{A}$
$I_{IL}$	Low-level control input current	$V_I = 0$			$\mu\text{A}$
$I_{I(op)}$	Peak analog input current (operating) (see Note 6)	$V_{CC} = V_{REF+} = 5\ \text{V}, V_I = 2.5\ \text{V}$ $f_{clock} = 200\ \text{kHz}, T_A = 25^\circ\text{C}$			$\mu\text{A}$
$I_{I(stdb)}$	Analog input current (standby) (see Note 7)	$V_{CC} = 5\ \text{V}, V_I = 5\ \text{V}$			10
		$T_A = 25^\circ\text{C}, V_I = 0$			200
		$V_{CC} = 5\ \text{V}, V_I = 5\ \text{V}$			-10
		$T_A = 85^\circ\text{C}, V_I = 0$			-200
$I_{CC}$	Supply current (see Note 8)	REF+ and REF- terminals open, $f_{clock} = 200\ \text{kHz}$			1
					-1
$I_{CC} + I_{REF+}$	Supply current plus reference current (see Note 8)	$V_{CC} = V_{REF+} = 5\ \text{V}, V_{REF-} = 0,$ $f_{clock} = 200\ \text{kHz}$			0.5
		$V_{CC} = V_{REF+} = 3\ \text{V}, V_{REF-} = 0,$ $f_{clock} = 100\ \text{kHz}$			1
					mA

<sup>†</sup>All typical characteristics are at  $V_{CC} = 5\ \text{V}$  and  $T_A = 25^\circ\text{C}$  (unless otherwise specified)

NOTES: 6.  $I_{I(op)}$  is measured on a selected channel and decays exponentially during the first clock pulse.

7.  $I_{I(stdb)}$  is measured on a selected channel with the clock input at 0 V.

8. Current increases linearly with frequency of the clock at the rate of approximately 10% per 100 kHz.

TL520, TL521 operating characteristics,  $T_A = 25^\circ\text{C}, V_{CC} = V_{REF+} = 5\ \text{V}, V_{REF-} = 0,$   
 $f_{clock} = 370\ \text{kHz}$  for TL520 and 260 kHz for TL521 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	TL520			TL521			UNIT	
		MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX		
$k_{SVS}$	Supply voltage sensitivity	$V_{CC} = V_{REF+} = 4.75\ \text{V to }5.25\ \text{V}$			0.05			%/V	
	Linearity error (see Note 9)				$\pm 0.25$			LSB	
	Origin error (see Note 9)				$\pm 0.25$			LSB	
	Total unadjusted error (see Note 9)	$T_A = 25^\circ\text{C}$			$\pm 0.25 \pm 0.5$			LSB	
		$T_A = -40^\circ\text{C to }85^\circ\text{C}$			$\pm 0.75$				
$t_{en}$	Output enable time	$C_L = 50\ \text{pF}$			100	250	100	ns	
$t_{dis}$	Output disable time	$C_L = 10\ \text{pF}, R_L = 10\ \text{k}\Omega$			100	250	100	ns	
$t_d(\text{EOC-L})$	Delay time, end-of-conversion output				0	100	0	100	ns

<sup>‡</sup>Typical values for all except supply voltage sensitivity are at  $V_{CC} = 5\ \text{V}$ .

NOTE 9: All errors are measured with reference to an ideal straight-line transfer curve from 9.8 mV to 4.99 V with  $REF+ = V_{CC}$ .

# TYPE TL522

## CMOS ANALOG-TO-DIGITAL CONVERTER WITH 8-CHANNEL MULTIPLEXER

**TL522 electrical characteristics over recommended operating free-air temperature range,  
V<sub>CC</sub> = 3 V to 5.25 V, f<sub>clock</sub> = 125 kHz (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		MIN	TYP <sup>†</sup>	MAX	UNIT	
V <sub>OH</sub>	High-level output voltage	I <sub>O</sub> = -1 μA		V <sub>CC</sub> - 0.05			V	
		V <sub>CC</sub> = 2.75 V, T <sub>A</sub> = 0°C to 85°C	I <sub>O</sub> = -0.1 mA,	2.35				
		I <sub>O</sub> = -0.36 mA, V <sub>CC</sub> = 5 V						
V <sub>OL</sub>	Low-level output voltage	I <sub>O</sub> = -1 μA		0.05			V	
		V <sub>CC</sub> = 2.75 V, T <sub>A</sub> = 0°C to 85°C	I <sub>O</sub> = 0.4 mA,	0.4				
		V <sub>CC</sub> = 5 V, I <sub>O</sub> = 1.6 mA		0.4				
I <sub>OZ</sub>	Off-state (high-impedance state) output current	V <sub>CC</sub> = 5.25 V,	V <sub>O</sub> = 5.5 V V <sub>O</sub> = 0	1		-1	μA	
I <sub>IH</sub>	High-level input current	V <sub>CC</sub> = 5.25 V,	V <sub>I</sub> = 5.5 V	1			μA	
I <sub>IL</sub>	Low-level input current	V <sub>I</sub> = 0		-1			μA	
I <sub>I(op)</sub>	Peak analog input current (operating) (see Note 6)	V <sub>CC</sub> = V <sub>REF+</sub> = 3 V, f <sub>clock</sub> = 125 kHz, T <sub>A</sub> = 25°C	V <sub>I</sub> = 1.5 V, T <sub>A</sub> = 25°C	-5		-10	μA	
I <sub>I(stdby)</sub>	Analog input current (see Note 7)	V <sub>CC</sub> = 3 V, T <sub>A</sub> = 25°C	V <sub>I</sub> = 3 V V <sub>I</sub> = 0	10		200	nA	
		V <sub>CC</sub> = 3 V, T <sub>A</sub> = 85°C	V <sub>I</sub> = 3 V V <sub>I</sub> = 0	-10		-200		
				V <sub>I</sub> = 3 V	1			μA
				V <sub>I</sub> = 0	-1			
I <sub>CC</sub>	Supply current from V <sub>CC1</sub>	REF+ and REF- terminals open		10		50	μA	
I <sub>CC</sub> + I <sub>REF</sub>	Supply current plus reference current (see Note 8)	V <sub>CC</sub> = V <sub>REF+</sub> = 5 V, V <sub>REF-</sub> = 0, f <sub>clock</sub> = 200 kHz		0.5			mA	
		V <sub>CC</sub> = V <sub>REF+</sub> = 3 V, V <sub>REF-</sub> = 0, f <sub>clock</sub> = 125 kHz		0.1		0.2		
C <sub>i</sub>	Input capacitance			10			pF	
C <sub>o</sub>	Output capacitance			10			pF	

NOTES: 6. I<sub>I(op)</sub> is measured on a selected channel and decays exponentially during the first clock pulse.

7. I<sub>I(stdby)</sub> is measured on a selected channel with the clock input at 0 V.

8. Current increases linearly with frequency of the clock at the rate of approximately 10% per 100 kHz.

**TL522 operating characteristics, T<sub>A</sub> = 25°C, V<sub>REF+</sub> = 3 V to 5.5 V, V<sub>REF-</sub> = 0, f<sub>clock</sub> = 130 kHz (unless otherwise noted)**

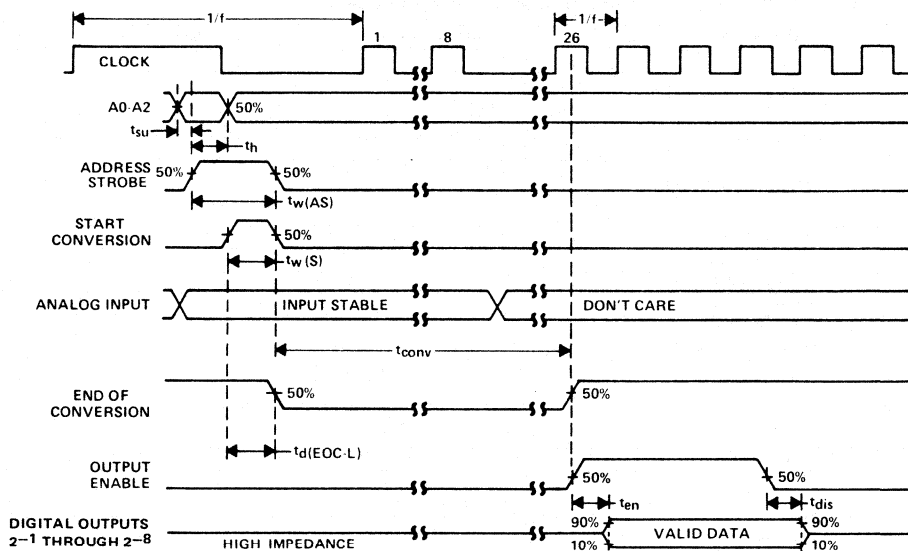
PARAMETER		TEST CONDITIONS		MIN	TYP <sup>†</sup>	MAX	UNIT
k <sub>SVS</sub>	Supply voltage sensitivity			0.05			%/V
Linearity error (see Note 9)				±0.25			LSB
Origin error (see Note 9)				±0.25			LSB
Total unadjusted error (see Note 9)		V <sub>CC</sub> = 2.75 V, T <sub>A</sub> = 0°C to 70°C		±0.25		±0.5	LSB
		T <sub>A</sub> = -40°C to 85°C		±0.25		±0.5	
t <sub>en</sub>	Output enable time	C <sub>L</sub> = 50 pF, R <sub>L</sub> = 10 kΩ		0.7		1	μs
t <sub>dis</sub>	Output disable time	C <sub>L</sub> = 10 pF, R <sub>L</sub> = 10 kΩ		0.6		0.8	μs
t <sub>d(EOC-L)</sub>	Delay time, end-of-conversion output			0		100	ns

<sup>†</sup>All typical values are at V<sub>CC</sub> = 3 V, T<sub>A</sub> = 25°C (unless otherwise noted)

NOTE 9: All errors are measured with reference to an ideal straight-line transfer curve from 9.8 mV to 4.99 V with REF+ = V<sub>CC</sub>.

**TYPES TL520, TL521, TL522**  
**CMOS ANALOG-TO-DIGITAL CONVERTERS**  
**WITH 8-CHANNEL MULTIPLEXERS**

timing diagram



**PRINCIPLES OF OPERATION**

**timing diagram**

The analog multiplexer selects 1 of 8 single-ended input channels as determined by the input address code. The address strobe transfers and latches the address into the decoder on the positive-going edge of the signal. The output latch is reset by the positive-going edge of the start pulse. Sampling also starts with the positive-going edge of the start pulse and lasts for 8 clock periods. The conversion process may be interrupted by a new start pulse before the end of 24 clock periods. The previous data will be lost if a new start of conversion occurs before the 24th clock pulse. Continuous conversion may be accomplished by connecting the end-of-conversion output to the start input. If used in this mode an external pulse should be applied after power up to assure start up.

**converter**

The CMOS threshold detector in the successive-approximation conversion system determines each bit by examining the charge on a series of binary-weighted capacitors (Figure 1). In the first phase of the conversion process, the analog input is sampled by closing switch  $S_C$  and all  $S_T$  switches, and by simultaneously charging all the capacitors to the input voltage.

In the next phase of the conversion process, all  $S_T$  and  $S_C$  switches are opened and the threshold detector begins identifying bits by identifying the charge (voltage) on each capacitor relative to the reference voltage. In the switching sequence, all eight capacitors are examined separately until all 8 bits are identified, and then the charge-convert sequence is repeated. In the first step of the conversion phase, the threshold detector looks at the first capacitor (weight = 128). Node 128 of this capacitor is switched to the reference voltage, and the equivalent nodes of all the other capacitors on the ladder are switched to REF-. If the voltage at the summing node is greater than the trip-point of the threshold detector (approximately one-half the reference voltage), a bit is placed in the output register, and the 128-weight capacitor is switched to REF-. If the voltage at the summing node is less than the trip point of the threshold detector, this 128-weight capacitor remains connected to REF+ through the remainder of the capacitor-sampling (bit-counting) process. The process is repeated for the 64-weight capacitor, the 32-weight capacitor, and so forth down the line, until all bits are counted.

With each step of the capacitor-sampling process, the initial charge is redistributed among the capacitors. The conversion process is successive approximation, but relies on charge shifting rather than a successive-approximation register (and reference D/A) to count and weigh the bits from MSB to LSB.

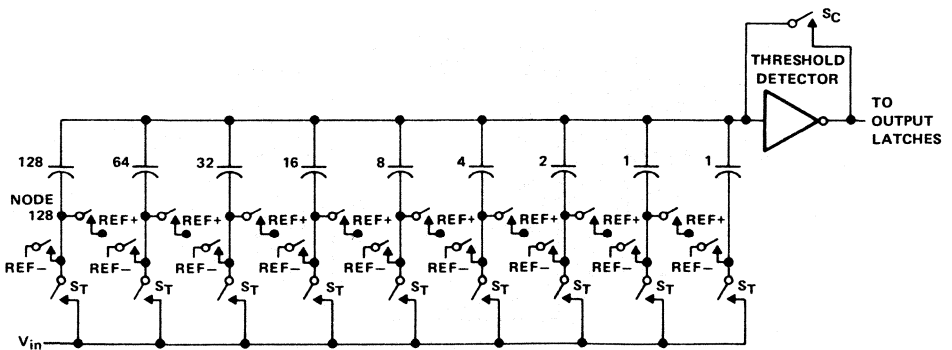


FIGURE 1—SIMPLIFIED MODEL OF THE SUCCESSIVE-APPROXIMATION SYSTEM

# TYPES TL520, TL521, TL522 CMOS ANALOG-TO-DIGITAL CONVERTERS WITH 8-CHANNEL MULTIPLEXERS

## TYPICAL APPLICATION INFORMATION

The TL520, TL521, and TL522 are CMOS devices using charge redistribution to achieve A/D conversion. In typical applications as a ratiometric conversion system for a microprocessor, REF - will be connected to ground and REF + will be connected to V<sub>CC</sub>. The output will then be a simple proportional ratio between the analog input voltage and V<sub>CC</sub> (Figure 3). The general relationship is

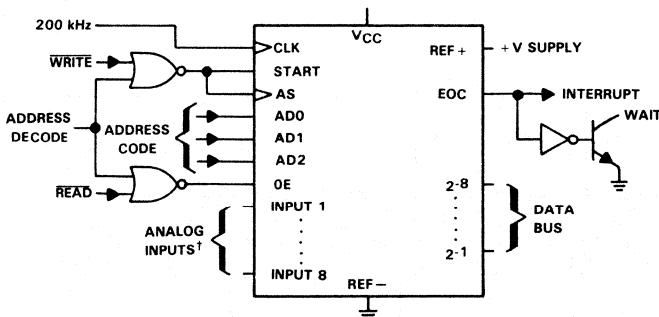
$$\frac{D_{out}}{2^8} = \frac{V_{in}}{V_{REF+} - V_{REF-}}$$

where  $D_{out}$  = decimal value of binary output word  
 $V_{in}$  = analog input voltage  
 $V_{REF+}$  = positive reference voltage = V<sub>CC</sub>  
 $V_{REF-}$  = negative reference voltage = V<sub>GND</sub>

Latchup may overheat and destroy the device and may occur by either of two kinds of circumstances: out of range reference voltages or by incorrect power-up sequence. V<sub>REF+</sub> should not be more positive than V<sub>CC</sub> by more than 300 millivolts or V<sub>REF-</sub> should not be more negative than GND by more than 300 millivolts. Apply V<sub>CC</sub> before either of the reference voltages. The advantage of the compressed reference potential is that the full 8-bit resolution applies to be compressed voltage range (Figure 4). However, the cautions mentioned above must be observed. Operation at voltages down to V<sub>CC</sub> = 3 volts is possible but limits the frequency to 100 kilohertz maximum and thus conversion time to 260 microseconds minimum. Interface for the common microprocessors is shown in Figure 2.

MICROPROCESSOR INTERFACE TABLE

PROCESSOR	READ	WRITE	INTERRUPT (COMMENT)
TMS7000	RD	WR	EINT
TMS9900	MEMEN	WE	INTREQ
8080	MEMR	MEMW	INTR (Thru RST Circuit)
8085	RD	WR	INTR (Thru RST Circuit)
Z-80	RD	WR	INT (Thru RST Circuit, Mode 0)
SC/MP	NRDS	NWDS	SA (Thru Sense A)
6800	VMA + 2 R/W	VMA + 2 R/W	IRQA or IRQB (Thru PIA)



† The full-scale value of the analog input voltage can be shifted between 3 volts and 6.5 volts by varying V<sub>REF-</sub> and V<sub>CC</sub>, but only 5 volts guarantees TTL compatibility.

FIGURE 2 — TYPICAL MICROPROCESSOR APPLICATION

# TYPES TL520, TL521, TL522 CMOS ANALOG-TO-DIGITAL CONVERTERS WITH 8-CHANNEL MULTIPLEXERS

## TYPICAL APPLICATION INFORMATION

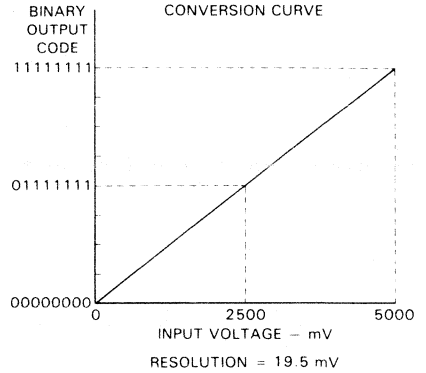
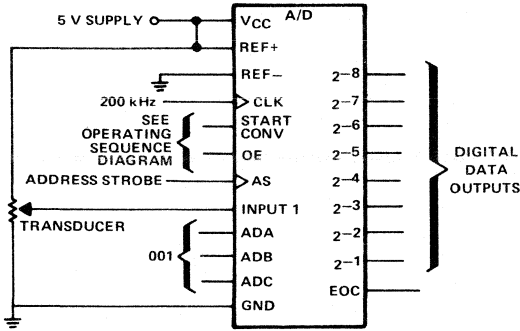
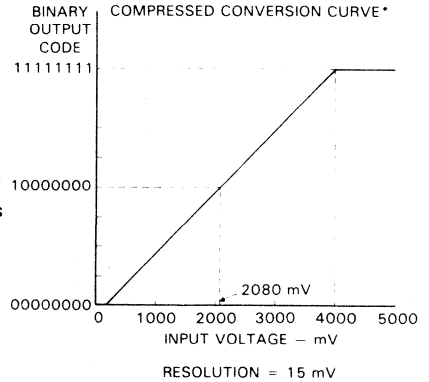
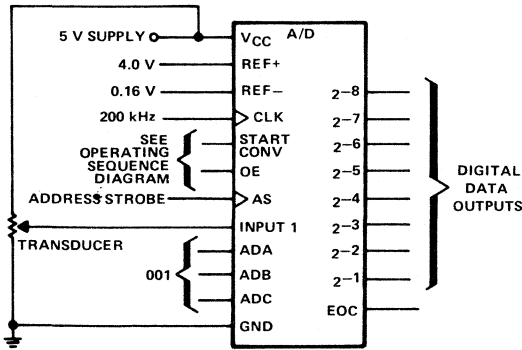


FIGURE 3 — RATIOMETRIC SYSTEM



NOTE: Input voltage below  $V_{REF-}$  converts as all zeros  
Input voltage above  $V_{REF+}$  converts as all ones

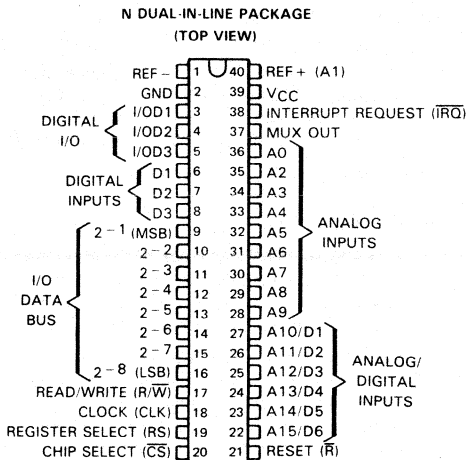
\*Equivalent to 9-bit resolution over a 5-V range

FIGURE 4—COMPRESSED RATIOMETRIC SYSTEM





- 8-Bit Resolution
- Total Unadjusted Error . . .  $\pm 0.5$  LSB Max for TL530 and  $\pm 1$  LSB Max for TL531
- Ratiometric Conversion
- Conversion Time (Including Access Time) . . . 300  $\mu$ s (290 Clock Cycles)
- 3-State, Bidirectional I/O Data Bus
- Up to 12 Digital Inputs Including 3 I/O Pins
- 10 Analog and 6 Multipurpose Analog or Digital Inputs
- On-Chip 16-Channel Analog Multiplexer
- Three On-Chip 16-Bit Data Registers
- Polled or Interrupt Driven
- Single 5-V Supply Operation
- Low Power Consumption . . . 15 mW Typ
- Pin-for-Pin Compatible Functional Replacements for Motorola MC14444 and National Semiconductor ADC0830



**description**

The TL530 and TL531 are monolithic CMOS peripheral integrated circuits each designed to interface a microprocessor for analog data acquisition. These devices are complete peripheral data acquisition systems on a single chip and can convert analog signals to digital data from up to 15 external analog terminals. Each device features operation from a single 5-volt supply and additional digital input/output capabilities. Each contains a 16-channel analog multiplexer, an 8-bit ratiometric analog-to-digital (A/D) converter, three 16-bit registers, and microprocessor-compatible control logic circuitry. Additional features include a built-in self-test, six multipurpose (analog or digital) inputs, nine external analog inputs, and an 8-pin input/output (I/O) data port. The three on-chip data registers store the control data, the conversion results, and the input digital data that can be accessed via the microprocessor data bus in two 8-bit bytes (most-significant byte first). In this manner, a microprocessor can access up to 15 external analog inputs or 6 digital signals and the positive reference voltage that may be used for self-test.

**FUNCTION TABLE**

ADDRESS/CONTROL					DESCRIPTION
R/W	RS	CS	R	CLK	
X	X	X	L <sup>†</sup>		Reset
L	H	L	H	↓	Write bus data to control register
H	L	L	H	↑	Read data from analog conversion register
H	H	L	H	↑	Read data from digital data register
X	X	H	H	X	No response

H = High-level, L = Low-level, X = Irrelevant.  
 ↓ = High-to-low transition, ↑ = Low-to-high transition  
<sup>†</sup>For proper operation, Reset must be low for at least three clock cycles.

# TYPES TL530, TL531

## CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY

---

### description (continued)

The A/D conversion uses the successive-approximation technique employing a high-impedance chopper-stabilized comparator, a 256R end-compensated voltage divider with analog switch tree, and a successive-approximation register (SAR). This method eliminates the possibility of missing codes, nonmonotonicity, and a need for zero or full-scale adjustment. Positive and negative reference voltage inputs make possible ratiometric conversion and reference isolation from supply noises.

The TL530I and TL531I are characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

### functional description

The TL530 and TL531 provide direct interface to a microprocessor-based system. Control of the TL530 and TL531 is handled via the 8-line TTL-compatible 3-state data bus, the three control inputs (Read/Write, Register Select, and Chip Select), and the Clock input. Each device contains three 16-bit internal registers. These registers are the control register, the analog conversion data register, and the digital data register.

A high level at the Read/Write input and a low level at the Chip Select input set the device to output data on the 8-line data bus for the processor to read. A low level at the Read/Write input and a low level at the Chip Select input set the device to receive instructions into the internal control register on the 8-line data bus from the processor. When the device is in the read mode and the Register Select input is low, the processor will read the data contained in the analog conversion data register. However, when the Register Select input is high, the processor reads the data contained in the digital data register.

The control register is a write-only register into which the microprocessor writes command instructions for the device to start A/D conversion and to select the analog channel to be converted, to select the output logic levels and the direction (input or output) of the 3-bit digital I/O port, and to set interrupt enable for the Interrupt Request output. The analog conversion data register is a read-only register that contains the current converter status and most recent conversion results. The digital data register is also a read-only register that holds the 3-bit I/O port status and digital input logic levels from the six multipurpose and the three digital inputs.

Internally each device contains a byte pointer that selects the appropriate byte during two cycles of the Clock input in a normal 16-bit microprocessor instruction. The internal pointer will automatically point to the most-significant (MS) byte after the first complete clock cycle any time that the Chip Select is at the high level for at least one clock cycle. This causes the device to treat the next signal on the 8-line data bus as the MS byte. A low level at the Chip Select input activates the inputs and outputs and an internal function decoder. However, no data is transferred until the Clock goes high. The internal byte pointer first points to the MS byte of the selected register during the first clock cycle. After the first clock cycle in which the MS byte is accessed, the internal pointer switches to the LS byte and remains there for as long as Chip Select is low. The MS byte of any register may be accessed by either an 8-bit or a 16-bit microprocessor instruction; however, the LS byte may only be accessed by a 16-bit microprocessor instruction.

Normally, a two-byte word is written into or read from the controlling processor, but a single byte can be read by the processor by proper manipulation of the Chip Select input. This can be used to read conversion status from the analog conversion data register or the digital multipurpose input levels from the digital data register. The format and content of each two-byte word is shown in Figures 1 through 3.

A conversion cycle is started after a two-byte instruction is written into the control register and the start conversion (SC) bit is a logic high. This two-byte instruction also selects the input analog channel, configures the 3-bit digital I/O pins, and sets the interrupt enable bit. The status (EOC) bit in the analog conversion data register is reset and remains reset until the conversion is completed, at that time the status bit is then set again. After conversion, the results are loaded into the analog conversion data register. These results remain in the analog conversion data register until the next conversion cycle is completed. If the interrupt enable bit is set to a logic high level in the control register, the Interrupt Request (IRQ) output

# TYPES TL530, TL531

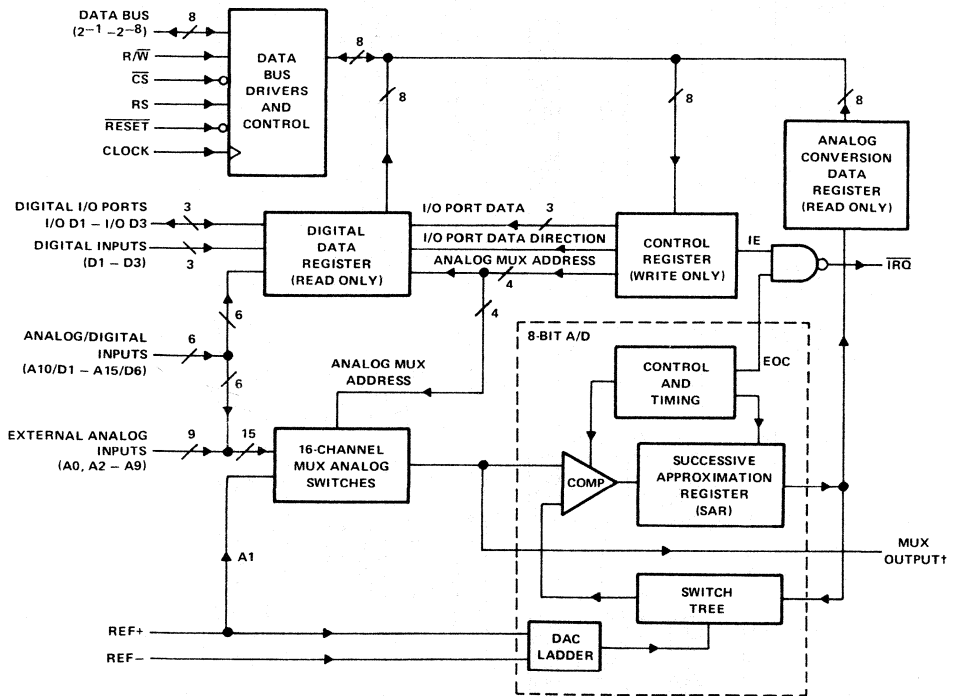
## CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY

### functional description (continued)

will go low after the next conversion cycle is completed. If a new conversion command is entered into the control register while the conversion cycle is in progress, the on-going conversion will be aborted and a new channel acquisition cycle will immediately begin.

The Reset input allows the device to be externally forced to a known state. When a low level is applied to the Reset input for a minimum of three clock periods, the start conversion, interrupt enable, and the I/O port data direction bits of the control register are cleared. The A/D converter is then idled and all the outputs including the 3-bit I/O digital port are placed in the high-impedance off-state. However, the content of the analog conversion data register is not affected by the Reset input going to a low level.

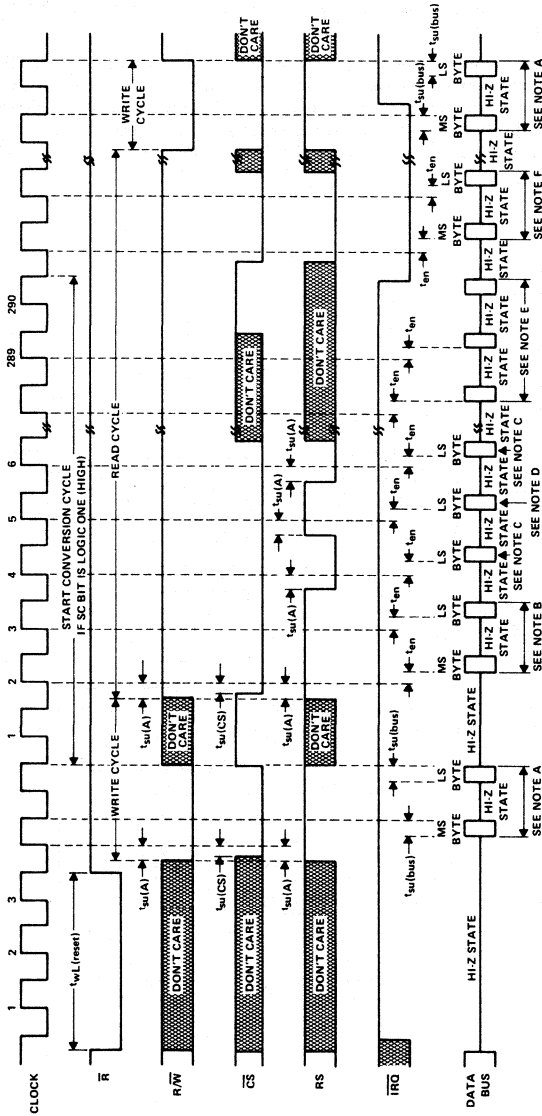
### functional block diagram



† Loading of the MUX output affects the changing times of the DAC; it is recommended that no connection be made to this pin.

**TYPES TL530, TL531**  
**CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH**  
**ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY**

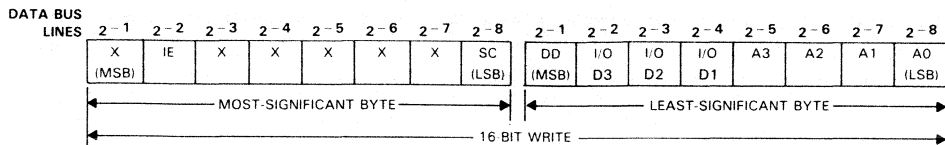
**typical operating sequence**



- NOTES: A. This is a 16-bit input instruction from the microprocessor being sent to the control data register.  
 B. This is the 2-byte (16-bit) content of the digital data register being sent to the microprocessor.  
 C. This is the LS byte (8-bit) content of the analog conversion data register being sent to the microprocessor.  
 D. This is the MS byte (8-bit) content of the digital data register being sent to the microprocessor.  
 E. These are 8-bit or 16-bit output data from either the analog conversion data register or the digital data register being sent to the microprocessor.  
 F. This is the 2-byte (16-bit) content of the analog conversion data register being sent to the microprocessor.

# TYPES TL530, TL531

## CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY



**Interrupt Enable (IE)** – The interrupt enable bit, when set to a logical 1 (high level), allows the  $\overline{IRQ}$  pin to be activated at the completion of the next analog-to-digital conversion.

**Unused Bits (X)** – The MS byte bits 2<sup>-1</sup> through 2<sup>-7</sup> and LS byte bits 2<sup>-1</sup> through 2<sup>-4</sup> of the control register are not used internally.

**Start Conversion (SC)** – When the SC bit in the MS byte is set to a logical 1 (high level), analog-to-digital conversion on the specified analog channel will begin immediately after the completion of the control register write.

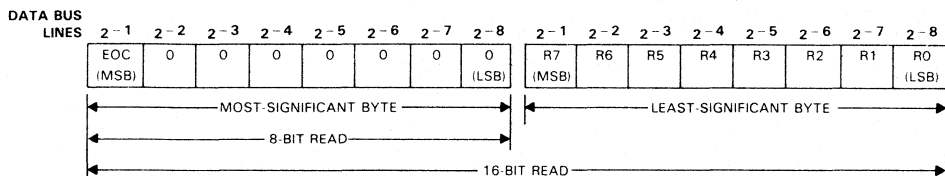
**I/O Port Data Direction (DD)** – The MSB of the LS byte is the data direction bit for the 3-bit I/O port. A logical 1 configures the port as the output while a logical 0 configures the port as an input.

**Digital I/O Output (I/OD1-I/OD3)** – When the microprocessor configures the 3-bit I/O port as an output, these are the bit locations into which the output states are written. A logical 1 written by the microprocessor will cause the output to be high, while a logical 0 will cause the output to be low.

**Analog Multiplex Address (A0-A3)** – These four address bits are decoded by the analog multiplexer and used to select the appropriate analog channel as shown below:

Hexadecimal Address (A3 = MSB)	Channel Select
0	A0
1	REF + (A1)
2-9	A2-A9
A-F	A10-A15

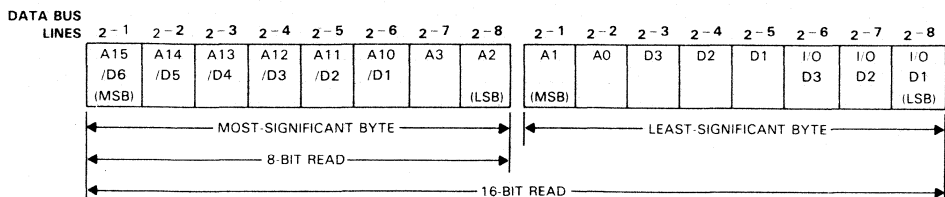
**FIGURE 1—CONTROL REGISTER TWO-BYTE WRITE WORD FORMAT AND CONTENT**



**A/D Status (EOC)** – The A/D status-end-of-conversion (EOC) bit is set whenever an analog-to-digital conversion is successfully completed by the A/D converter. The status bit is cleared by a 16-bit write from the microprocessor to the control register. The remainder of the bits in the MS byte of the analog conversion data are always reset to logical 0 to simplify microprocessor interrogation of the A/D converter status.

**A/D Result (R0-R7)** – The LS byte of the analog conversion data register contains the result of the analog-to-digital conversion. Result bit R7 is the MSB and the converter follows the standard convention of assigning a code of all ones (11111111) to a full-scale analog voltage. There are no special overflow or underflow indications.

**FIGURE 2—ANALOG CONVERSION DATA REGISTER ONE-BYTE OR TWO-BYTE READ WORD FORMAT AND CONTENT**



**Shared Digital Port (A10/D1-A15/D6)** – The voltage present on these pins is interpreted as a digital signal and the corresponding states are read from these bits. A digital value will be given for each pin even if some or all of these pins are being used as analog inputs.

**Analog Multiplexer Address (A0-A3)** – The address of the selected analog channel presently addressed is given by these bits.

**Digital Inputs (D1-D3)** – The states of the three digital inputs are read from these bits.

**Digital I/O Port (I/OD1-I/OD3)** – The states of the three digital I/O pins are read from these bits regardless of whether the port is configured as input or output.

**FIGURE 3—DIGITAL DATA REGISTER ONE-BYTE AND TWO-BYTE READ WORD FORMAT AND CONTENT**

# TYPES TL530, TL531

## CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	-0.3 V to 6.5 V
Input voltage range: Positive reference voltage	$V_{REF+}$ to $V_{CC} + 0.3$ V
Negative reference voltage	-0.3 V to $V_{REF+}$
All other inputs	-0.3 V to $V_{CC} + 0.3$ V
Input current, $I_I$ (any input)	$\pm 10$ mA
Total input current (all inputs)	$\pm 20$ mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	1250 mW
Storage temperature range	-65°C to 150°C
Operating free-air temperature range	-40°C to 85°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

- NOTES: 1. All voltage values are with respect to network ground terminal.  
2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2.

### recommended operating conditions

	TL530			TL531			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{CC}$	4.75	5	5.5	4.75	5	5.5	V
Positive reference voltage, $V_{REF+}$ (see Note 3)	4.6	$V_{CC}$		4.6	$V_{CC}$		V
Negative reference voltage, $V_{REF-}$ (see Note 3)	0		0.1	0		0.1	V
Average voltage across ladder	$V_{CC}-0.2$	$V_{CC}$	$V_{CC}+0.2$	$V_{CC}-0.2$	$V_{CC}$	$V_{CC}+0.2$	V
High-level input voltage, $V_{IH}$	Clock input		$V_{CC}-0.8$	$V_{CC}-0.8$			V
	All other digital inputs		2	2			
Low-level input voltage, $V_{IL}$	Any digital input		0.8			0.8	V
	Clock frequency, $f_{CLK}$		0.1	1.048	0.1	1.048	
Clock period, $1/f_{CLK}$	943		943				ns
$\overline{CS}$ setup time, $t_{su}(CS)$	100		100				ns
Address (R/W and RS) setup time, $t_{su}(A)$	145		145				ns
Data bus input setup time, $t_{su}(bus)$	185		185				ns
Control (R/W, RS, and $\overline{CS}$ ) hold time, $t_h(C)$	20		20				ns
Data bus input hold time, $t_h(bus)$	20		25				ns
Pulse duration of control inputs during read cycle, $t_w(C)$	575		575				ns
Pulse duration, reset low, $t_{wL}(reset)$	3		3				Clock Cycles
Pulse duration of clock high, $t_{wH}(CLK)$	440		440				ns
Pulse duration of clock low, $t_{wL}(CLK)$	410		410				ns
Clock rise time, $t_r(CLK)$			25			25	ns
Clock fall time, $t_f(CLK)$			30			30	ns
Operating free-air temperature, $T_A$	-40		85	-40		85	°C

NOTE 3: Analog input voltages greater than or equal to that applied to the  $REF+$  terminal convert to all ones (11111111), while input voltages equal to or less than that applied to the  $REF-$  terminal convert to all zeros (00000000).

# TYPE TL530

## CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERAL WITH ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY

electrical characteristics over recommended ranges of  $V_{CC}$ ,  $V_{REF+}$ , and operating free-air temperature,  $V_{REF-} = 0$ ,  $f_{CLK} = 1.048$  MHz (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT	
$V_{OH}$	High-level output voltage	I/O Digital pins 3, 4, and 5	$I_{OH} = -190 \mu A$	$V_{CC} - 0.4$		V	
		I/O Data Bus	$I_{OH} = -1.6$ mA	2.4			
$V_{OL}$	Low-level output voltage	I/O Digital pins 3, 4, and 5	$I_{OL} = 975 \mu A$		0.4	V	
		$\overline{IRQ}$ and I/O Data Bus	$I_{OL} = 1.6$ mA		0.4		
$I_{IH}$	High-level input current	Any control input	$V_{IH} = 5.5$ V		1	$\mu A$	
		Any other digital input			10		
$I_{IL}$	Low-level input current	Any control input	$V_{IL} = 0$		-1	$\mu A$	
		Any other digital input			-10		
$I_{OH}$	High-level output current	$\overline{IRQ}$ output	$V_{OH} = V_{CC} = 4.75$ V		10	$\mu A$	
$I_{OZ}$	Off-state (high-impedance-state) output current		$V_O = V_{CC}$		10	$\mu A$	
			$V_O = 0$		-10		
$I_I$	Analog input current (see Note 4)		$V_I = 0$ to $V_{CC}$		$\pm 500$	nA	
	Leakage current between selected channel and all other analog channels		$V_I = 0$ to $V_{CC}$ , Clock input at 0 V		$\pm 400$	nA	
$r_{i(on)}$	Analog channel input on-state resistance				5	k $\Omega$	
	Ladder resistance ( $REF+$ to $REF-$ )			1	5	10	k $\Omega$
$C_i$	Input capacitance	Digital pins 9 thru 16			7	30	pF
		Any other input pin			5	15	
$I_{CC+I_{REF+}}$	Supply current plus reference current		$V_{CC} = V_{REF+} = 5.5$ V, Outputs open		3	16	mA
$I_{CC}$	Supply current		$V_{CC} = 5.5$ V		2	10	mA

<sup>†</sup>Typical values are at  $V_{CC} = 5$  V,  $T_A = 25^\circ C$ .

NOTE 4: Analog input current is an average of the current flowing into a selected analog channel input during one full conversion cycle.

# TYPE TL530

## CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERAL WITH ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY

operating characteristics over recommended ranges of  $V_{CC}$ ,  $V_{REF+}$ , and operating free-air temperature,  $V_{REF-}$  at ground,  $f_{CLK} = 1.048$  MHz (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>1</sup>	MAX	UNIT
Linearity error		See Note 5			± 0.5	LSB
Zero error		See Note 6			± 0.5	LSB
Full-scale error		See Note 6			± 0.5	LSB
Total unadjusted error		See Note 7			± 0.5	LSB
Absolute accuracy error		See Note 8			± 1	LSB
$t_{conv}$	Conversion time (including channel acquisition time)				290	Clock Cycles
$t_{acq}$	Channel acquisition time				30	Clock Cycles
$t_{en}$	Data output enable time (see Note 9)	$R_L = 3$ k $\Omega$ , $C_L = 50$ pF,			335	ns
$t_{dis}$	Data output disable time	$R_L = 3$ k $\Omega$ , $C_L = 50$ pF	10			ns
$t_{r(bus)}$	Data bus output rise time	High-impedance to high-level	$R_L = 3$ k $\Omega$ , $C_L = 50$ pF		150	ns
		Low to high-level			300	
$t_{r(I/O)}$	Digital I/O output rise time	High-impedance to high-level			0.5	$\mu$ s
		Low to high-level			1	
$t_{f(bus)}$	Data bus output fall time	High-impedance to low-level	$R_L = 3$ k $\Omega$ , $C_L = 50$ pF		150	ns
		High to low-level			300	
$t_{f(I/O)}$	Digital I/O output fall time	High-impedance to low-level			0.5	$\mu$ s
		High to low-level			1	
$t_{f(IRQ)}$	IRQ output fall time	High-impedance or high-level to low-level			0.5	$\mu$ s

<sup>1</sup>Typical values are at  $V_{CC} = 5$  V,  $T_A = 25^\circ$ C.

NOTES: 5. Linearity error is the deviation from the best straight line through the A/D transfer characteristics.

6. Zero error is the difference between the output of an ideal and an actual A/D for zero input voltage; full-scale error is that same difference for full-scale input voltage.

7. Total unadjusted error is the sum of linearity, zero, and full-scale errors.

8. Absolute accuracy error is the maximum difference between an analog value and the nominal midstep value within any step. This includes all errors including inherent quantization error, which is the  $\pm 0.5$  LSB uncertainty caused by the A/D converters finite resolution.

9. If chip-select setup time,  $t_{su}(CS)$ , is less than 0.14 microseconds, the effective data output enable time,  $t_{en}$ , may extend such that  $t_{su}(CS) + t_{en}$  is equal to a maximum of 0.475 microseconds.



# TYPE TL531

## CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERAL WITH ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY

electrical characteristics over recommended ranges of  $V_{CC}$ ,  $V_{REF+}$ , and operating free-air temperature,  $V_{REF-} = 0$ ,  $f_{CLK} = 1.048$  MHz (unless otherwise noted)

PARAMETER			TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT	
$V_{OH}$	High-level output voltage	I/O Digital pins 3, 4, and 5	$I_{OH} = -190 \text{ A}$	$V_{CC} - 0.4$			V	
		I/O Data Bus	$I_{OH} = -1.6 \text{ mA}$	2.4				
$V_{OL}$	Low-level output voltage	I/O Digital pins 3, 4, and 5	$I_{OL} = 975 \text{ } \mu\text{A}$			0.4	V	
		$\overline{IRQ}$ and I/O Data Bus	$I_{OL} = 1.6 \text{ mA}$			0.4		
$I_{IH}$	High-level input current	Any control input	$V_{IH} = 5.5 \text{ V}$			1	$\mu\text{A}$	
		Any other digital input				10		
$I_{IL}$	Low-level input current	Any control input	$V_{IL} = 0$			-1	$\mu\text{A}$	
		Any other digital input				-10		
$I_{OH}$	High-level output current	$\overline{IRQ}$ output	$V_{OH} = V_{CC} = 4.75 \text{ V}$			10	$\mu\text{A}$	
$I_{OZ}$	Off-state (high-impedance-state) output current		$V_O = V_{CC}$			10	$\mu\text{A}$	
			$V_O = 0$			-10		
$I_I$	Analog input current (see Note 4)		$V_I = 0$ to $V_{CC}$			$\pm 700$	nA	
	Leakage current between selected channel and all other analog channels		$V_I = 0$ to $V_{CC}$ , Clock input at 0 V			$\pm 500$	nA	
$r_{i(on)}$	Analog channel input on-state resistance					5	k $\Omega$	
	Ladder resistance ( $REF+$ to $REF-$ )					1	5 10	k $\Omega$
$C_i$	Input capacitance	Digital pins 9 thru 16				7	30	pF
		Any other input pins				5	15	
$I_{CC} + I_{REF+}$	Supply current plus reference current		$V_{CC} = V_{REF+} = 5.5 \text{ V}$ , Outputs open			3	16	mA
$I_{CC}$	Supply current		$V_{CC} = 5.5 \text{ V}$			2	10	mA

<sup>†</sup>Typical values are at  $V_{CC} = 5 \text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

NOTE 4: Analog input current is an average of the current flowing into a selected analog channel input during one full conversion cycle.

# TYPE TL531

## CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERAL WITH ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY

operating characteristics over recommended operating free-air temperature range,  $V_{REF+} = V_{CC}$ ,  $V_{REF-}$  at ground,  $f_{CLK} = 2$  MHz (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
Linearity error		See Note 5		± 0.5		LSB
Zero error		See Note 6		± 0.25		LSB
Full-scale error		See Note 6		± 0.25		LSB
Total unadjusted error		See Note 7	$T_A = 25^\circ\text{C}$		± 0.5	LSB
			$T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$		± 1	
Absolute accuracy error		See Note 8			± 1.5	LSB
$t_{conv}$	Conversion time (including channel acquisition time)				290	Clock Cycles
$t_{acq}$	Channel acquisition time				30	Clock Cycles
$t_{en}$	Data output enable time (see Note 9)	$R_L = 3\text{ k}\Omega$ , $C_L = 50\text{ pF}$			335	ns
$t_{dis}$	Data output disable time	$R_L = 3\text{ k}\Omega$ , $C_L = 50\text{ pF}$	10			ns
$t_{r(\text{bus})}$	Data bus output rise time	High-impedance to high-level	$R_L = 3\text{ k}\Omega$ , $C_L = 50\text{ pF}$		150	ns
		Low to high-level			300	
$t_{r(I/O)}$	Digital I/O output rise time	High-impedance to high-level			0.5	$\mu\text{s}$
		Low to high-level			1	
$t_{f(\text{bus})}$	Data bus output fall time	High-impedance to low-level	$R_L = 3\text{ k}\Omega$ , $C_L = 50\text{ pF}$		150	ns
		High to low-level			300	
$t_{f(I/O)}$	Digital I/O output fall time	High-impedance to low-level			0.5	$\mu\text{s}$
		High to low-level			1	
$t_{f(\text{IRQ})}$	IRQ output fall time	High-impedance or high-level to low-level			0.5	$\mu\text{s}$

- NOTES: 5. Linearity error is the deviation from the best straight line through the A/D transfer characteristics.  
6. Zero error is the difference between the output of an ideal and an actual A/D for zero input voltage; full-scale error is that same difference for full-scale input voltage.  
7. Total unadjusted error is the sum of linearity, zero, and full-scale errors.  
8. Absolute accuracy error is the maximum difference between an analog value and the nominal midstep value within any step. This includes all errors including inherent quantization error, which is the  $\pm 0.5$  LSB uncertainty caused by the A/D converters finite resolution.  
9. If chip-select setup time,  $t_{su}(\text{CS})$ , is less than 0.14 microseconds, the effective data output enable time,  $t_{en}$ , may extend such that  $t_{su}(\text{CS}) + t_{en}$  is equal to a maximum of 0.475 microseconds.

- 8-Bit Resolution
- Total Unadjusted Error . . .  $\pm 0.5$  LSB Max for TL532 and  $\pm 1$  LSB Max for TL533
- Access Plus Conversion Time . . . 300  $\mu$ s (290 Clock Cycles)
- Ratiometric Conversion
- 3-State, Bidirectional I/O Data Bus
- 5 Analog and 6 Multipurpose Inputs
- On-Chip 12-Channel Analog Multiplexer
- Three On-Chip 16-Bit Data Registers
- Software Compatible with Larger TL530 and TL531 (21-Input Versions)
- Single 5-V Supply Operation
- Low Power Consumption . . . 15 mW Typ
- Pin-for-Pin Compatible and Functionally Compatible with Motorola MC14442
- Direct Replacement for National Semiconductor ADC0829

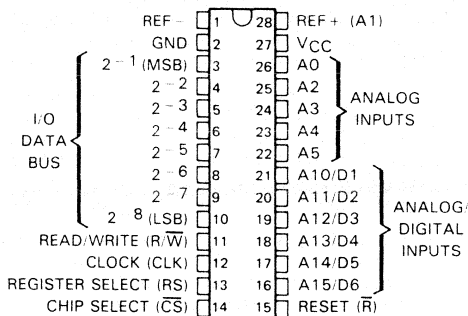
**description**

The TL532 and TL533 are monolithic CMOS peripheral integrated circuits each designed to interface a microprocessor for analog data acquisition. These devices are complete peripheral data acquisition systems on a single chip that can convert analog signals to digital data from up to 11 external analog terminals. Each device features operation from a single 5-volt supply. Each contains a 12-channel analog multiplexer, an 8-bit ratiometric analog-to-digital (A/D) converter, three 16-bit registers, and microprocessor-compatible control logic circuitry. Additional features include a built-in self-test, six multipurpose (analog or digital) inputs, five external analog inputs, and an 8-pin input/output (I/O) data port. The three on-chip data registers store the control data, the conversion results, and the input digital data that can be accessed via the microprocessor data bus in two 8-bit bytes (most-significant byte first). In this manner, a microprocessor can access up to 11 external analog inputs or 6 digital signals and the positive reference voltage that may be used for self-test.

The A/D conversion uses the successive-approximation technique employing a high-impedance chopper-stabilized comparator, a 256R end-compensated voltage divider with analog switch tree, and a successive-approximation register (SAR). This method eliminates the possibility of missing codes, nonmonotonicity, and a need for zero or full-scale adjustment. Positive and negative reference voltage inputs make possible ratiometric conversion and reference isolation from supply noises.

The TL532I and TL533I are characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

**N DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



**FUNCTION TABLE**

ADDRESS/CONTROL					DESCRIPTION
R/W	RS	CS	R	CLK	
X	X	X	X	L <sup>†</sup>	Reset
L	H	L	H	↓	Write bus data to control register
H	L	L	H	↑	Read data from analog conversion register
H	H	L	H	↑	Read data from digital data register
X	X	H	H	X	No response

H = High-level, L = Low-level, X = Irrelevant,  
 ↓ = High-to-low transition, ↑ = Low-to-high transition  
<sup>†</sup>For proper operation, Reset must be low for at least three clock cycles.

## TYPES TL532, TL533

### CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY

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#### functional description

The TL532 and TL533 provide direct interface to a microprocessor-based system. Control of the TL532 and TL533 is handled via the 8-line TTL-compatible 3-state data bus, the three control inputs (Read/Write, Register Select, and Chip Select), and the Clock input. Each device contains three 16-bit internal registers. These registers are the control register, the analog conversion data register, and the digital data register.

A high level at the Read/Write input and a low level at the Chip Select input set the device to output data on the 8-line data bus for the processor to read. A low level at the Read/Write input and a low level at the Chip Select input set the device to receive instructions into the internal control register on the 8-line data bus from the processor. When the device is in the read mode and the Register Select input is low, the processor will read the data contained in the analog conversion data register. However, when the Register Select input is high, the processor reads the data contained in the digital data register.

The control register is a write-only register into which the microprocessor writes command instructions for the device to start A/D conversion and to select the analog channel to be converted. The analog conversion data register is a read-only register that contains the current converter status and most recent conversion results. The digital data register is also a read-only register that holds the digital input logic levels from the six multipurpose inputs.

Internally each device contains a byte pointer that selects the appropriate byte during two cycles of the Clock input in a normal 16-bit microprocessor instruction. The internal pointer will automatically point to the most-significant (MS) byte after the first complete clock cycle any time that the Chip Select is at the high level for at least one clock cycle. This causes the device to treat the next signal on the 8-line data bus as the MS byte. A low level at the Chip Select input activates the inputs and outputs and an internal function decoder. However, no data is transferred until the Clock goes high. The internal byte pointer first points to the MS byte of the selected register during the first clock cycle. After the first clock cycle in which the MS byte is accessed, the internal pointer switches to the LS byte and remains there for as long as Chip Select is low. The MS byte of any register may be accessed by either an 8-bit or a 16-bit microprocessor instruction; however, the LS byte may only be accessed by a 16-bit microprocessor instruction.

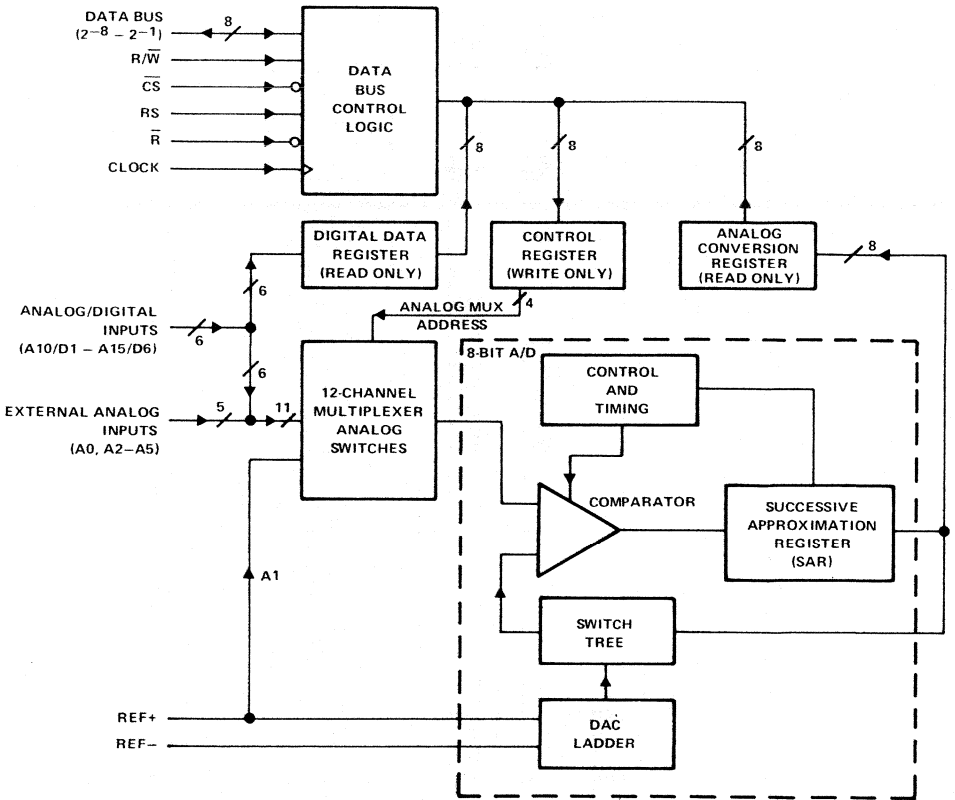
Normally, a two-byte word is written into or read from the controlling processor, but a single byte can be read by the processor by proper manipulation of the Chip Select input. This can be used to read conversion status from the analog conversion data register or the digital multipurpose input levels from the digital data register. The format and content of each two-byte word is shown in Figures 1 through 3.

A conversion cycle is started after a two-byte instruction is written into the control register and the start conversion (SC) bit is a logic high. This two-byte instruction also selects the input analog channel to be converted. The status (EOC) bit in the analog conversion data register is reset and remains reset until the conversion is completed, at that time the status bit is then set again. After conversion, the results are loaded into the analog conversion data register. These results remain in the analog conversion data register until the next conversion cycle is completed. If a new conversion command is entered into the control register while the conversion cycle is in progress, the on-going conversion will be aborted and a new channel acquisition cycle will immediately begin.

The Reset input allows the device to be externally forced to a known state. When a low level is applied to the Reset input for a minimum of three clock periods, the start conversion bit of the control register is cleared. The A/D converter is then idled and all the outputs are placed in the high-impedance off-state. However, the content of the analog conversion data register is not affected by the Reset input going to a low level.

**TYPES TL532, TL533**  
**CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH**  
**ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY**

functional block diagram



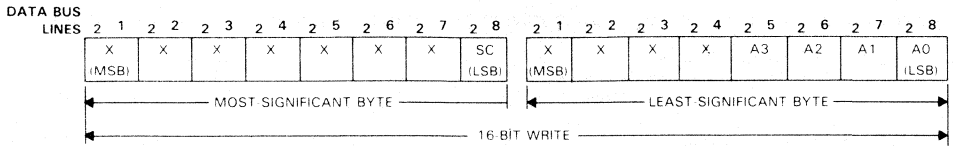
Data Acquisition

7



# TYPES TL532, TL533

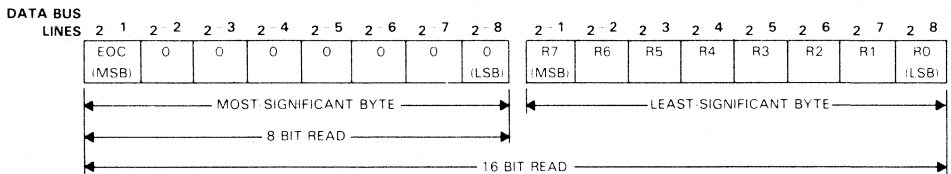
## CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY



Unused Bits (X) – The MS byte bits 2<sup>-1</sup> through 2<sup>-7</sup> and LS byte bits 2<sup>-1</sup> through 2<sup>-4</sup> of the control register are not used internally.  
 Start Conversion (SC) – When the SC bit in the MS byte is set to a logical 1 (high level), analog-to-digital conversion of the specified analog channel will begin immediately after the completion of the control register write.  
 Analog Multiplexer Address (A0-A3) – These four address bits are decoded by the analog multiplexer and used to select the appropriate analog channel as shown below:

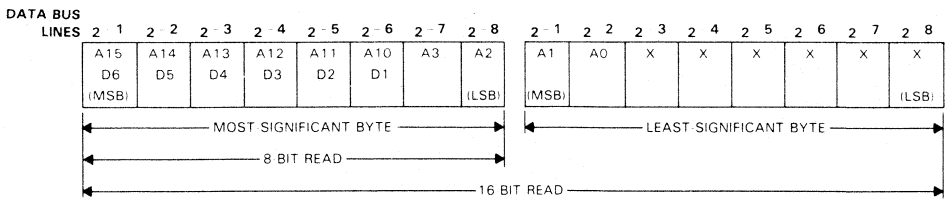
Hexadecimal Address (A3 – MSB)	Channel Select
0	A0
1	REF + (A1)
2-5	A2 A5
6-9 (not used)	
A-F	A10 A15

**FIGURE 1—CONTROL REGISTER TWO-BYTE WRITE WORD FORMAT AND CONTENT**



A/D Status (EOC) – The A/D status end-of-conversion (EOC) bit is set whenever an analog-to-digital conversion is successfully completed by the A/D converter. The status bit is cleared by a 16-bit write from the microprocessor to the control register. The remainder of the bits in the MS byte of the analog conversion data register are always reset to logical 0 to simplify microprocessor interrogation of the A/D converter status.  
 A/D Result (R0-R7) – The LS byte of the analog conversion data register contains the result of the analog-to-digital conversion. Result bit R7 is the MSB and the converter follows the standard convention of assigning a code of all ones (11111111) to a full-scale analog voltage. There are no special overflow or underflow indications.

**FIGURE 2—ANALOG CONVERSION DATA REGISTER ONE-BYTE AND TWO-BYTE READ WORD FORMAT AND CONTENT**



Shared Digital Port (A10-D1-A15-D6) – The voltage present on these pins is interpreted as a digital signal and the corresponding states are read from these bits. A digital value will be given for each pin even if some or all of these pins are being used as analog inputs.  
 Analog Multiplexer Address (A0-A3) – The address of the selected analog channel presently addressed is given by these bits.  
 Unused Bits (X) – LS byte bits 2<sup>-3</sup> through 2<sup>-8</sup> of the digital data register are not used.

**FIGURE 3—DIGITAL DATA REGISTER ONE-BYTE AND TWO-BYTE READ WORD FORMAT AND CONTENT**

# TYPES TL532, TL533

## CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	-0.3 V to 6.5 V
Input voltage range: Positive reference voltage	$V_{REF+}$ to $V_{CC} + 0.3$ V
Negative reference voltage	-0.3 V to $V_{REF+}$
All other inputs	-0.3 V to $V_{CC} + 0.3$ V
Input current, $I_I$ (any input)	$\pm 10$ mA
Total input current, (all inputs)	$\pm 20$ mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	1250 mW
Storage temperature range	-65°C to 150°C
Operating free-air temperature range	-40°C to 85°C
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds	260°C

- NOTES: 1. All voltage values are with respect to network ground terminal.  
2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves in Section 2.

### recommended operating conditions

	TL532			TL533			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{CC}$	4.75	5	5.5	4.75	5	5.5	V
Positive reference voltage, $V_{REF+}$ (see Note 3)	4.6		$V_{CC}$	4.6		$V_{CC}$	V
Negative reference voltage, $V_{REF-}$ (see Note 3)	0		0.1	0		0.1	V
Average voltage across ladder	$V_{CC} - 0.2$	$V_{CC}$	$V_{CC} + 0.2$	$V_{CC} - 0.2$	$V_{CC}$	$V_{CC} + 0.2$	V
High-level input voltage, $V_{IH}$	Clock input		$V_{CC} - 0.8$	$V_{CC} - 0.8$			V
	All other digital inputs		2	2			
Low-level input voltage, $V_{IL}$	Any digital input					0.8	V
Clock frequency, $f_{CLK}$	0.1	1.048		0.1	1.048		MHz
Clock period, $1/f_{CLK}$		943			943		ns
CS setup time, $t_{su}(CS)$		100			100		ns
Address (R/W and RS) setup time, $t_{su}(A)$		145			145		ns
Data bus input setup time, $t_{su}(bus)$		185			185		ns
Control (R/W, RS, and CS) hold time, $t_h(C)$		20			20		ns
Data bus input hold time, $t_h(bus)$		20			25		ns
Pulse duration of control inputs during read cycle, $t_w(C)$		575			575		ns
Pulse duration, reset low, $t_{wL}(reset)$		3			3		Clock Periods
Pulse duration of clock high, $t_{wH}(CLK)$		440			440		ns
Pulse duration of clock low, $t_{wL}(CLK)$		410			410		ns
Clock rise time, $t_r(CLK)$			25			25	ns
Clock fall time, $t_f(CLK)$			30			30	ns
Operating free-air temperature, $T_A$	-40		85	-40		85	°C

NOTE 3: Analog input voltages greater than or equal to that applied to the REF+ terminal convert to all ones (11111111), while input voltages equal to or less than that applied to the REF- terminal convert to all zeros (00000000).



# TYPE TL532

## CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERAL WITH ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY

**electrical characteristics over recommended ranges of  $V_{CC}$ ,  $V_{REF+}$ , and operating free-air temperature,  $V_{REF-}$  at ground,  $f_{CLK} = 1.048$  MHz (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT	
$V_{OH}$	High-level output voltage	I/O Data bus $I_{OH} = 1.6$ mA	2.4			V	
$V_{OL}$	Low-level output voltage	I/O Data bus $I_{OL} = 1.6$ mA			0.4	V	
$I_{IH}$	High-level input current	Any control input	$V_{IH} = 5.5$ V		1	$\mu$ A	
		Any other digital input			10		
$I_{IL}$	Low-level input current	Any control input	$V_{IL} = 0$		-1	$\mu$ A	
		Any other digital input			-10		
$I_{OZ}$	Off-state (high-impedance-state) output current	$V_O = V_{CC}$			10	$\mu$ A	
		$V_O = 0$			-10		
$I_I$	Analog input current (see Note 4)	$V_I = 0$ to $V_{CC}$			$\pm 500$	nA	
		Leakage current between selected channel and all other analog channels Clock input at 0 V			$\pm 400$		
$r_{i(on)}$	Analog channel input on-state resistance Ladder resistance ( $REF+$ to $REF-$ )				5	k $\Omega$	
				1	5		10
$C_i$	Input capacitance	Digital pins 3 thru 10			7	pF	
		Any other input pin			5		15
$I_{CC+REF+}$	Supply current plus reference current	$V_{CC} = V_{REF+} = 5.5$ V, Outputs open			3	16	mA
$I_{CC}$	Supply current	$V_{CC} = 5.5$ V			2	10	mA

<sup>†</sup>Typical values are at  $V_{CC} = 5$  V,  $T_A = 25^\circ\text{C}$ .

NOTE 4: Analog input current is an average of the current flowing into a selected analog channel input during one full conversion cycle.

**operating characteristics over recommended ranges of  $V_{CC}$ ,  $V_{REF+}$ , and operating free-air temperature,  $V_{REF-}$  at ground,  $f_{CLK} = 1.048$  MHz (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
	Linearity error	See Note 5			$\pm 0.5$	LSB
	Zero error	See Note 6			$\pm 0.5$	LSB
	Full-scale error	See Note 6			$\pm 0.5$	LSB
	Total unadjusted error	See Note 7			$\pm 0.5$	LSB
	Absolute accuracy error	See Note 8			$\pm 1$	LSB
$t_{conv}$	Conversion time (including channel acquisition time)				290	Clock Cycles
$t_{acq}$	Channel acquisition time				30	Clock Cycles
$t_{en}$	Data output enable time (See Note 9)	$R_L = 3$ k $\Omega$ , $C_L = 50$ pF			335	ns
$t_{dis}$	Data output disable time	$R_L = 3$ k $\Omega$ , $C_L = 50$ pF	10			ns
$t_{r(bus)}$	Data bus output rise time	High-impedance to high-level	$R_L = 3$ k $\Omega$ , $C_L = 50$ pF		150	ns
		Low to high-level			300	
$t_{f(bus)}$	Data bus output fall time	High-impedance to low-level	$R_L = 3$ k $\Omega$ , $C_L = 50$ pF		150	ns
		High to low-level			300	

<sup>†</sup>Typical values are at  $V_{CC} = 5$  V,  $T_A = 25^\circ\text{C}$ .

NOTES: 5. Linearity error is the deviation from the best straight line through the A/D transfer characteristics.

6. Zero error is the difference between the output of an ideal and an actual A/D for zero input voltage; full-scale error is that same difference for full-scale input voltage.

7. Total unadjusted error is the sum of linearity, zero, and full-scale errors.

8. Absolute accuracy error is the maximum difference between an analog value and the nominal midstep value within any step. This includes all errors including inherent quantization error, which is the  $\pm 0.5$  LSB uncertainty caused by the A/D converters finite resolution.

9. If chip select setup time,  $t_{su}(CS)$ , is less than 0.14 microseconds, the effective data output enable time,  $t_{en}$ , may extend such that  $t_{su}(CS) + t_{en}$  is equal to a maximum of 0.475 microseconds.

# TYPE TL533

## CMOS 8-BIT ANALOG-TO-DIGITAL PERIPHERAL WITH ADDITIONAL DIGITAL INPUT/OUTPUT CAPABILITY

electrical characteristics over recommended ranges of  $V_{CC}$ ,  $V_{REF+}$ , and operating free-air temperature,  $V_{REF-}$  at ground,  $f_{CLK} = 1.048$  MHz (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT	
$V_{OH}$	High-level output voltage	I/O Data bus $I_{OH} = -1.6$ mA	2.5			V	
$V_{OL}$	Low-level output voltage	I/O Data bus $I_{OL} = 1.6$ mA			0.4	V	
$I_{IH}$	High-level input current	Any control input			1	$\mu$ A	
		Any other digital input	$V_{IH} = 5.5$ V		10		
$I_{iL}$	Low-level input current	Any control input	$V_{iL} = 0$		-1	$\mu$ A	
		Any other digital input			-10		
$I_{OZ}$	Off-state (high-impedance-state) output current	$V_O = V_{CC}$			10	$\mu$ A	
		$V_O = 0$			-10		
$I_I$	Analog input current (see Note 4)	$V_I = 0$ to $V_{CC}$			$\pm 700$	nA	
	Leakage current between selected channel and all other analog channels	$V_I = 0$ to $V_{CC}$ , Clock input at 0 V			$\pm 500$	nA	
$r_{i(on)}$	Analog channel input on-state resistance				5	k $\Omega$	
	Ladder resistance (REF+ to REF-)		1	5	10	k $\Omega$	
$C_i$	Input capacitance	Digital pins 3 thru 10			7	pF	
		Any other input pin			5		
$I_{CC+I_{REF+}}$	Supply current plus reference current	$V_{CC} = V_{REF+} = 5.5$ V, Outputs open			3	16	mA
$I_{CC}$	Supply current	$V_{CC} = 5.5$ V			2	10	mA

<sup>†</sup>Typical values are at  $V_{CC} = 5$  V,  $T_A = 25^\circ\text{C}$ .

NOTE 4: Analog input current is an average of the current flowing into a selected analog channel input during one full conversion cycle.

operating characteristics over recommended ranges of  $V_{CC}$ ,  $V_{REF+}$ , and operating free-air temperature,  $V_{REF-}$  at ground,  $f_{CLK} = 1.048$  MHz (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
	Linearity error	See Note 5		$\pm 0.5$		LSB
	Zero error	See Note 6		$\pm 0.25$		LSB
	Full-scale error	See Note 6		$\pm 0.25$		LSB
	Total unadjusted error	See Note 7		$\pm 0.5$		LSB
	Absolute accuracy error	See Note 8		$\pm 1$		
$t_{conv}$	Conversion time (including channel acquisition time)				290	Clock Cycles
$t_{acq}$	Channel acquisition time				30	Clock Cycles
$t_{en}$	Data output enable time (See Note 9)	$R_L = 3$ k $\Omega$ , $C_L = 50$ pF			335	ns
$t_{dis}$	Data output disable time	$R_L = 3$ k $\Omega$ , $C_L = 50$ pF	10			ns
$t_{r(bus)}$	Data bus output rise time	High-impedance to high-level			150	ns
		Low to high-level	$R_L = 3$ k $\Omega$ , $C_L = 50$ pF		300	
$t_{f(bus)}$	Data bus output fall time	High-impedance to low-level			150	ns
		High to low-level	$R_L = 3$ k $\Omega$ , $C_L = 50$ pF		300	

<sup>†</sup>Typical values are at  $V_{CC} = 5$  V,  $T_A = 25^\circ\text{C}$ .

NOTES: 5. Linearity error is the deviation from the best straight line through the A/D transfer characteristics.

6. Zero error is the difference between the output of an ideal and an actual A/D for zero input voltage; full-scale error is that same difference for full-scale input voltage.

7. Total unadjusted error is the sum of linearity, zero, and full-scale errors.

8. Absolute accuracy error is the maximum difference between an analog value and the nominal midstep value within any step. This includes all errors including inherent quantization error, which is the  $\pm 0.5$  LSB uncertainty caused by the A/D converters finite resolution.

9. If chip-select setup time,  $t_{SU}(CS)$ , is less than 0.14 microseconds, the effective data output enable time,  $t_{en}$ , may extend such that  $t_{SU}(CS) + t_{en}$  is equal to a maximum of 0.475 microseconds.

**NOT RECOMMENDED  
FOR NEW DESIGN**

For New Design, see TL182 Series

**description**

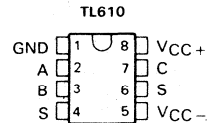
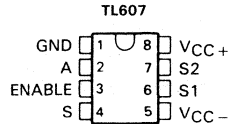
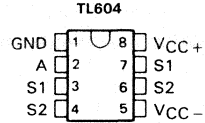
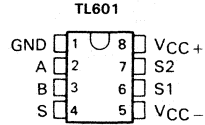
The TL601, TL604, TL607, and TL610 are a family of monolithic P-MOS analog switches that provide fast switching speeds with high  $r_{off}/r_{on}$  ratio and no offset voltage. The p-channel enhancement-type MOS switches will accept analog signals up to  $\pm 10$  volts and are controlled by TTL-compatible logic inputs. The monolithic structure is made possible by BI-MOS technology, which combines p-channel MOS with standard bipolar transistors.

These switches are particularly suited for use in military, industrial, and commercial applications such as data acquisition, multiplexers, A/D and D/A converters, MODEMS, sample-and-hold systems, signal multiplexing, integrators, programmable operational amplifiers, programmable voltage regulators, crosspoint switching networks, logic interface, and many other analog systems.

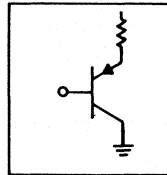
The TL601 is an SPDT switch with two logic control inputs. The TL604 is a dual complementary SPST switch with a single control input. The TL607 is an SPDT switch with one logic control input and one enable input. The TL610 is an SPST switch with three logic control inputs. The TL610 features a higher  $r_{off}/r_{on}$  ratio than the other members of the family.

The TL601M, TL604M, TL607M, and TL610M are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , the TL6011, TL6041, TL6071, and TL6101 are characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the TL601C, TL604C, TL607C, and TL610C are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

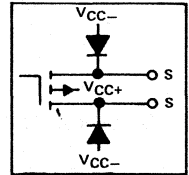
**JG OR P DUAL-IN-LINE PACKAGE  
(TOP VIEW)**



**TYPICAL OF  
ALL INPUTS**

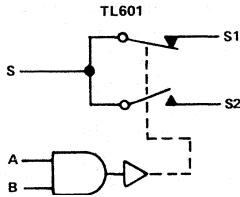


**TYPICAL OF  
ALL SWITCHES**



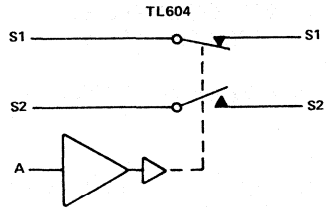
# TYPES TL601, TL604, TL607, TL610

## P-MOS ANALOG SWITCHES



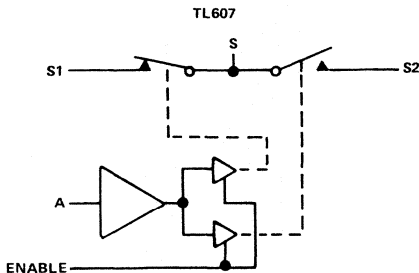
FUNCTION TABLE

LOGIC INPUTS		ANALOG SWITCH	
A	B	S1	S2
L	X	OFF (OPEN)	ON (CLOSED)
X	L	OFF (OPEN)	ON (CLOSED)
H	H	ON (CLOSED)	OFF (OPEN)



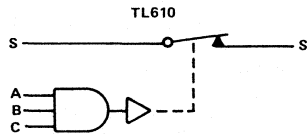
FUNCTION TABLE

LOGIC INPUT	ANALOG SWITCH	
A	S1	S2
H	ON (CLOSED)	OFF (OPEN)
L	OFF (OPEN)	ON (CLOSED)



FUNCTION TABLE

INPUTS		ANALOG SWITCH	
A	ENABLE	S1	S2
X	L	OFF (OPEN)	OFF (OPEN)
L	H	OFF (OPEN)	ON (CLOSED)
H	H	ON (CLOSED)	OFF (OPEN)



FUNCTION TABLE

INPUTS			ANALOG SWITCH
A	B	C	S
L	X	X	OFF (OPEN)
X	L	X	OFF (OPEN)
X	X	L	OFF (OPEN)
H	H	H	ON (CLOSED)

H = high logic level

L = low logic level

X = irrelevant

Switch positions shown are for all inputs high.

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC+}$ (see Note 1)	30 V
Supply voltage, $V_{CC-}$	-30 V
$V_{CC+}$ to $V_{CC-}$ supply voltage differential	35 V
Control input voltage	$V_{CC+}$
Switch off-state voltage	30 V
Switch on-state current	10 mA
Operating free-air temperature range: TL601M, TL604M, TL607M, TL610M	-55°C to 125°C
TL601I, TL604I, TL607I, TL610I	-25°C to 85°C
TL601C, TL604C, TL607C, TL610C	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds: JG package	300°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds: P package	260°C

NOTE 1: All voltage values are with respect to network ground terminal.

# TYPES TL601, TI604, TL607, TL610 P-MOS ANALOG SWITCHES

## recommended operating conditions

	TL601M, TL604M TL607M, TL610M			TL601I, TL604I TL607I, TL610I			TL601C, TL604C TL607C, TL610C			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{CC+}$ (see Figure 1)	5	10	25	5	10	25	5	10	25	V
Supply voltage, $V_{CC-}$ (see Figure 1)	-5	-20	-25	-5	-20	-25	-5	-20	-25	V
$V_{CC+}$ to $V_{CC-}$ supply voltage differential (see Figure 1)	15		30	15		30	15		30	V
Control input voltage	0		5.5	0		5.5	0		5.5	V
Voltage at any analog switch (S) terminal	$V_{CC-} + 8$		$V_{CC+}$	$V_{CC-} + 8$		$V_{CC+}$	$V_{CC-} + 8$		$V_{CC+}$	V
Switch on-state current			10			10			10	mA
Operating free-air temperature, $T_A$	-55		125	-25		85	0		70	°C

Figure 1 shows power supply boundary conditions for proper operation of the TL601 Series. The range of operation for supply  $V_{CC+}$  from +5 V to +25 V is shown on the vertical axis. The range of  $V_{CC-}$  from -5 volts to -25 volts is shown on the horizontal axis. A recommended 30-volt maximum voltage differential from  $V_{CC+}$  to  $V_{CC-}$  governs the maximum  $V_{CC+}$  for a chosen  $V_{CC-}$  (or vice versa). A minimum recommended difference of 15 volts from  $V_{CC+}$  to  $V_{CC-}$  and the boundaries shown in Figure 1 allow the designer to select the proper combinations of the two supplies.

The designer-selected  $V_{CC+}$  for a chosen  $V_{CC-}$  supply values limit the maximum input voltage that can be applied to either switch terminal; that is, the input voltage should be between  $V_{CC-} + 8$  V and  $V_{CC+}$  to keep the on-state resistance within specified limits.

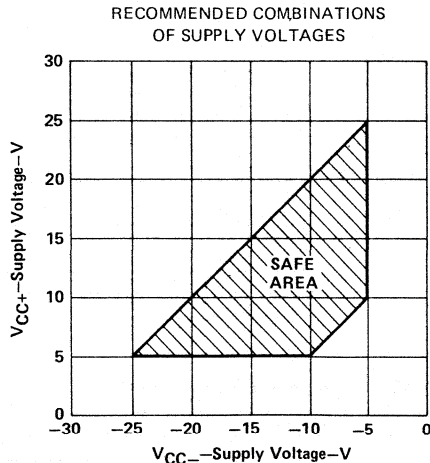


FIGURE 1

# TYPES TL601, TL604, TL607, TL610

## P-MOS ANALOG SWITCHES

electrical characteristics over recommended operating free-air temperature range,  
 $V_{CC+} = 10\text{ V}$ ,  $V_{CC-} = -20\text{ V}$ , analog switch test current = 1 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		TL6__M			TL6__C			UNIT	
			MIN	TYP‡	MAX	MIN	TYP‡	MAX		
$V_{IH}$ High-level input voltage			2			2			V	
$V_{IL}$ Low-level input voltage	Enable input of TL607M		0.6						V	
	All other inputs		0.8			0.8				
$I_{IH}$ High-level input current	$V_I = 5.5\text{ V}$		0.5 10			0.5 10			$\mu\text{A}$	
$I_{IL}$ Low-level input current	$V_I = 0.4\text{ V}$		-50 -250			-50 -250			$\mu\text{A}$	
$I_{off}$ Switch off-state current	$V_{I(sw)} = -10\text{ V}$ , See Note 2	$T_A = 25^\circ\text{C}$	-400			-500			$\mu\text{A}$	
		$T_A = \text{MAX}$	-50 -100			-10 -20			nA	
$r_{on}$ Switch on-state resistance	$V_{I(sw)} = 10\text{ V}$ , $I_{O(sw)} = -1\text{ mA}$	TL601							$\Omega$	
		TL604	55 100			75 200				
	TL607									
	TL610	40 80			40 100					
	$V_{I(sw)} = -10\text{ V}$ , $I_{O(sw)} = -1\text{ mA}$	TL601								
TL604		220 400			220 600					
		TL607								
		TL610	120 300			120 400				
$r_{off}$ Switch off-state resistance			$1 \times 10^{11}$			$5 \times 10^{10}$			$\Omega$	
$C_{on}$ Switch on-state input capacitance	$V_{I(sw)} = 0\text{ V}$ , $f = 1\text{ MHz}$		16			16			pF	
$C_{off}$ Switch off-state input capacitance	$V_{I(sw)} = 0\text{ V}$ , $f = 1\text{ MHz}$		8			8			pF	
$I_{CC+}$ Supply current from $V_{CC+}$	Logic input(s) at 5.5 V, All switch terminals open		TL601							mA
			TL604	5 10			5 10			
		Enable input high	TL607	5 10			5 10			
		Enable input low		3 5			3 5			
		TL610	5 10			5 10				
$I_{CC-}$ Supply current from $V_{CC-}$	Logic input(s) at 5.5 V, All switch terminals open		TL601	-1.2 -2.5			-1.2 -2.5			mA
			TL604							
		Enable input high	TL607	-2.5 -5			-2.5 -5			
		Enable input low		-0.05 -0.5			-0.05 -0.5			
		TL610	-1.2 -2.5			-1.2 -2.5				

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ All typical values are at  $T_A = 25^\circ\text{C}$ .

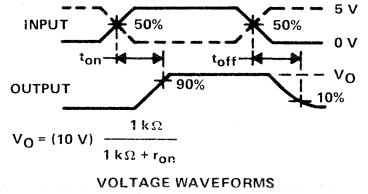
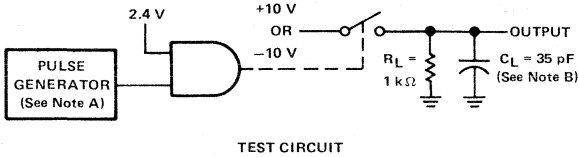
NOTE 2: The other terminal of the switch under test is at  $V_{CC+} = 10\text{ V}$ .

switching characteristics,  $V_{CC} = 10\text{ V}$ ,  $V_{CC-} = -20\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{off}$ Switch turn-off time	$R_L = 1\text{ k}\Omega$ , $C_L = 35\text{ pF}$ , See Figure 2		400	500	ns
$t_{on}$ Switch turn-on time			100	150	

# TYPES TL601, TL604, TL607, TL610 P-MOS ANALOG SWITCHES

## PARAMETER MEASUREMENT INFORMATION

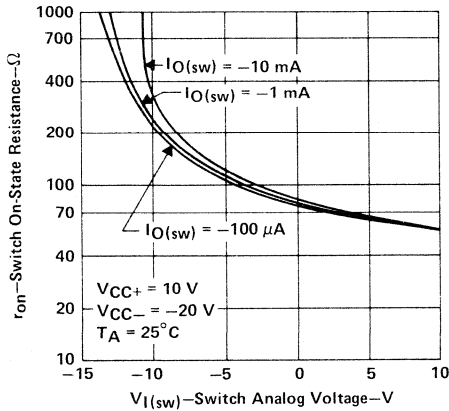


- NOTES: A. The pulse generator has the following characteristics:  
 $Z_{out} = 50\Omega$ ,  $t_r = 15 \text{ ns}$ ,  $t_f = 15 \text{ ns}$ ,  $t_w = 500 \text{ ns}$ .  
 B.  $C_L$  includes probe and jig capacitance.

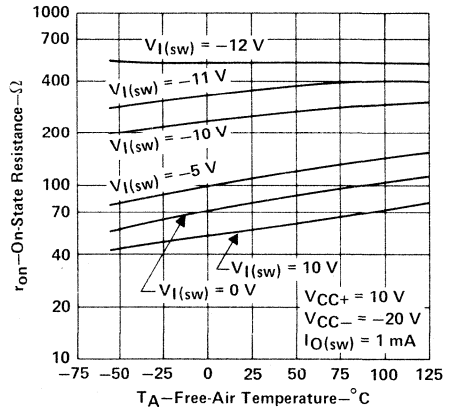
FIGURE 2

## TYPICAL CHARACTERISTICS

SWITCH ON-STATE RESISTANCE  
vs  
FREE-AIR TEMPERATURE



SWITCH ON-STATE RESISTANCE  
vs  
SWITCH ANALOG VOLTAGE







# DATA ACQUISITION CIRCUITS

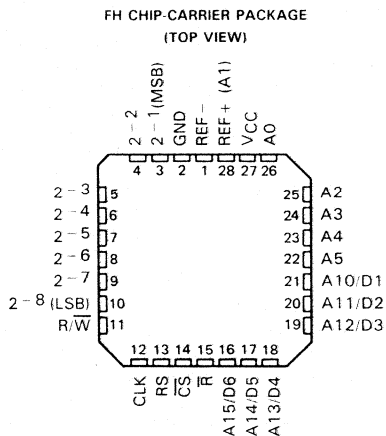
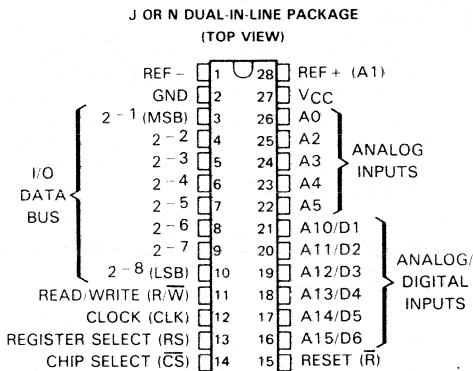
# TYPES TLC532AM, TLC532AI, TLC533AM, TLC533AI LinCMOSTM 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH 5 ANALOG AND 6 MULTIPURPOSE INPUTS

D2819, NOVEMBER 1983

- LinCMOSTM Technology
- 8-Bit Resolution
- Total Unadjusted Error . . .  $\pm 0.5$  LSB Max
- Ratiometric Conversion
- Access Plus Conversion Time:  
TLC532A . . . 15  $\mu$ s Max  
TLC533A . . . 30  $\mu$ s Max
- 3-State, Bidirectional I/O Data Bus
- 5 Analog and 6 Multipurpose Inputs
- On-Chip 12-Channel Analog Multiplexer
- Three On-Chip 16-Bit Data Registers
- Software Compatible with Larger TL530 and TL531 (21-Input Versions)
- On-Chip Sample-and-Hold Circuit
- Single 5-V Supply Operation
- Low Power Consumption . . . 6.5 mW Typ
- Improved Direct Replacements for Texas Instruments TL532 and TL533, National Semiconductor ADC0829, and Motorola MC14442

## description

The TLC532A and TLC533A are monolithic LinCMOSTM peripheral integrated circuits each designed to interface a microprocessor for analog data acquisition. These devices are complete peripheral data acquisition systems on a single chip and can convert analog signals to digital data from up to 11 external analog terminals. Each device features operation from a single 5-volt supply. Each contains a 12-channel analog multiplexer, an 8-bit ratiometric analog-to-digital (A/D) converter, a sample-and-hold, three 16-bit registers, and microprocessor-compatible control logic circuitry. Additional features include a built-in self-test, six multipurpose (analog or digital) inputs, five external analog inputs, and an 8-pin input/output (I/O) data port. The three on-chip data registers store the control data, the conversion results, and the input digital data that can be accessed via the microprocessor data bus in two 8-bit bytes (most-significant byte first). In this manner, a microprocessor can access up to 11 external analog inputs or 6 digital signals and the positive reference voltage that may be used for self-test.



FUNCTION TABLE

ADDRESS/CONTROL					DESCRIPTION
R/W	RS	CS	R	CLK	
X	X	X	L		Reset
L	H	L	H	↓	Write bus data to control register
H	L	L	H	↑	Read data from analog conversion register
H	H	L	H	↑	Read data from digital data register
X	X	H	H	X	No response

H = High-level, L = Low-level, X = Irrelevant.  
 ↓ = High-to-low transition, ↑ = Low-to-high transition  
 † For proper operation, Reset must be low for at least three clock cycles.

## ADVANCE INFORMATION

This document contains information on a new product. Specifications are subject to change without notice.

# TYPES TLC532AM, TLC532AI, TLC533AM, TLC533AI LinCMOS™ 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH 5 ANALOG AND 6 MULTIPURPOSE INPUTS

---

## description (continued)

The A/D conversion uses the successive-approximation technique and switched-capacitor circuitry. This method eliminates the possibility of missing codes, nonmonotonicity, and a need for zero or full-scale adjustment. Any one of 11 analog inputs (or self-test) can be converted to an 8-bit digital word and stored in 10 microseconds (TLC532A) or 20 microseconds (TLC533A) after instructions from the microprocessor have been recognized. The on-chip sample-and-hold functions automatically minimize errors due to noise on the analog inputs. Furthermore, differential high-impedance reference inputs are available to help isolate the analog circuitry from the logic and supply noises while easing ratiometric conversion and scaling.

The TLC532AM and TLC533AM are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The TLC532AI and TLC533AI are characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

## functional description

The TLC532A and TLC533A provide direct interface to a microprocessor-based system. Control of the TLC532A and TLC533A is handled via the 8-line TTL-compatible 3-state data bus, the three control inputs (Read/Write, Register Select, and Chip Select), and the Clock input. Each device contains three 16-bit internal registers. These registers are the control register, the analog conversion data register, and the digital data register.

A high level at the Read/Write input and a low level at the Chip Select input set the device to output data on the 8-line data bus for the processor to read. A low level at the Read/Write input and a low level at the Chip Select input set the device to receive instructions into the internal control register on the 8-line data bus from the processor. When the device is in the read mode and the Register Select input is low, the processor will read the data contained in the analog conversion data register. However, when the Register Select input is high, the processor reads the data contained in the digital data register.

The control register is a write-only register into which the microprocessor writes command instructions for the device to start A/D conversion and to select the analog channel to be converted. The analog conversion data register is a read-only register that contains the current converter status and most recent conversion results. The digital data register is also a read-only register that holds the digital input logic levels from the six multipurpose inputs.

Internally each device contains a byte pointer that selects the appropriate byte during two cycles of the Clock input in a normal 16-bit microprocessor instruction. The internal pointer will automatically point to the most-significant (MS) byte after the first complete clock cycle any time that the Chip Select is at the high level for at least one clock cycle. This causes the device to treat the next signal on the 8-line data bus as the MS byte. A low level at the Chip Select input activates the inputs and outputs and an internal function decoder. However, no data is transferred until the Clock goes high. The internal byte pointer first points to the MS byte of the selected register during the first clock cycle. After the first clock cycle in which the MS byte is accessed, the internal pointer switches to the LS byte and remains there for as long as Chip Select is low. The MS byte of any register may be accessed by either an 8-bit or a 16-bit microprocessor instruction; however, the LS byte may only be accessed by a 16-bit microprocessor instruction.

Normally, a two-byte word is written into or read from the controlling processor, but a single byte can be read by the processor by proper manipulation of the Chip Select input. This can be used to read conversion status from the analog conversion data register or the digital multipurpose input levels from the digital data register. The format and content of each two-byte word is shown in Figures 1 through 3.

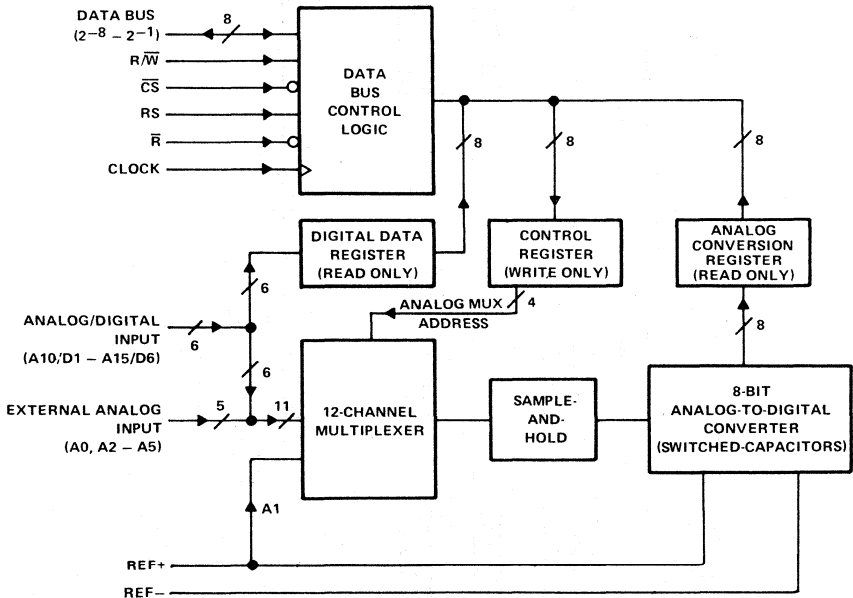
# TYPES TLC532AM, TLC532AI, TLC533AM, TLC533AI LinCMOS™ 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH 5 ANALOG AND 6 MULTIPURPOSE INPUTS

## functional description (continued)

A conversion cycle is started after a two-byte instruction is written into the control register and the start conversion (SC) bit is a logic high. This two-byte instruction also selects the input analog channel to be converted. The status (EOC) bit in the analog conversion data register is reset and remains reset until the conversion is completed, at that time the status bit is then set again. After conversion, the results are loaded into the analog conversion data register. These results remain in the analog conversion data register until the next conversion cycle is completed. If a new conversion command is entered into the control register while the conversion cycle is in progress, the on-going conversion will be aborted and a new channel acquisition cycle will immediately begin.

The Reset input allows the device to be externally forced to a known state. When a low level is applied to the Reset input for a minimum of three clock periods, the start conversion bit of the control register is cleared. The A/D converter is then idled and all the outputs are placed in the high-impedance off-state. However, the content of the analog conversion data register is not affected by the Reset input going to a low level.

## functional block diagram

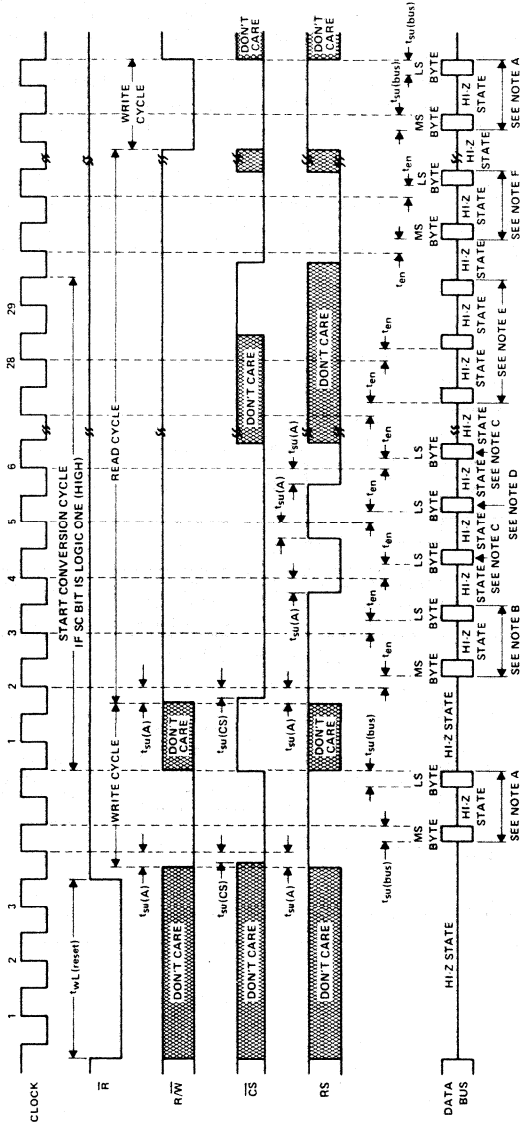


**TYPES TLC532AM, TLC532AI, TLC533AM, TLC533AI**  
**LinCMOS™ 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH**  
**5 ANALOG AND 6 MULTIPURPOSE INPUTS**

typical operating sequence

**Data Acquisition**

**7**



NOTES: A. This is a 16 bit input instruction from the microprocessor being sent to the control data register.

B. This is the 2-byte (16-bit) content of the digital data register being sent to the microprocessor.

C. This is the LS byte (8-bit) content of the analog conversion data register being sent to the microprocessor.

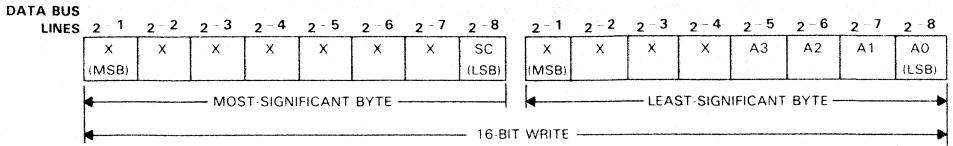
D. This is the LS byte (8-bit) content of the digital data register being sent to the microprocessor.

E. These are 8-bit or 16 bit output data from either the analog conversion data register or the digital data register being sent to the microprocessor.

F. This is the 2-byte (16-bit) content of the analog conversion data register being sent to the microprocessor.

# TYPES TLC532AM, TLC532AI, TLC533AM, TLC533AI

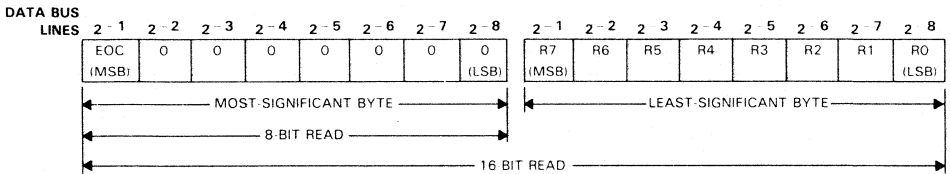
## LinCMOST™ 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH 5 ANALOG AND 6 MULTIPURPOSE INPUTS



Unused Bits (X) – The MS byte bits 2<sup>-1</sup> through 2<sup>-7</sup> and LS byte bits 2<sup>-1</sup> through 2<sup>-4</sup> of the control register are not used internally.  
 Start Conversion (SC) – When the SC bit in the MS byte is set to a logical 1 (high level), analog-to-digital conversion of the specified analog channel will begin immediately after the completion of the control register write.  
 Analog Multiplex Address (A0-A3) – These four address bits are decoded by the analog multiplexer and used to select the appropriate analog channel as shown below.

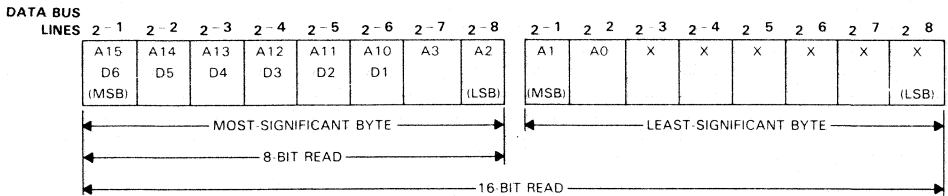
<b>Hexadecimal Address (A3 = MSB)</b>	<b>Channel Select</b>
0	A0
1	REF + (A1)
2-5	A2-A5
6-9 (not used)	
A-F	A10-A15

**FIGURE 1—CONTROL REGISTER TWO-BYTE WRITE WORD FORMAT AND CONTENT**



A/D Status (EOC) – The A/D status end-of-conversion (EOC) bit is set whenever an analog-to-digital conversion is successfully completed by the A/D converter. The status bit is cleared by a 16-bit write from the microprocessor to the control register. The remainder of the bits in the MS byte of the analog conversion data register are always reset to logical 0 to simplify microprocessor interrogation of the A/D converter status.  
 A/D Result (R0-R7) – The LS byte of the analog conversion data register contains the result of the analog-to-digital conversion. Result bit R7 is the MSB and the converter follows the standard convention of assigning a code of all ones (11111111) to a full-scale analog voltage. There are no special overflow or underflow indications.

**FIGURE 2—ANALOG CONVERSION DATA REGISTER ONE-BYTE AND TWO-BYTE READ WORD FORMAT AND CONTENT**



Shared Digital Port (A10/D1-A15/D6) – The voltage present on these pins is interpreted as a digital signal and the corresponding states are read from these bits. A digital value will be given for each pin even if some or all of these pins are being used as analog inputs.  
 Analog Multiplex Address (A0-A3) – The address of the selected analog channel presently addressed is given by these bits.  
 Unused Bits (X) – LS byte bits 2<sup>-3</sup> through 2<sup>-8</sup> of the digital data register are not used.

**FIGURE 3—DIGITAL DATA REGISTER ONE-BYTE AND TWO-BYTE READ WORD FORMAT AND CONTENT**

# TYPES TLC532AM, TLC532AI, TLC533AM, TLC533AI

## LinCMOST™ 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH 5 ANALOG AND 6 MULTIPURPOSE INPUTS

### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	-0.3 V to 6.5 V
Input voltage range: Positive reference voltage	$V_{REF-}$ to $V_{CC} + 0.3$ V
Negative reference voltage	-0.3 V to $V_{REF+}$
All other inputs	-0.3 V to $V_{CC} + 0.3$ V
Input current, $I_I$ (any input)	$\pm 10$ mA
Total input current, (all inputs)	$\pm 20$ mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	1025 mW
Operating free-air temperature range: TLC532AM, TLC533AM	-55°C to 125°C
TLC532AI, TLC533AI	-40°C to 85°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: FH or J package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N package	260°C

- NOTES: 1. All voltage values are with respect to network ground terminal.  
 2. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2.

### recommended operating conditions

	TLC532A			TLC533A			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{CC}$	4.75	5	5.5	4.75	5	5.5	V
Positive reference voltage, $V_{REF+}$ (see Note 3)	2.5	$V_{CC}$	$V_{CC} + 0.1$	2.5	$V_{CC}$	$V_{CC} + 0.1$	V
Negative reference voltage, $V_{REF-}$ (see Note 3)	-0.1	0	2.5	-0.1	0	2.5	V
Differential reference voltage, $V_{REF+} - V_{REF-}$	1	$V_{CC}$	$V_{CC} + 0.2$	1	$V_{CC}$	$V_{CC} + 0.2$	V
High-level input voltage, $V_{IH}$	Clock input	$V_{CC} - 0.8$		$V_{CC} - 0.8$			V
	All other digital inputs	2		2			
Low-level input voltage, $V_{IL}$	Any digital input		0.8	Any digital input		0.8	V
Clock frequency, $f_{CLK}$	0.1	2	2.048	0.1	1.048	1.06	MHz
$\overline{CS}$ setup time, $t_{su}(CS)$	75			100			ns
Address (R/W and RS) setup time, $t_{su}(A)$	100			145			ns
Data bus input setup time, $t_{su}(bus)$	140			185			ns
Control (R/W, RS, and $\overline{CS}$ ) hold time, $t_h(C)$	10			20			ns
Data bus input hold time, $t_h(bus)$	15			20			ns
Pulse duration of control during read, $t_w(C)$	305			575			ns
Pulse duration, reset low, $t_w(reset)$	3			3			Clock Cycles
Pulse duration of clock high, $t_wH(CLK)$	230			440			ns
Pulse duration of clock low, $t_wL(CLK)$	200			410			ns
Clock rise time, $t_r(CLK)$	15			25			ns
Clock fall time, $t_f(CLK)$	16			30			ns
Operating free-air temperature, $T_A$	TLC ___ AM	-55		-55		125	°C
	TLC ___ AI	-40		-40		85	

NOTE 3: Analog input voltages greater than or equal to that applied to the  $REF+$  terminal convert to all ones (11111111), while input voltages equal to or less than that applied to the  $REF-$  terminal convert to all zeros (00000000). For proper operation, the positive reference voltage,  $V_{REF+}$ , must be at least 1-volt greater than the negative reference voltage,  $V_{REF-}$ . In addition, unadjusted errors may increase as the differential reference voltage,  $V_{REF+} - V_{REF-}$ , falls below 4.75 volts.

# TYPES TLC532AM, TLC532AI

## LinCMOS™ 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH 5 ANALOG AND 6 MULTIPURPOSE INPUTS

electrical characteristics over recommended operating free-air temperature range,  $V_{REF+} = V_{CC}$ ,  $V_{REF-}$  at ground,  $f_{CLK} = 2$  MHz (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
$V_{OH}$	High-level output voltage	$I_{OH} = -1.6$ mA	2.4			V
$V_{OL}$	low-level output voltage	$I_{OL} = 1.6$ mA				V
$I_{IH}$	High-level input current	Any digital or Clock input	$V_{IH} = 5.5$ V		10	$\mu$ A
		Any control input			1	
$I_{IL}$	Low-level input current	Any digital or Clock input	$V_{IL} = 0$		-10	$\mu$ A
		Any control input			-1	
$I_{OZ}$	Off-state (high impedance-state) output current	$V_O = V_{CC}$			10	$\mu$ A
		$V_O = 0$			-10	
$I_I$	Analog input current (see Note 4)	$V_I = 0$ to $V_{CC}$			$\pm 500$	nA
	Leakage current between selected channel and all other analog channels	$V_I = 0$ to $V_{CC}$ , Clock input at 0 V			$\pm 400$	nA
$C_i$	Input capacitance	Digital pins 3 thru 10			4 30	pF
		Any other input pin			2 15	
$I_{CC} + I_{REF+}$	Supply current plus reference current	$V_{CC} = V_{REF+} = 5.5$ V, Outputs open		1.5	3	mA
$I_{CC}$	Supply current	$V_{CC} = 5.5$ V		1.4	2	mA

NOTE 4: Analog input current is an average of the current flowing into a selected analog channel input during one full conversion cycle.

operating characteristics over recommended operating free-air temperature range,  $V_{REF+} = V_{CC}$ ,  $V_{REF-}$  at ground,  $f_{CLK} = 2$  MHz (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
	Linearity error	See Note 5			$\pm 0.5$	LSB
	Zero error	See Note 6			$\pm 0.5$	LSB
	Full-scale error	See Note 6			$\pm 0.5$	LSB
	Total unadjusted error	See Note 7			$\pm 0.5$	LSB
	Absolute accuracy error	See Note 8			$\pm 1$	LSB
$t_{conv}$	Conversion time (including channel acquisition time)			30		Clock Cycles
$t_{acq}$	Channel acquisition time			10		Clock Cycles
$t_{en}$	Data output enable time (see Note 9)	$C_L = 50$ pF, $R_L = 3$ k $\Omega$			250	ns
$t_{dis}$	Data output disable time	$C_L = 50$ pF, $R_L = 3$ k $\Omega$	10			ns
$t_{r(bus)}$	Data bus output rise time	High-impedance to high-level	$C_L = 50$ pF, $R_L = 3$ k $\Omega$		150	ns
		Low to high-level			300	
$t_{f(bus)}$	Data bus output fall time	High-impedance to low-level	$C_L = 50$ pF, $R_L = 3$ k $\Omega$		150	ns
		High to low-level			300	

<sup>†</sup>Typical values are at  $V_{CC} = 5$  V,  $T_A = 25^\circ\text{C}$ .

- NOTES:
- Linearity error is the deviation from the best straight line through the A/D transfer characteristics.
  - Zero error is the difference between the output of an ideal and an actual A/D for zero input voltage; full-scale error is that same difference for full-scale input voltage.
  - Total unadjusted error is the sum of linearity, zero, and full-scale errors.
  - Absolute accuracy error is the maximum difference between an analog value and the nominal midstep value within any step. This includes all errors including inherent quantization error, which is the  $\pm 0.5$  LSB uncertainty caused by the A/D converters finite resolution.
  - If chip-select setup time,  $t_{SU}(CS)$ , is less than 0.14 microseconds, the effective data output enable time,  $t_{EN}$ , may extend such that  $t_{SU}(CS) + t_{EN}$  is equal to a maximum of 0.475 microseconds.

# TYPES TLC533AM, TLC533AI

## LinCMOST™ 8-BIT ANALOG-TO-DIGITAL PERIPHERAL WITH 5 ANALOG AND 6 MULTIPURPOSE INPUTS

electrical characteristics over recommended ranges of  $V_{CC}$ ,  $V_{REF+}$ , and operating free-air temperature,  $V_{REF-}$  at ground,  $f_{CLK} = 1.048$  MHz (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP†	MAX	UNIT	
$V_{OH}$	High-level output voltage	$I_{OH} = -1.6$ mA	2.4			V	
$V_{OL}$	Low-level output voltage	$I_{OL} = 1.6$ mA			0.4	V	
$I_{IH}$	High-level input current	Any digital or Clock input	$V_{IH} = 5.5$ V		10	$\mu$ A	
		Any control input			1		
$I_{IL}$	Low-level input current	Any digital or Clock input	$V_{IL} = 0$		-10	$\mu$ A	
		Any control input			-1		
$I_{OZ}$	Off-state (high impedance-state) output current	$V_O = V_{CC}$			10	$\mu$ A	
		$V_O = 0$			-10		
$I_I$	Analog input current (see Note 4)	$V_I = 0$ to $V_{CC}$			$\pm 500$	nA	
	Leakage current between selected channel and all other analog channels	$V_I = 0$ to $V_{CC}$ , Clock input at 0 V			$\pm 400$	nA	
$C_i$	Input capacitance	Digital pins 3 thru 10			4	30	pF
		Any other input pin			2	15	
$I_{CC+I_{REF+}}$	Supply current plus reference current	$V_{CC} = V_{REF+} = 5.5$ V, Outputs open			1.3	3	mA
$I_{CC}$	Supply current	$V_{CC} = 5.5$ V			1.2	2	mA

NOTE 4: Analog input current is an average of the current flowing into a selected analog channel input during one full conversion cycle.

operating characteristics over recommended ranges  $V_{CC}$ ,  $V_{REF+}$ , and operating free-air temperature,  $V_{REF-}$  at ground,  $f_{clock} = 1.048$  MHz for TLC532A and  $f_{clock} = 1.048$  MHz for TLC533A (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP†	MAX	UNIT
	Linearity error	See Note 5			$\pm 0.5$	LSB
	Zero error	See Note 6			$\pm 0.5$	LSB
	Full-scale error	See Note 6			$\pm 0.5$	LSB
	Total unadjusted error	See Note 7			$\pm 0.5$	LSB
	Absolute accuracy error	See Note 8			$\pm 1$	LSB
$t_{conv}$	Conversion time (including channel acquisition time)			30		Clock Cycles
$t_{acq}$	Channel acquisition time			10		Clock Cycles
$t_{en}$	Data output enable time (see Note 9)	$C_L = 50$ pF, $R_L = 3$ k $\Omega$ ,			335	ns
$t_{dis}$	Data output disable time	$C_L = 50$ pF, $R_L = 3$ k $\Omega$	10			ns
$t_r(\text{bus})$	Data bus output rise time	High-impedance to high-level	$C_L = 50$ pF, $R_L = 3$ k $\Omega$		150	ns
		Low to high-level			300	
$t_f(\text{bus})$	Data bus output fall time	High-impedance to low-level	$C_L = 50$ pF, $R_L = 3$ k $\Omega$		150	ns
		High to low-level			300	

†Typical values are at  $V_{CC} = 5$  V,  $T_A = 25^\circ\text{C}$ .

NOTES: 5. Linearity error is the deviation from the best straight line through the A/D transfer characteristics.

6. Zero error is the difference between the output of an ideal and an actual A/D for zero input voltage; full-scale error is that same difference for full-scale input voltage.

7. Total unadjusted error is the sum of linearity, zero, and full-scale errors.

8. Absolute accuracy error is the maximum difference between an analog value and the nominal midstep value within any step. This includes all errors including inherent quantization error, which is the  $\pm 0.5$  LSB uncertainty caused by the A/D converter's finite resolution.

9. If chip-select setup time,  $t_{su}(\text{CS})$ , is less than 0.14 microseconds, the effective data output enable time,  $t_{en}$ , may extend such that  $t_{su}(\text{CS}) + t_{en}$  is equal to a maximum of 0.475 microseconds.



- LinCMOST™ Technology
- 8-Bit Resolution A/D Converter
- On-Chip 12-Channel Analog Multiplexer
- Built-In Self-Test Mode
- Software-Controllable Sample and Hold
- Total Unadjusted Error . . .  $\pm 0.5$  LSB Max
- Direct Replacement for Motorola MC145040

TYPICAL PERFORMANCE:	TLC540	TLC541
Channel Acquisition Time	2 $\mu$ s	7 $\mu$ s
Conversion Time	10 $\mu$ s	19 $\mu$ s
Sampling Rate	$71 \times 10^3$	$29 \times 10^3$
Power Dissipation	6 mW	6 mW

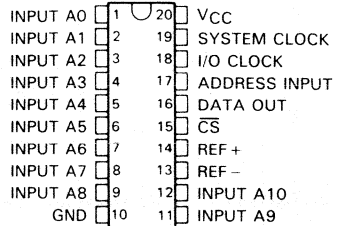
**description**

The TLC540 and TLC541 are LinCMOST™ A/D peripherals built around an 8-bit switched-capacitor successive-approximation A/D converter. They are designed for serial interface to a microprocessor or peripheral via a three-state output with up to four control inputs [including independent System Clock, I/O Clock, Chip Select (CS), and Address Input]. A 4-megahertz system clock for the TLC540 and a 2.1-megahertz system clock for the TLC541 with a design that includes simultaneous read/write operation allow high-speed data transfers and sample rates of up to 71,910 samples per second for the TLC540 and 29,144 samples per second for the TLC541. In addition to the high-speed converter and versatile control logic, there is an on-chip 12-channel analog multiplexer that can be used to sample any one of 11 inputs or an internal "self-test" voltage, and a sample-and-hold that can operate automatically or under processor control.

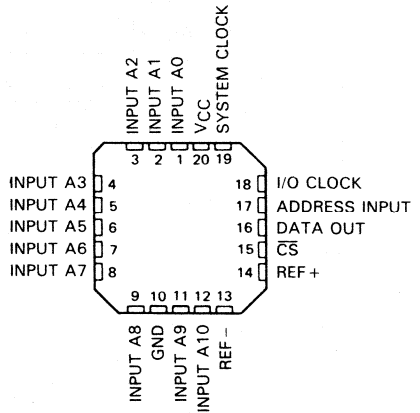
The converters incorporated in the TLC540 and TLC541 feature differential high-impedance reference inputs that facilitate ratiometric conversion, scaling, and analog circuitry isolation from logic and supply noises. A totally switched-capacitor design allows guaranteed low-error ( $\pm 0.5$  LSB) conversion in 10 microseconds for the TLC540 and 19 microseconds for the TLC541 over the full operating temperature range.

The TLC540M and the TLC541M are characterized for operation over the full military temperature range of  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ . The TLC540I and the TLC541I are characterized for operation from  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ .

J OR N DUAL-IN-LINE PACKAGE  
(TOP VIEW)

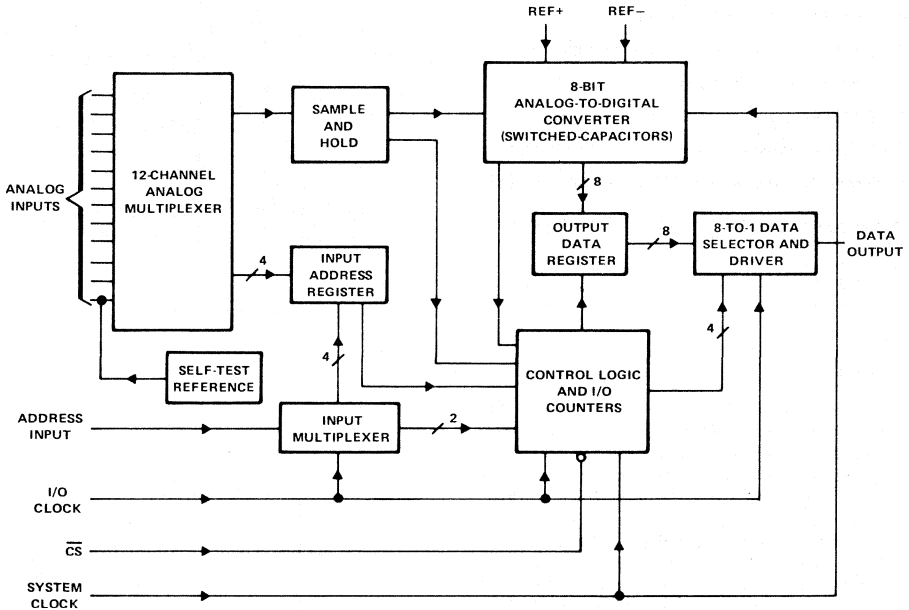


FK OR FN PACKAGE  
(TOP VIEW)

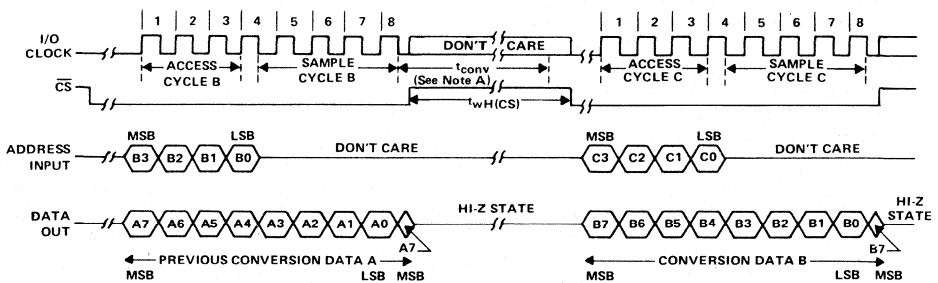


**TYPES TLC540M, TLC540I, TLC541M, TLC541I**  
**8-BIT ANALOG-TO-DIGITAL PERIPHERALS**  
**WITH SERIAL CONTROL AND 11 INPUTS**

functional block diagram



operating sequence



NOTE A: The conversion cycle, which requires 40 system clock periods, is initiated with the 8th I/O clock ↓ after CS ↓ for the channel whose address exists in memory at that time.

Data Acquisition

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# TYPES TLC540M, TLC540I, TLC541M, TLC541I

## 8-BIT ANALOG-TO-DIGITAL PERIPHERALS

### WITH SERIAL CONTROL AND 11 INPUTS

#### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1)	6.5 V
Input voltage range (any input)	-0.3 V to $V_{CC} + 0.3$ V
Output voltage range	-0.3 V to $V_{CC} + 0.3$ V
Peak input current range (any input)	$\pm 10$ mA
Peak total input current (all inputs)	$\pm 30$ mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	875 mW
Operating free-air temperature range: TLC540I, TLC541I	-40°C to 85°C
TLC540M, TLC541M	-55°C to 125°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: FK or J package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: FN or N package	260°C

- NOTES: 1. All voltage values are with respect to digital ground with REF- and GND wired together (unless otherwise noted).  
 2. For operation above 25°C free-air temperature, see Dissipation Derating Curves, Section 2. In the J package, TLC540M and TLC541M chips are alloy mounted, TLC540I and TLC541I chips are glass mounted.

#### recommended operating conditions

	TLC540			TLC541			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{CC}$	4.75	5	5.5	4.75	5	5.5	V
Positive reference voltage, $V_{REF+}$ (see Note 3)	1.25	$V_{CC}$	$V_{CC}+0.1$	1.25	$V_{CC}$	$V_{CC}+0.1$	V
Negative reference voltage, $V_{REF-}$ (see Note 3)	-0.1	0	$V_{CC}-1.25$	0.1	0	$V_{CC}-1.25$	V
Differential reference voltage, $V_{REF+} - V_{REF-}$ (see Note 3)	1	$V_{CC}$	$V_{CC}+0.2$	1	$V_{CC}$	$V_{CC}+0.2$	V
Analog input voltage (see Note 3)	0		$V_{CC}$	0		$V_{CC}$	V
High-level control input voltage, $V_{IH}$	2			2			V
Low-level control input voltage, $V_{IL}$			0.8			0.8	V
Setup time, address bits at data input before I/O CLK†, $t_{su}(A)$	200			400			ns
Setup time, $\overline{CS}$ low before clocking in first address bit, $t_{su}(CS)$ (see Note 4)	2			2			System clock cycles
Input/Output clock frequency, $f_{CLK(I/O)}$			2.048			0.525	MHz
System clock frequency, $f_{CLK(SYS)}$			$f_{CLK(I/O)}$			$f_{CLK(I/O)}$	MHz
System clock high, $t_{WH}(SYS)$			110			210	ns
System clock low, $t_{WL}(SYS)$			100			190	ns
Input/Output clock high, $t_{WH(I/O)}$			200			808	ns
Input/Output clock low, $t_{WL(I/O)}$			200			808	ns
Clock transition time (see Note 5)	System	$f_{CLK(SYS)} \leq 1048$ kHz		30		30	ns
		$f_{CLK(SYS)} > 1048$ kHz		20		20	
	I/O	$f_{CLK(I/O)} \leq 525$ kHz		100		100	ns
		$f_{CLK(I/O)} > 525$ kHz		40		40	
Operating free-air temperature, $T_A$	TLC540M, TLC541M	-55	125	-55	125	°C	
	TLC540I, TLC541I	-40	85	-40	85		

- NOTES: 3. Analog input voltages greater than that applied to REF+ convert as all "1"s (11111111), while input voltages less than that applied to REF- convert as all "0"s (00000000). For proper operation, REF+ voltage must be at least 1 volt higher than REF- voltage. Also, adjusted errors may increase as this differential reference voltage falls below 4.75 volts.
4. To minimize errors caused by noise at the Chip Select input, the internal circuitry waits for two system clock cycles (or less) after a chip select falling edge is detected before responding to control input signals. Therefore, no attempt should be made to clock-in address data until the chip select setup time has elapsed.
5. This is the time required for the clock input signal to fall from  $V_{IH}$  min to  $V_{IL}$  max or to rise from  $V_{IL}$  max to  $V_{IH}$  min.

# TYPES TLC540M, TLC540I, TLC541M, TLC541I

## 8-BIT ANALOG-TO-DIGITAL PERIPHERALS

### WITH SERIAL CONTROL AND 11 INPUTS

electrical characteristics over recommended operating temperature range,  
 $V_{CC} = V_{REF+} = 4.75 \text{ V to } 5.5 \text{ V}$  (unless otherwise noted),  $f_{CLK(I/O)} = 2.028 \text{ MHz}$  for TLC540 or  $f_{CLK(I/O)} = 0.525 \text{ MHz}$  for TLC541

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
V <sub>OH</sub>	High-level output voltage (pin 16)	$V_{CC} = 4.75 \text{ V}$ , $I_{OH} = 360 \mu\text{A}$	2.4			V
V <sub>OL</sub>	Low-level output voltage	$V_{CC} = 4.75 \text{ V}$ , $I_O = 3.2 \text{ mA}$			0.4	V
I <sub>OZ</sub>	Off-state (high-impedance state) output current	$V_O = V_{CC}$ , $\overline{CS}$ at $V_{CC}$			10	$\mu\text{A}$
		$V_O = 0$ , $\overline{CS}$ at $V_{CC}$			-10	
I <sub>IH</sub>	High-level input current	$V_I = V_{CC} + 0.3 \text{ V}$		0.005	2.5	$\mu\text{A}$
I <sub>IL</sub>	Low-level input current	$V_I = 0$	-0.005	-2.5		$\mu\text{A}$
I <sub>CC</sub>	Operating supply current	$\overline{CS}$ at 0 V		1.2	2	mA
Selected channel leakage current		Selected channel at $V_{CC}$ , Unselected channel at 0 V		0.4	1	$\mu\text{A}$
		Selected channel at 0 V, Unselected channel at $V_{CC}$		-0.4	-1	
I <sub>CC</sub> + I <sub>REF</sub>		Supply and reference current $V_{REF+} = V_{CC}$ , $\overline{CS}$ at 0 V		1.3	3	mA
C <sub>i</sub>	Input capacitance	Analog inputs		7	55	pF
		Control inputs		5	15	

<sup>†</sup>All typical values are at  $T_A = 25^\circ\text{C}$ .

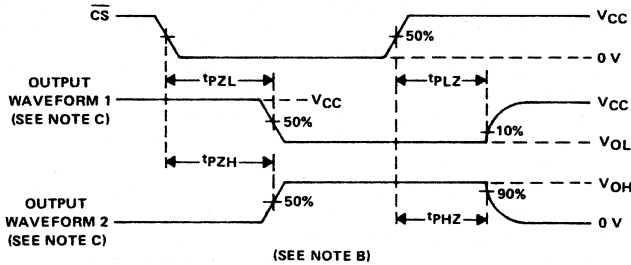
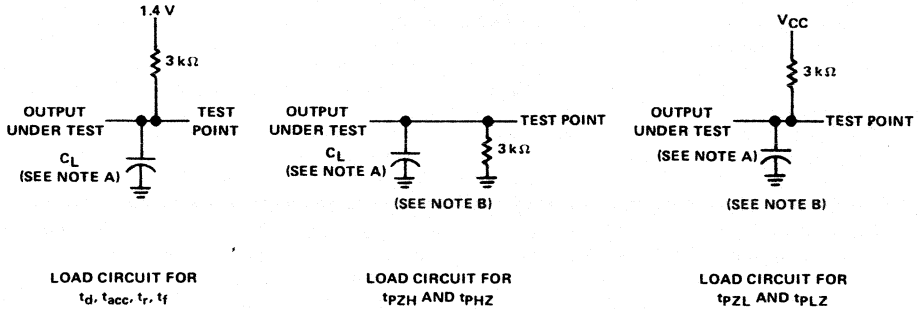
operating characteristics over recommended operating free-air temperature range,  
 $V_{CC} = V_{REF+} = 4.75 \text{ V to } 5.5 \text{ V}$ ,  $f_{CLK(I/O)} = 2.048 \text{ MHz}$  for TLC540 or  
 $0.525 \text{ MHz}$  for TLC541,  $f_{CLK(SYS)} = 4 \text{ MHz}$  for TLC540 or  $2.097 \text{ MHz}$  for TLC541.

PARAMETER	TEST CONDITIONS	TLC540		TLC541		UNIT	
		MIN	TYP	MAX	MIN		TYP
Linearity error	See Note 6			$\pm 0.5$		$\pm 0.5$	LSB
Zero error	See Note 7			$\pm 0.5$		$\pm 0.5$	LSB
Full-scale error	See Note 7			$\pm 0.5$		$\pm 0.5$	LSB
Total unadjusted error	See Note 8			$\pm 0.5$		$\pm 0.5$	LSB
Self-test output code	Input address = 1011 (A11) (See Note 9)	01111101 (125)		10000011 (131)	01111101 (125)	10000011 (131)	
t <sub>conv</sub>	Conversion time			10		19	$\mu\text{s}$
t <sub>acq</sub>	Channel acquisition time			4		4	I/O clock cycles
t <sub>v</sub>	Time output data remains valid after I/O clock↓		10		10		ns
t <sub>d</sub>	Delay time, I/O clock↓ to data output valid			200		400	ns
t <sub>acc</sub>	Output access time (delay to valid output after chip select↓)		1	3	1	3	System clock cycles
t <sub>en</sub>	Output enable time					150	ns
t <sub>dis</sub>	Output disable time			150		150	ns
t <sub>r(bus)</sub>	Data bus rise time			300		300	ns
t <sub>f(bus)</sub>	Data bus fall time			300		300	ns

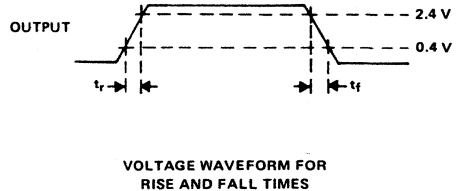
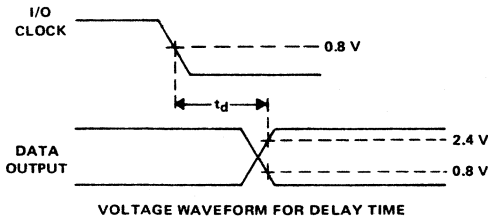
- NOTES: 6. Linearity error is the maximum deviation from the best straight line through the A/D transfer characteristics.  
7. Zero Error is the difference between the output of an ideal and an actual A/D for zero input voltage; full-scale error is that same difference for full-scale input voltage.  
8. Total Unadjusted Error is the sum of linearity, zero, and full-scale errors.  
9. Both the input address and the output codes are expressed in positive logic.

# TYPES TLC540M, TLC540I, TLC541M, TLC541I 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH SERIAL CONTROL AND 11 INPUTS

## PARAMETER MEASUREMENT INFORMATION



VOLTAGE WAVEFORMS FOR ENABLE AND DISABLE TIMES



NOTES: A.  $C_L = 50$  pF for TLC540 and 100 pF for TLC541

B.  $t_{en} = t_{pZH}$  or  $t_{pZL}$ ;  $t_{dis} = t_{pHZ}$  or  $t_{pLZ}$

C. Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high except when disabled by the output control.

# TYPES TLC540M, TLC540I, TLC541M, TLC541I

## 8-BIT ANALOG-TO-DIGITAL PERIPHERALS WITH SERIAL CONTROL AND 11 INPUTS

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### principles of operation

The TLC540 and TLC541 are each complete data acquisition systems on a single chip. They include such functions as analog multiplexer, sample-and-hold, 8-bit A/D converter, data and control registers, and control logic. For flexibility and access speed, there are four control inputs [two clocks, chip select ( $\overline{CS}$ ), and address]. These control inputs and a TTL-compatible 3-state output are intended for serial communications with a microprocessor or microcomputer. With judicious interface timing, with TLC540 a conversion can be completed in 10 microseconds, while complete input-conversion-output cycles are being repeated every 14 microseconds. With TLC541 a conversion can be completed in 19 microseconds, while complete input-conversion-output cycles are repeated every 35 microseconds. Furthermore, this fast conversion can be executed on any of 11 inputs or its built-in "self-test," and in any order desired by the controlling processor.

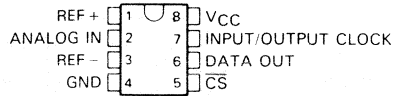
Though they can be operated "tied" together, the System Clock and I/O Clock are normally used independently, with no special phase or speed relationship to be considered. This allows integrated circuit operation to continue independent of serial Input/Output timing, permitting manipulation of the I/O Clock as desired for a wide range of software and hardware needs.

The I/O Clock, Data Input, and Data Output are controlled by  $\overline{CS}$ . It floats the 3-state output and shuts off signals to other control inputs while it is high. This allows any pins except pin 15 to share lines with other integrated circuits. A normal control sequence is as follows: (1)  $\overline{CS}$  goes low; (2) a new positive-logic multiplexer address is clocked in through the address input on the first four I/O Clock rising edges while previous conversion results are brought out on the first seven I/O Clock falling edges. Input and output most-significant bits (MSB) are first, with the output MSB available at the start of the cycle; (3) the on-chip sample-and-hold begins sampling a newly addressed input after the 4th falling edge, and goes into the hold mode on the 8th falling I/O Clock edge just before conversion; (4)  $\overline{CS}$  must then go high or the I/O Clock must remain low for at least 40 system clock cycles to allow conversion. A new address may then be loaded or the previous conversion results read any time  $\overline{CS}$  is brought low, but it should be noted that any pending conversion may stop.

The instant that the TLC540 or TLC541 holds a sample of the analog input, conversion can be determined under software control (or by external logic), by keeping the 8th I/O Clock cycle high. Any output data will have already been shifted out, and TLC540 or TLC541 will continue sampling a new analog input. At the desired time, the I/O Clock signal can then be lowered freezing the voltage and turning off all analog inputs. In this manner, signals can be sampled at precise intervals for a wide range of comparison or processing applications, in much the same manner as a strobe light is used to determine engine speed.

- LinCMOST™ Technology
- 8-Bit Resolution A/D Converter
- Differential Reference Input Voltages
- Conversion Time . . . 19  $\mu$ s Max
- Total Access and Conversion Cycles . . . 29,144 cps
- On-Chip Software-Controllable Sample-and-Hold
- Total Unadjusted Error . . .  $\pm 0.5$  LSB Max
- 4-MHz Internal System Clock
- Single 5-V Supply Operation
- Low Power Consumption . . . 6 mW Typ
- Dual-In-Line 8-pin Package

P DUAL-IN-LINE PACKAGE  
(TOP VIEW)



**description**

The TLC549 is a LinCMOST™ A/D Peripheral integrated circuit built around an 8-bit switched-capacitor successive-approximation A/D converter. It is designed for serial interface with a microprocessor or peripheral through a 3-state data output and an analog input. The TLC549 uses only the Input/Output Clock (I/O Clock) input along with the Chip Select (CS) input for data control. The I/O Clock input frequency of the TLC549 is guaranteed up to 525 kilohertz.

Operation of the TLC549 is very similar to that of the more complex TLC540 and TLC541 devices; however, unlike the TLC540 and TLC541, the TLC549 provides an on-chip system clock that operates typically at 4 megahertz and requires no external components. The on-chip system clock allows internal device operation to proceed independently of serial input/output data timing, permitting manipulation of the TLC549 as desired for a wide range of software and hardware requirements. The I/O Clock together with the internal system clock allow high-speed data transfer and sample rates of up to 29,144 cycles per second.

Additional TLC549 features include versatile control logic, an on-chip sample-and-hold circuit that can operate automatically or under processor control, and a high-speed converter with differential high-impedance reference voltage inputs that ease ratiometric conversion, scaling, and analog circuit isolation from logic and supply noises. Design of the totally switched-capacitor successive-approximation converter circuit allows guaranteed low-error conversion of  $\pm 0.5$  least-significant bit (LSB) in less than 19 microseconds.

The TLC549M is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The TLC549I is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .





# TYPE TLC549

## LinCMOST™ 8-BIT ANALOG-TO-DIGITAL PERIPHERAL WITH SERIAL CONTROL

### recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	3	5	6	V
Positive reference voltage, $V_{REF+}$ (see Note 3)	1.25	$V_{CC}$	$V_{CC} + 0.1$	V
Negative reference voltage, $V_{REF-}$ (see Note 3)	-0.1	0	$V_{CC} - 1.25$	V
Differential reference voltage, $V_{REF+} - V_{REF-}$ (see Note 3)	1	$V_{CC}$	$V_{CC} + 0.2$	V
Analog input voltage (see Note 3)	0		$V_{CC}$	V
High-level control input voltage, $V_{IH}$	2			V
Low-level control input voltage, $V_{IL}$			0.8	V
Peak input current, $I_I$			10	mA
Input/Output clock frequency, $f_{CLK(I/O)}$	0		525	kHz
Input/Output clock high, $t_{wH(I/O)}$	808			ns
Input/Output clock low, $t_{wL(I/O)}$	808			ns
Input/Output clock transition time, $t_{f(I/O)}$ (see Note 4)			100	ns
Duration of $\overline{CS}$ input high state during conversion, $t_{wH(CS)}$	19			$\mu$ s
Operating free-air temperature, $T_A$	TLC549M	-55	125	$^{\circ}$ C
	TLC549I	-40	85	

- NOTES: 3. Analog input voltages greater than that applied to  $REF+$  convert as all ones (11111111), while input voltages less than that applied to  $REF-$  convert to all zeros (00000000). For proper operation, the positive reference voltage  $V_{REF+}$  must be at least 1-volt greater than the negative reference voltage  $V_{REF-}$ . In addition, unadjusted errors may increase as the differential reference voltage  $V_{REF+} - V_{REF-}$  falls below 4.75 volts.
4. This is the time required for the input/output clock input signal to fall from  $V_{IH}$  min to  $V_{IL}$  max or to rise from  $V_{IL}$  max to  $V_{IH}$  min.

### electrical characteristics over recommended operating free-air temperature range, $V_{CC} = V_{REF+} = 4.75$ V to 5.5 V, $f_{CLK(I/O)} = 525$ kHz (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>†</sup>	MAX	UNIT
$V_{OH}$	High-level output voltage	$V_{CC} = 4.75$ V, $I_{OH} = -360$ $\mu$ A	2.4			V
$V_{OL}$	Low-level output voltage	$V_{CC} = 4.75$ V, $I_{OL} = 3.2$ mA			0.4	V
$I_{OZ}$	Off-state (high-impedance state) output current	$V_O = V_{CC}$ , $\overline{CS}$ at $V_{CC}$			10	V
		$V_O = 0$ , $\overline{CS}$ at $V_{CC}$			-10	
$I_{IH}$	High-level input current	Control inputs $V_I = V_{CC} + 0.3$ V		0.005	2.5	$\mu$ A
$I_{IL}$	Low-level input current	Control inputs $V_I = 0$		-0.005	-2.5	$\mu$ A
$I_{I(on)}$	Analog channel on-state input current, during sample cycle	Analog input at $V_{CC}$		0.4	1	$\mu$ A
		Analog input at 0 V		-0.4	-1	
$I_{CC}$	Operating supply current	$\overline{CS}$ at 0 V		1.2	2	mA
$I_{CC} + I_{REF}$	Supply and reference current	$V_{REF+} = V_{CC}$		1.3	3	mA
$C_i$	Input capacitance	Analog inputs		7	55	pF
		Control inputs		5	15	

<sup>†</sup>All typicals are at  $T_A = 25^{\circ}$ C.

**TYPE TLC549**  
**LinCMOSTM 8-BIT ANALOG-TO-DIGITAL**  
**PERIPHERAL WITH SERIAL CONTROL**

operating characteristics over recommended operating free-air temperature range,  
 $V_{CC} = V_{REF+} = 4.75\text{ V to }5.5\text{ V}$ ,  $f_{CLK(I/O)} = 525\text{ kHz}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Linearity error	See Note 5			± 0.5	LSB
Zero error	See Note 6			± 0.5	LSB
Full-scale error	See Note 6			± 0.5	LSB
Total unadjusted error	See Note 7			± 0.5	LSB
$t_{conv}$	Conversion time			19	μs
$t_{acq}$	Channel acquisition time			4	I/O Clock Cycles
$t_v$	Time output data remains valid after I/O clock↓	10			ns
$t_d$	Delay time, internal system clock to data output valid			400	ns
$t_{acc}$	Output access time (Delay to valid output after $\overline{CS}\downarrow$ )			975	ns
$t_{en}$	Output enable time			150	ns
$t_{dis}$	Output disable time			150	ns
$t_{r(bus)}$	Data bus rise time			300	ns
$t_{f(bus)}$	Data bus fall time			300	ns

- NOTES: 5. Linearity error is the deviation from the best straight line through the A/D transfer characteristics.  
6. Zero error is the difference between the output of an ideal and an actual A/D converter for zero input voltage; full-scale error is that same difference for full-scale input voltage.  
7. Total unadjusted error is the sum of linearity, zero, and full-scale errors.

# Linear Circuits

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General Information

1

Thermal Information

2

Operational Amplifiers

3

Voltage Comparators

4

Special Functions

5

Voltage Regulators

6

Data Acquisition

7

Appendix

A

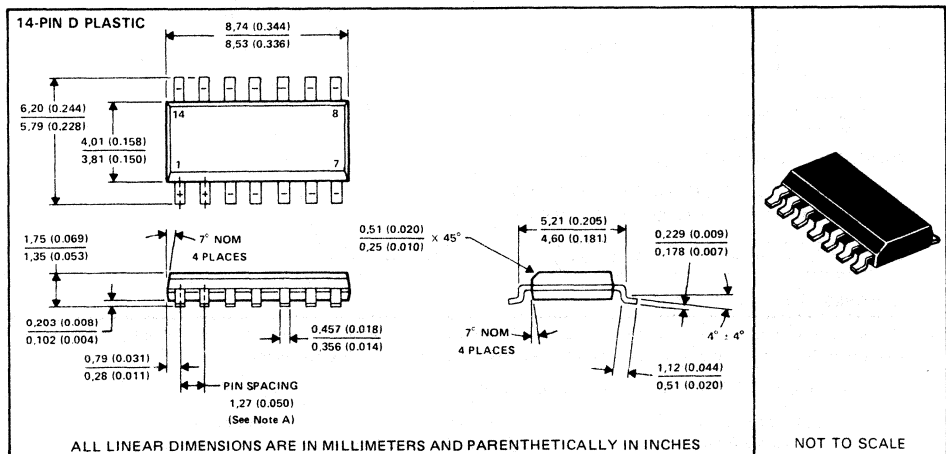
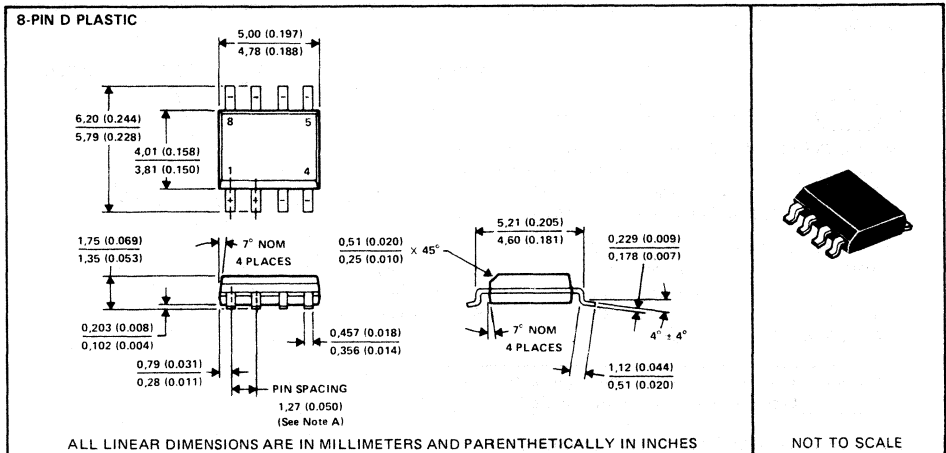




# MECHANICAL DATA

## D plastic dual-in-line packages

Each of these dual-in-line packages consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation, and circuit performance characteristics will remain stable when operated in high-humidity conditions. Leads require no additional cleaning or processing when used in soldered assembly.



NOTE A: Each pin centerline is located within 0,25 (0.010) of its true longitudinal position.

Appendix

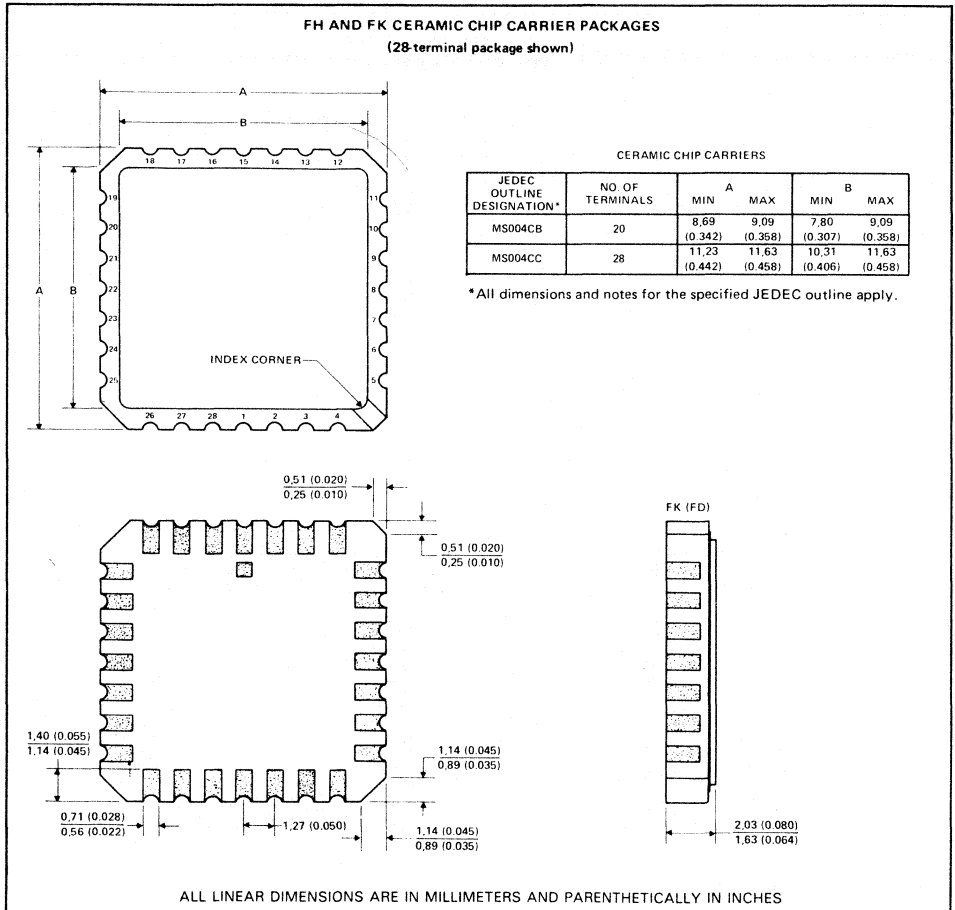
**A**

**FH and FK ceramic chip carrier packages**

Both versions of these hermetically sealed chip carrier packages have ceramic bases. The FH package is an all-ceramic package with a glass seal. The FK package has a three-layer base with a metal lid and braze seal.

The packages are intended for surface mounting on solder lands on 1,27 (0.050) centers. Terminals require no additional cleaning or processing when used in soldered assembly.

FH and FK package terminal assignments conform to JEDEC Standards 1 and 2.



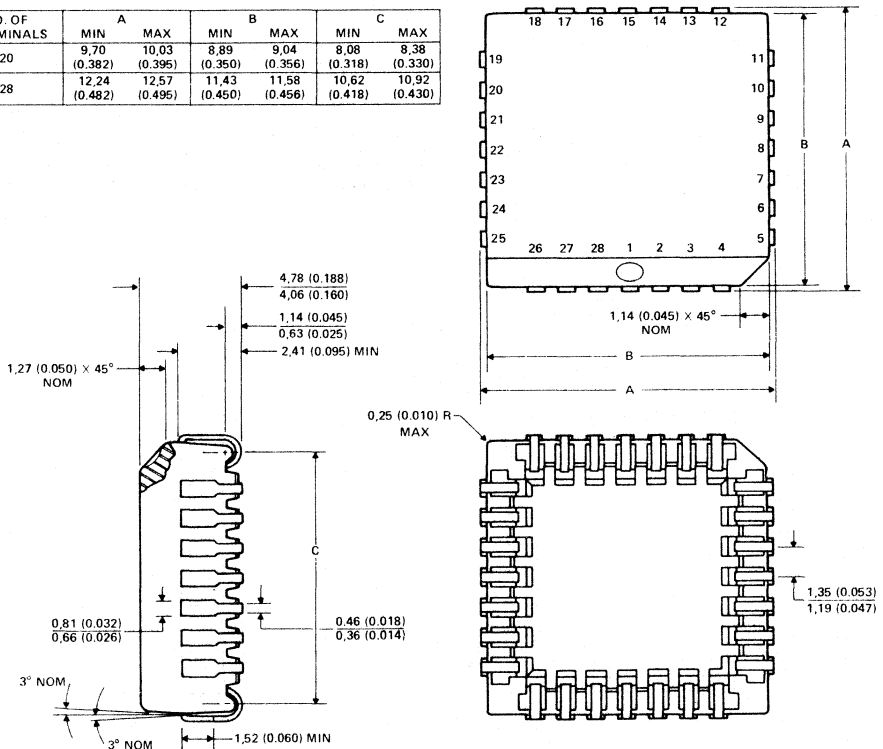
# MECHANICAL DATA

## FN plastic chip carrier package

Each of these chip carrier packages consists of a circuit mounted on a lead frame and encapsulated within an electrically nonconductive plastic compound. The compound withstands soldering temperatures with no deformation, and circuit performance characteristics remain stable when the devices are operated in high-humidity conditions. The packages are intended for surface mounting on solder lands on 1,27 (0.050) centers. Leads require no additional cleaning or processing when used in soldered assembly.

FN PLASTIC CHIP CARRIER PACKAGE  
(28-terminal package shown)

NO. OF TERMINALS	A		B		C	
	MIN	MAX	MIN	MAX	MIN	MAX
20	9,70 (0.382)	10,03 (0.395)	8,89 (0.350)	9,04 (0.356)	8,08 (0.318)	8,38 (0.330)
28	12,24 (0.482)	12,57 (0.495)	11,43 (0.450)	11,58 (0.456)	10,62 (0.418)	10,92 (0.430)



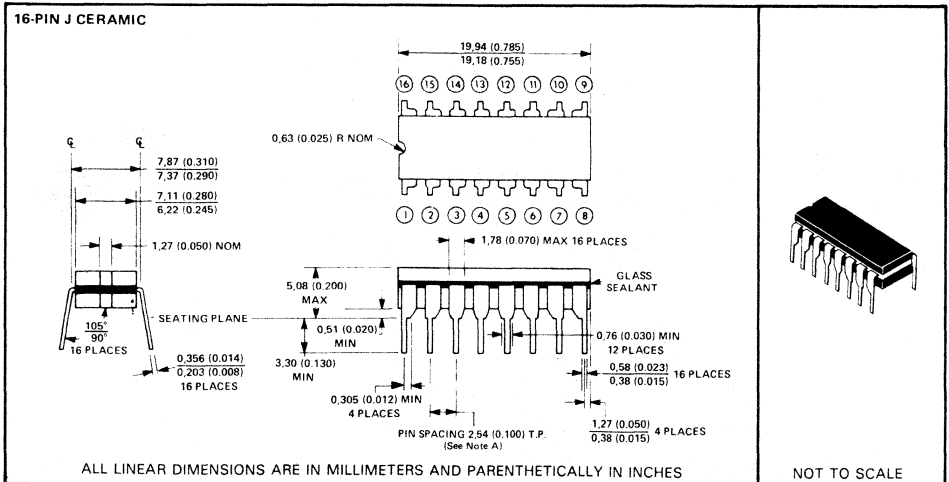
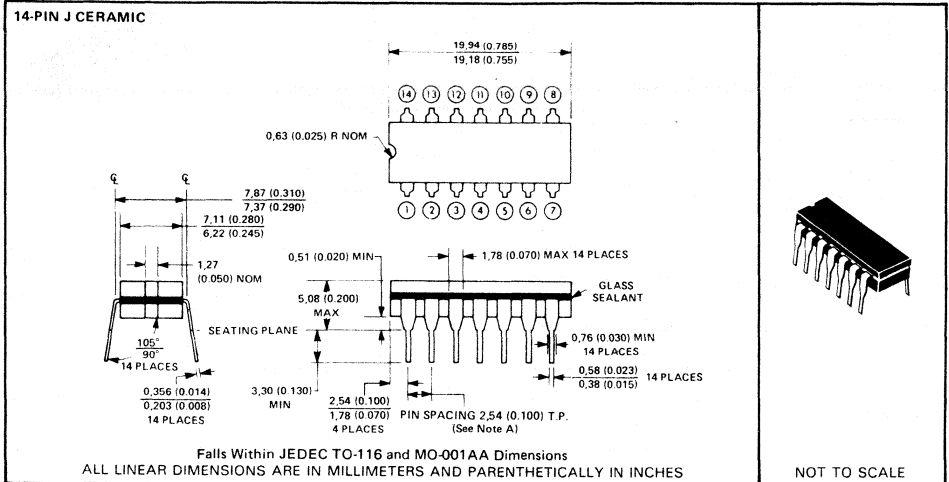
ALL LINEAR DIMENSIONS ARE IN MILLIMETERS AND PARENTHETICALLY IN INCHES

Appendix  
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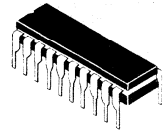
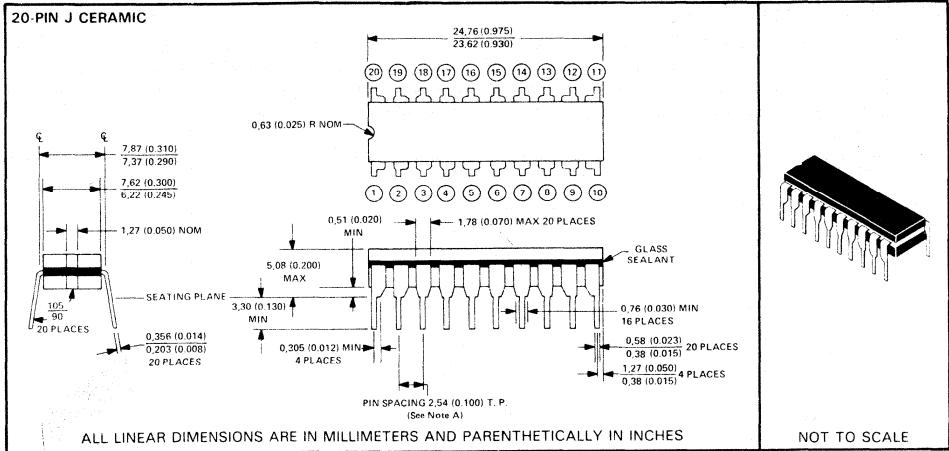
**J ceramic dual-in-line packages**

Each of these hermetically sealed dual-in-line packages consists of a ceramic base, ceramic cap, and a lead frame. Hermetic sealing is accomplished with glass. The packages are intended for insertion in mounting-hole rows on 7,62 (0.300) centers (see Note A). Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Leads require no additional cleaning or processing when used in soldering assembly.



NOTE A: Each pin centerline is located within 0.25 (0.010) of its true longitudinal position.

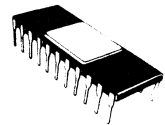
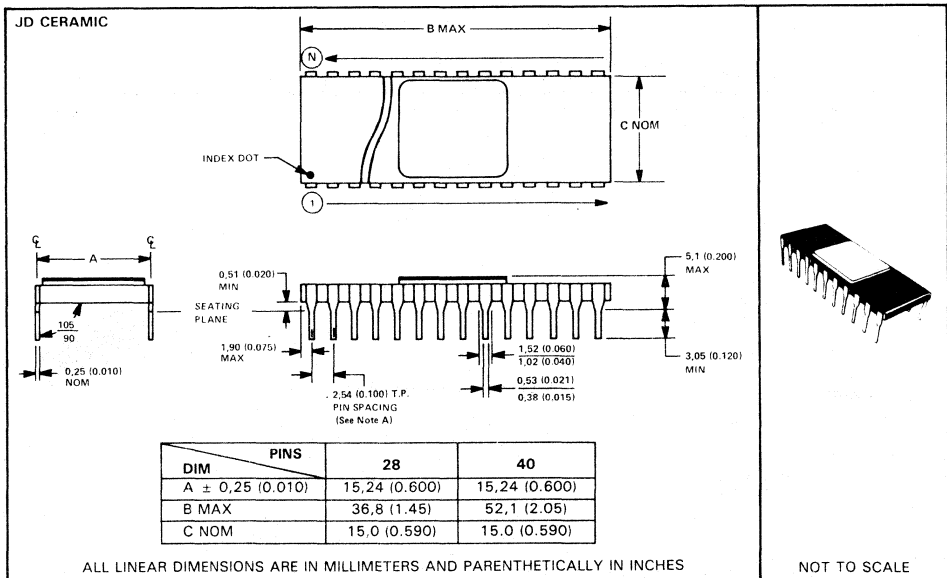
# MECHANICAL DATA



NOT TO SCALE

## ceramic dual-in-line packages—side-braze (JD)

This is a hermetically sealed ceramic package with a metal cap and side-brazed tin-plated leads.



NOT TO SCALE

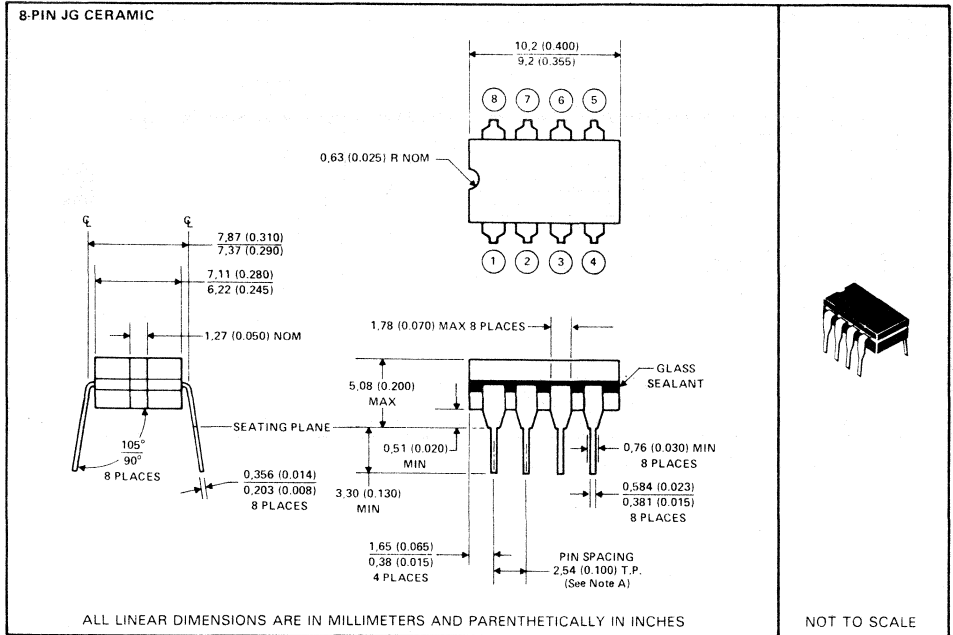
NOTE A: Each pin centerline is located within 0,25 (0.010) of its true longitudinal position.

Appendix

A

JG ceramic dual-in-line package

This hermetically sealed dual-in-line package consists of a ceramic base, ceramic cap, and a lead frame. The package is intended for insertion in mounting-hole rows 7,62 (0.300) centers (see Note A). Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering.

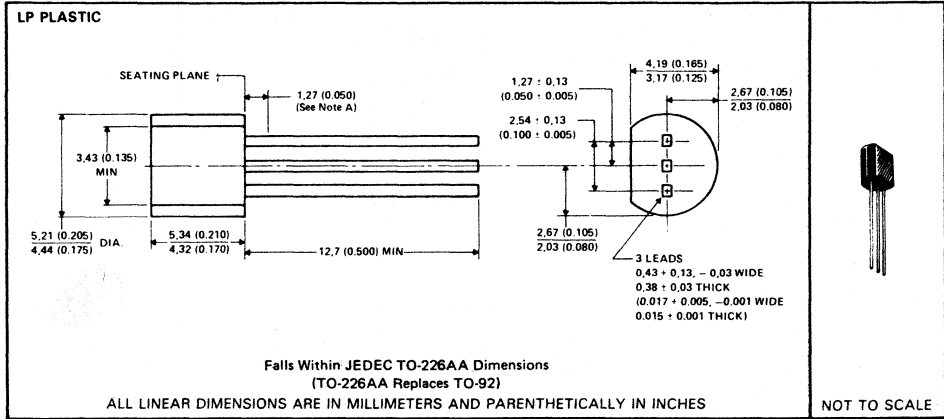


NOTE A: Each pin centerline is located within 0.25 (0.010) of its true longitudinal position.

# MECHANICAL DATA

## LP plastic package

These packages each consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation and circuit performance characteristics remain stable when operated in high-humidity conditions. Leads require no additional cleaning or processing when used in soldered assembly.



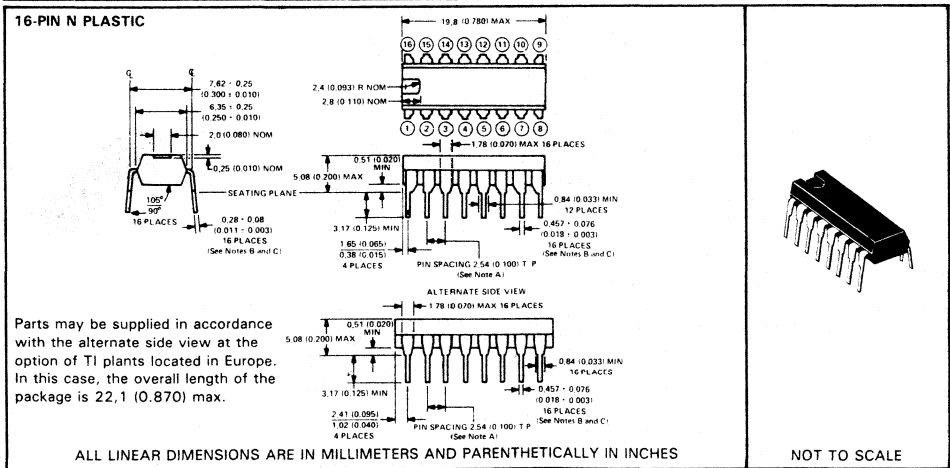
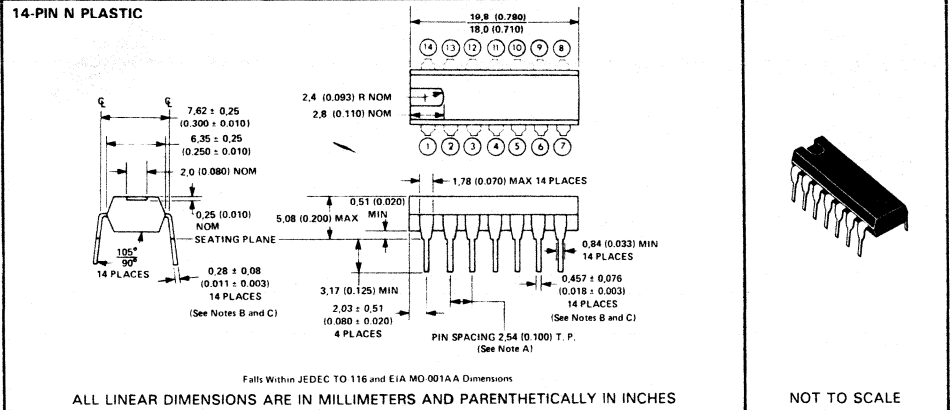
NOTE A: Lead dimensions are not controlled within this area.

Appendix

A

**N plastic dual-in-line package**

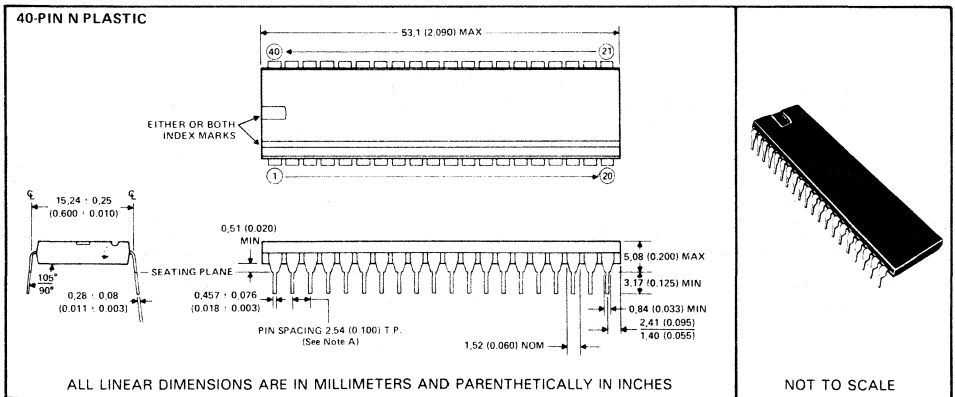
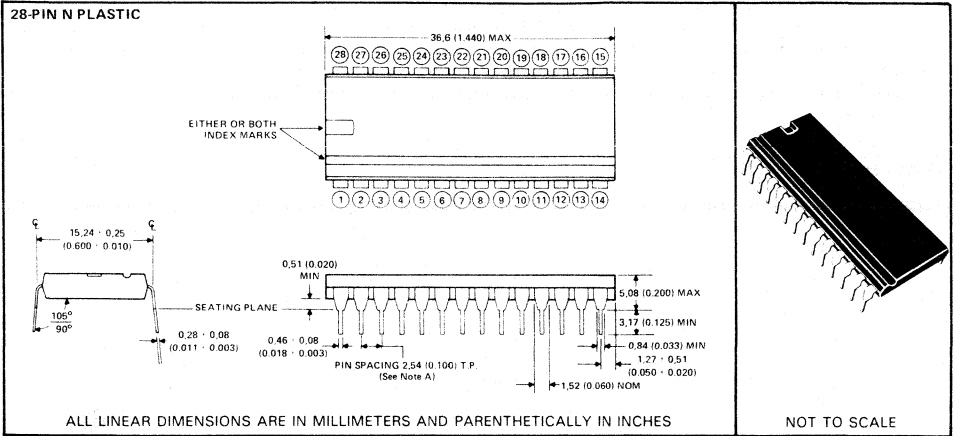
Each of these dual-in-line packages consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation, and circuit performance characteristics will remain stable when operated in high-humidity conditions. The packages are intended for insertion in mounting-hole rows on 7,62 (0.300) or 15,24 (0.600) centers (see Note A). Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Leads require no additional cleaning or processing when used in soldered assembly.



- NOTES: A. Each pin centerline is located within 0,25 (0.010) of its true longitudinal position. This dimension does not apply for solder-dipped leads.  
 B. When solder-dipped leads are specified, dipped area of the lead extends from the lead tip to at least 0,51 (0.020) above seating plane.



N plastic packages (continued)



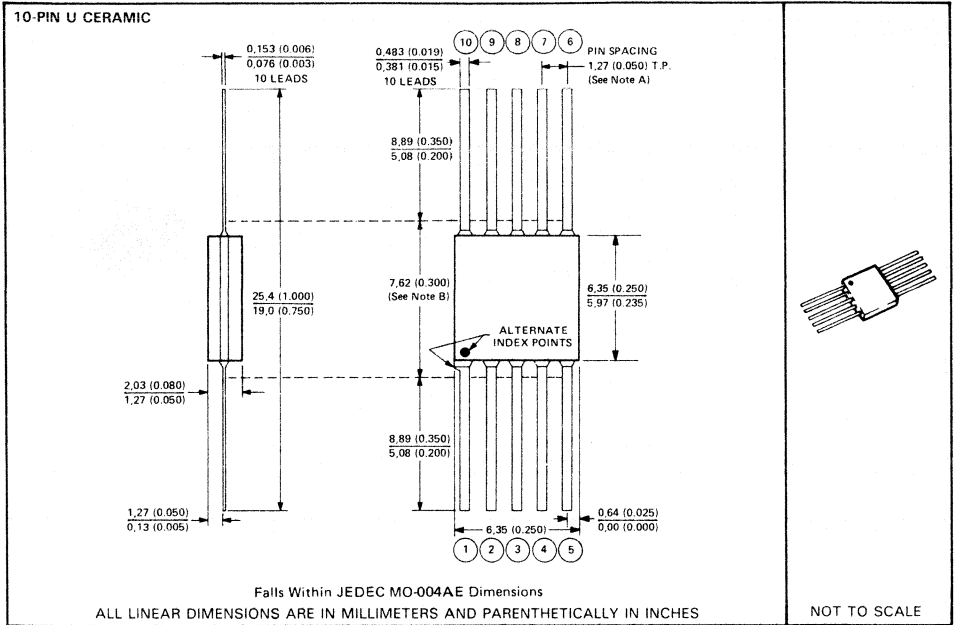
NOTE A: Each pin centerline is located within 0.25 (0.010) of its true longitudinal position.





U ceramic flat packages

This flat package consists of a ceramic base, ceramic cap, and lead frame. Circuit bars are alloy mounted. Hermetic sealing is accomplished with glass. Leads require no additional cleaning or processing when used in soldered assembly.

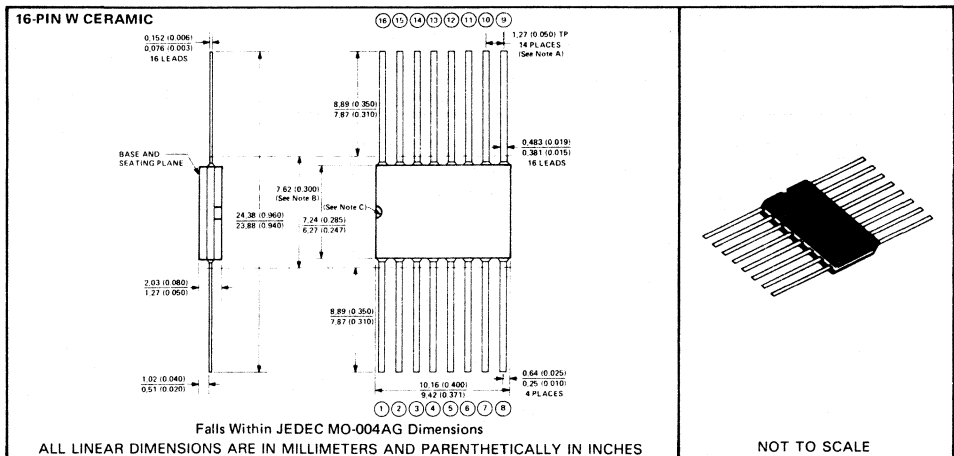
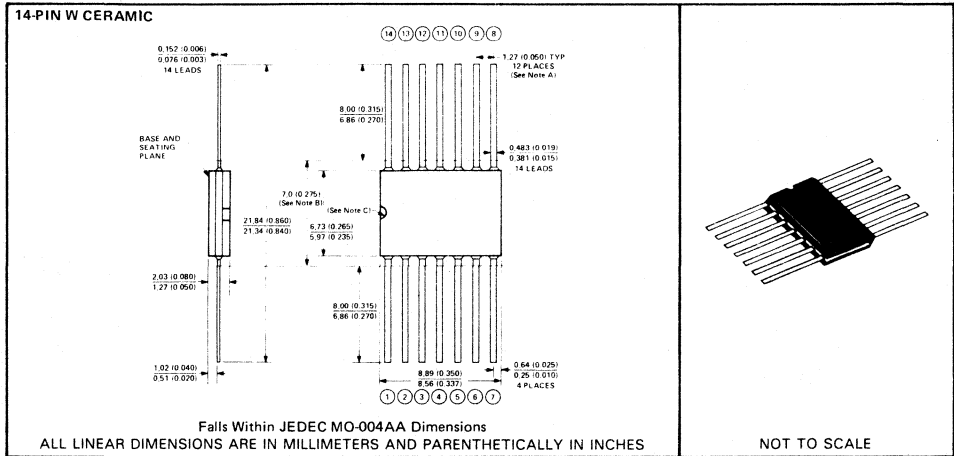


- NOTES: A. Leads are within 0.005 radius of true position (TP) at maximum material condition.  
B. T<sub>15</sub> this dimension determines a zone within which all body and lead irregularities lie.

# MECHANICAL DATA

## W ceramic flat packages

These hermetically sealed flat packages consist of an electrically nonconductive ceramic base and cap and a lead frame. Hermetic sealing is accomplished with glass. Leads require no additional cleaning or processing when used in soldered assembly.



NOTES: A. Leads are within 0,13 (0.005) radius of true position (TP) at maximum material condition.  
B. This dimension determines a zone within which all body and lead irregularities lie.  
C. Index point is provided on cap for terminal identification only.

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