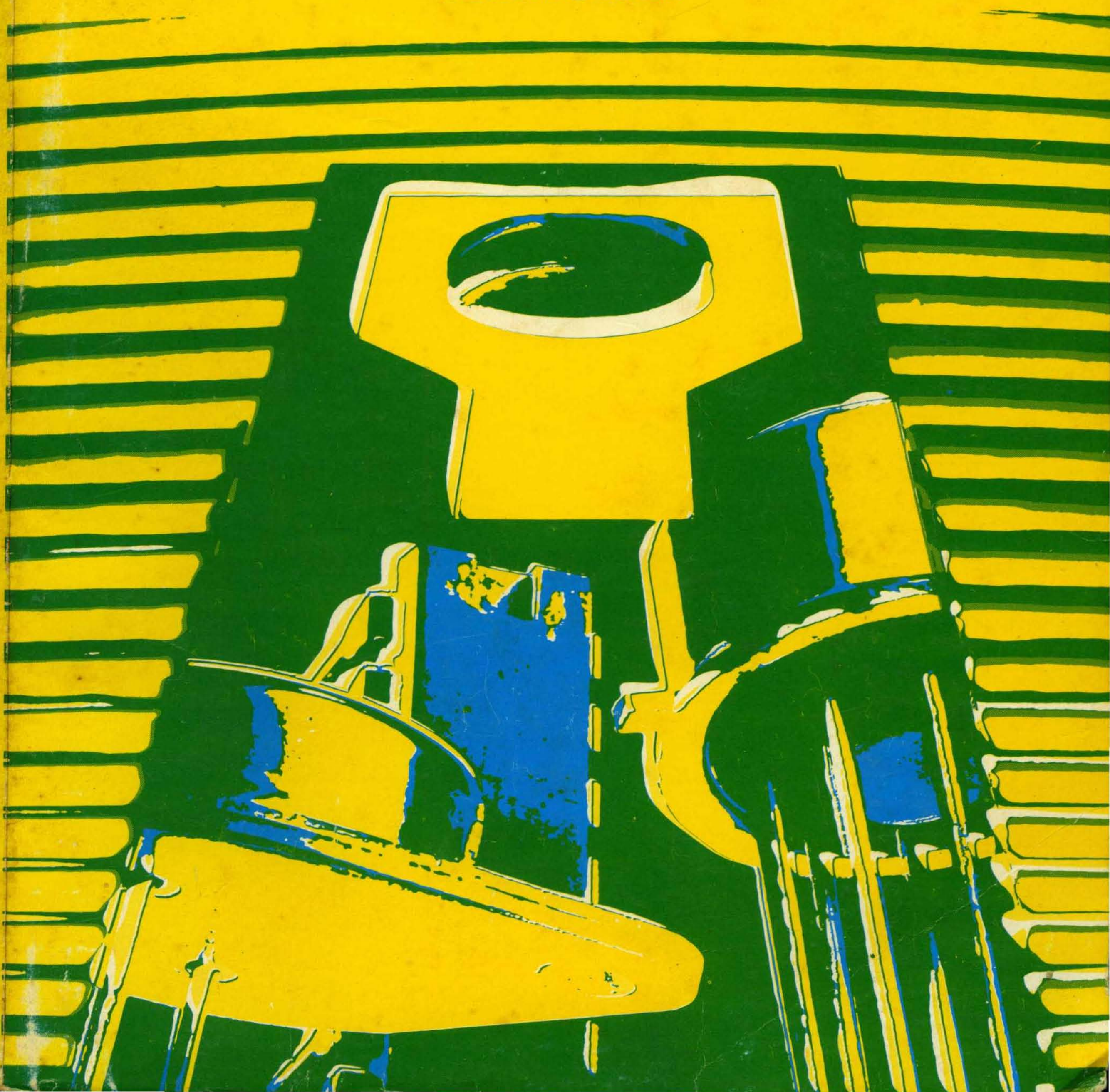
LINEAR
INTEGRATED CIRCUITS

National



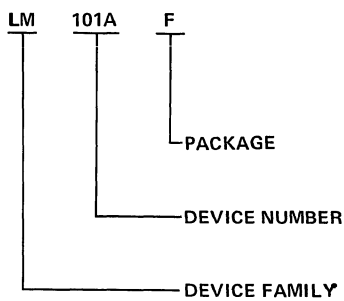
LINEAR INTEGRATED CIRCUITS FEB 1975 National

Edge Index by Product Family

Here is the new Linear Data Handbook from National. It gives complete specifications for devices useful in building nearly all types of electronic systems, from communications and consumer oriented circuits to precision instrumentation and computer designs.

For information regarding newer devices introduced since the printing of this handbook, or for further information on listed parts, please contact our local representative, distributor, or regional office.

Ordering Information



PACKAGE

D – Glass/Metal Dual-In-Line Package
F – Glass/Metal Flat Pack
H – TO-5 (TO-99, TO-100, TO-46)
J – Low Temperature Glass Dual-In-Line Package
K – TO-3, TO-66
M – "Wide-Track" Power Plastic Dual-In-Line Package
N – Plastic Dual-In-Line Package
P – TO-202 (D-40, Durawatt)
R – "DIACON" Type Dual-In-Line Package
S – "SGS" Type Power Dual-In-Line Package
T – TO-220
W – Low Temperature Glass Flat-Pack
Z – TO-92

DEVICE NUMBER

3, 4, or 5 Digit Number Suffix Indicators:
A – Improved Electrical Specification
C – Commercial Temperature Range

DEVICE FAMILY

AH – Analog Hybrid
AM – Analog Monolithic
LF – Linear FET
LH – Linear Hybrid
LM – Linear Monolithic
LX – Transducer
MM – MOS Monolithic

Devices are listed in the table of contents alpha-numerically by device family (LH, LM, LX, etc.) and then by device number. **With most of National's proprietary linear circuits, a 1-2-3 numbering system is employed. The 1 denotes a Military temperature range device (−55°C to +125°C), the 2 denotes an Industrial temperature range device (−25°C to +85°C), and the 3 denotes a Commercial temperature range device (0°C to +70°C), i.e. LM101/LM201/LM301.**

Exceptions to this are the LM1800 series of consumer circuits which are specified for the commercial temperature range; some hybrid circuits which employ a "C" suffix to denote the commercial temperature range; and second-source products which follow the original manufacturers numbering system, i.e. LM741/LM741C or LM1414/LM1514.

Parts are generally listed in the table of contents by military part number first, i.e. LM139/LM239/LM339. Where a separate data sheet exists for a different temperature range, the device will be listed separately, i.e. LM119/LM219 and listed separately LM319. Where only one temperature range exists, the part will be listed in its proper order, i.e. LM340.

National Product Catalogs

CMOS INTEGRATED CIRCUITS
Gates
Buffers
Flip-Flops
Counters
Shift Registers
Decoders/Multiplexers
Memories
Arithmetic Functions
Special Functions

DIGITAL INTEGRATED CIRCUITS
Series 54/74
Series 54H/74H
Series 54L/74L
Series 74S
Series 930
Series 9000
Series 10,000

INTERFACE INTEGRATED CIRCUITS
Level Translators/Buffers
Memory/Clock Drivers
Line Drivers/Receivers
Peripheral/Power Drivers
Display Drivers
Sense Amplifiers
Applications

JFET TRANSISTORS
Specifications
Applications
Curves
Selection Guides
Scheduled Publication Date: First Quarter 1975

LINEAR INTEGRATED CIRCUITS
Voltage Regulators
Operational Amplifiers
Voltage Comparators/Buffers
Functional Blocks
Consumer Circuits
Transistor/Diode Arrays
Analog Switches

LINEAR APPLICATIONS
Indexed Cross Referenced Collection of Linear Integrated Circuit Applications using Both Monolithic and Hybrid Linear Circuits

MEMORY INTEGRATED CIRCUITS
Bipolar and MOS RAMs
Bipolar and MOS ROMs
Bipolar and MOS PROMs
Clock Drivers and Their Applications
Scheduled Publication Date: First Quarter 1975

MICROPROCESSOR MANUAL
Includes LSI Processor Building Blocks and Support Items Including Chip Sets, Microcomputer Cards, and Prototyping Systems. Scheduled Publication Date: First Quarter 1975.

MOS INTEGRATED CIRCUITS
Dynamic Shift Registers
Static Shift Registers
PROMs/ROMs
RAMs
Clock Drivers
Analog Switches
ROM Character Generators
ROM Code Convertors
Custom MOS/LSI
Complex Standards
Integrated Circuits
Microprocessors
Applications

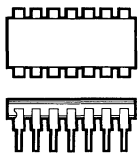
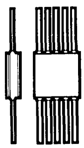
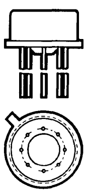
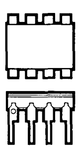
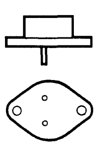
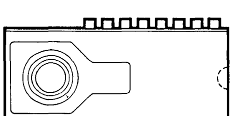
OPTOELECTRONICS HANDBOOK
Opto-Couplers
Calculator Display Arrays
Numeric Displays
LED Lamps
LED Drivers
Calculator Circuits
Digital Clock Circuits
Application Notes
Scheduled Publication Date: First Quarter 1975

SPECIAL FUNCTION ANALOG AND DIGITAL CIRCUITS
Amplifiers
Buffers
Sample and Hold Amplifiers
Comparators
Analog Switches
MOS Clock Drivers
Digital Drivers
Power Supplies

TRANSDUCER
Pressure
Temperature

TRANSISTOR
Small Signal
Field Effect
Power

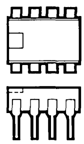
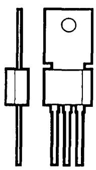
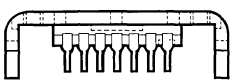
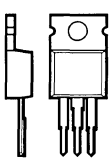
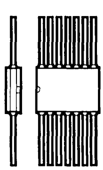
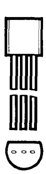
Industry Package Cross-Reference

Package	NSC	Signetics	Fairchild	Motorola	TI	RCA	Silicon General	AMD	Raytheon
 Glass/Metal DIP	D	I	D	L		D	D	D	D, M
 Glass/Metal Flat-Pack	F	Q	F	F	F, S	K	F	F	J, F, Q
 TO-99, TO-100, TO-5	H	T, K, L, DB	H	G	L	S*, V1**	T	H	T, H
 Low-Temperature Glass DIP	J	F	D	L	J				DC, DD
 TO-3, TO-66	K	DA	J	K, R			K		K, LK, TK
 "Wide-Track" Power Plastic DIP (Package 36)	M								

*With dual-in-line formed leads.

**With radially formed leads.

Industry Package Cross-Reference (Con't)

Package	NSC	Signetics	Fairchild	Motorola	TI	RCA	Silicon General	AMD	Raytheon
 Plastic DIP	N	V, A, B	T, P	P	P, N	E	M, N	PC	N, DN, DP, MP
 TO-202 (D-40, Durawatt) (Package 37)	P								
 "SGS" Type Power DIP (Package 39)	S		BP						
 TO-220 (Package 26)	T		U						
 Low Temperature Glass Hermetic Flat Pack	W		F	F	W			FM	
 TO-92 (Plastic) (Package 38)	Z		W	G					

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VOLTAGE COMPARATORS/BUFFERS – SECTION 3

VOLTAGE COMPARATORS/BUFFERS – SECTION 3 (CONTINUED)

FUNCTIONAL BLOCKS – SECTION 4

CONSUMER CIRCUITS – SECTION 5

CONSUMER CIRCUITS – SECTION 5 (CONTINUED)

TRANSISTOR/DIODE ARRAYS – SECTION 6

ANALOG SWITCHES – SECTION 7

NEW PRODUCTS – SECTION 8

PHYSICAL DIMENSIONS/DEFINITIONS OF TERMS – SECTION 9

Additional Linear Information Available:

Linear Applications Handbook

Alpha-Numerical Index

MILITARY TEMPERATURE RANGE: −55°C to +125°C

Device	Input Offset Voltage Max (mV)	Input Offset Voltage Drift Typ (μV/°C)	Input Offset Current Max (nA)	Input Bias Current Max (nA)	Voltage Gain Min (Volts/V)	Bandwidth $A_V = 1$ Typ (MHz)	Slew Rate $A_V = 1$ TYP (V/μs)	Output Current (mA)	Supply Voltage Min (V)	Supply Voltage Max (V)	Common Mode Range (V)	Differential Input Voltage (V)	Supply Current Max (mW)	Compensation Components	Package Types
LH0001	1	4	20	100	25,000	1	.25	±5	±5	±20	$\pm V_s$	±7	.5	2	TO-5
LH0001A	2.5	3	20	100	25,000	1	.25	±5	±5	±20	$\pm V_s$	±7	.5	2	TO-5 DIP F.P.
LH0002	30	(Note 2)	10×10^3	10^4	.95	50	100	±100	±5	±22	$\pm V_s$	(Note 2)	100	0	TO-5 DIP
LH0003	3	4	200	2000	15	30 (Note 1)	30 (Note 1)	±50	±5	±20	$\pm V_s$	±7	30	2	TO-5
LH0004	1	4	20	100	30	1	.25	±15	±5	±45	$\pm V_s$	±7	1.5	2	TO-5
LH0005	10	20	20	50	2	30 (Note 1)	20 (Note 1)	±50	±9	±20	$\pm V_s$	±15	90	3	TO-5
LH0020	2.5	10	50	250	100,000	1	.25	±40	±5	±22	$\pm V_s$	±30	50	2	TO-5
LH0021	3	3	100	300	100,000	1	3	±1000	±5	±18	$\pm V_s$	±30	35	0	TO-3
LH0022	4	5	.002	.01	100,000	1	3	±10	±5	±22	$\pm V_s$	±30	35	0	TO-5 DIP F.P.
LH0024	4	20	3×10^3	20×10^3	4000	50	400	±100	±9	±18	$\pm V_s$	±5	252	1	TO-5
LH0032	5	25	.01	.02	1000	50	500	±100	±5	±18	$\pm V_s$	±30	200	2	TO-8
LH0033	10	(Note 3)	(Note 3)	.1	.97 (Note 3)	100	1500	±100	±5	±20	$\pm V_s$	(Note 3)	220	0	TO-8 8 PIN J
LH0041	3	3	100	300	100,000	1	3	±200	±5	±18	$\pm V_s$	±30	35	0	TO-8 8 PIN J
LH0042	20	5	.005	.025	50,000	1	3	±10	±5	±22	$\pm V_s$	±30	35	0	TO-5 DIP F.P.
LH0052	.5	2	.0001	.001	100,000	1	3	±10	±5	±22	$\pm V_s$	±30	25	0	TO-5 DIP
LH0061	4	5	100	300	50,000	15	70	±500	±5	±18	$\pm V_s$	(Note 4)	100	1	TO-3
LH0062	5	5	.001	.025	50,000	15	70	±6	±5	±20	$\pm V_s$	±30	80	0	TO-5 DIP
LH0063	25	(Note 1)	(Note 3)	.2	.96 (Note 3)	150	6000	±400	±5	±18	$\pm V_s$	(Note 3)	500	0	TO-3

Note 1: Specified for $A_V = -10$.
Note 2: Current booster.
Note 3: Voltage follower.
Note 4: Inputs have shunt-diode protection; current must be limited to ±10 mA.

Military Op Amp Selection Guide

MILITARY TEMPERATURE RANGE: $-55^{\circ}C \leq T_A \leq +125^{\circ}C$

Device	Input Offset Voltage† Max (mV)	Input Offset Voltage Drift Max (μV/°C)	Input Offset Current† Max (nA)	Input Bias Current† Max (nA)	Voltage Gain† (Volts/V)	Bandwidth $A_V = 1$ Typ (MHz)	Slew Rate $A_V = 1$ Typ (V/μs)	Output Current Max (mA)	Supply Voltage Min Typ (V)	Supply Voltage Max (V)	Common Mode Range (V)	Differential Input Voltage (V)	Supply Current† Max (mA)	Compensation Components	Package Types
LH101	6	6	500	1500	50k	1	.5	5	±3	±22	±12	±30	3	0	TO-5 F.P.
LM101	6	6	500	1500	50k	1	.5	5	±3	±22	±12	±30	3	1	TO-5 F.P.
LM101A LH2101A (Note 1)	3	15	20	100	50k	1	.5	7.5	±3	±22	±12	±30	3	1	TO-5 DIP F.P.
LM102	7.5	6 typ	*	100	.999	10	10	1	±12	±18	±10	*	5.5	1	TO-5
LM107	3	15	20	100	50k	1	.5	7.5	±3	±22	±12	±30	3	0	TO-5 DIP F.P.
LM108 LH2108 (Note 1)	3	15	.4	3	50k	1	.3	1	±2	±20	±14	(Note 2)	.6	1	TO-5 DIP F.P.
LM108A LM2108A (Note 1)	1	5	.4	3	80k	1	.3	1	±2	±20	±14	(Note 2)	.6	1	TO-5 DIP F.P.
LM110 LH2110 (Note 1)	6	12	*	10	.999	20	30	1	±5	±18	±10	*	5.5	0	TO-5 DIP
LM112	3	15	.4	3	50k	1	.2	1	±2	±20	±14	(Note 2)	.6	0	TO-5 DIP F.P.
LM118	4	*	50	250	50k	15	50 min†	5	±5	±18	±11.5	(Note 2)	7	0	TO-5 DIP F.P.
LM124 (Quad)	5	*	30	300	100k	1	*	40	5 (±1.5)	32 (±15)	$V^+ - 1.5$	32	2	0	DIP F.P.
LM709	6	6	500	1500	25k	1	.3	5	±9	±18	±8	±5	5.5	3	TO-5
LM725	1.5	5	40	200	1000	.5	.005	5	±3	±22	±13.5†	±5	3.5	4	TO-5 F.P.
LM741	6	*	500	1500	50k	1	.5	5	±3	±22	±12	±30	2.9	0	TO-5 DIP F.P.
LM747	6	*	500	1500	50k	1	.5	5	±3	±22	±12	±30	5.6	0	TO-5 DIP F.P.
LM748	6	6	500	1500	50k	1	.5	5	±3	±22	±12	±30	2.9	1	TO-5
LM1558 (Dual)	6	*	500	1500	50k	1	.5	5	±3	±22	±12	±30	2.9	0	TO-5
LM4250 LH24250 (Note 1)	4	*	5	15	100k	.25	.16	.75	±1	±18	±12	±15	.03 set	0	TO-5

*Not specified.
†Guaranteed at +25°C.

Note 1: Dual version of device.
Note 2: Inputs have shunt-diode protection; current must be limited.

INDUSTRIAL TEMPERATURE RANGE: −25°C to +85°C

Device	Input Offset Voltage Max (mV)	Input Offset Voltage Drift Typ (μV/°C)	Input Offset Current Max (nA)	Input Bias Current Max (nA)	Voltage Gain Min (Volts/V)	Bandwidth $A_V = 1$ Typ (MHz)	Slew Rate $A_V = 1$ Typ (V/μs)	Output Current (mA)	Supply Voltage Min (V)	Supply Voltage Max (V)	Common Mode Range (V)	Differential Input Voltage (V)	Supply Current Max (mW)	Compensation Components	Package Types
LH0001AC	5	3	60	200	.25	1	.25	±5	±5	±20	$\pm V_s$	±7	1.3	2	TO-5 DIP F.P.
LH0002C	30	(Note 2)	10 x 10^3	10^4	.95 (Note 2)	50	100	±100	±5	±22	$\pm V_s$	(Note 2)	100	0	TO-5 DIP
LH0003C	3	4	200	2000	15,000	30 (Note 1)	30 (Note 1)	±50	±5	±20	$\pm V_s$	±7	30	2	TO-5
LH0004C	1.5	4	45	120	30,000	1	.25	±15	±5	±45	$\pm V_s$	±7	1.5	2	TO-5
LH0005C	10	25	25	100	2000	30 (Note 1)	20 (Note 1)	±50	±9	±20	$\pm V_s$	±15	90	3	TO-5
LH0020C	6	10	200	500	50,000	1	.25	±100	±5	±18	$\pm V_s$	±30	50	2	TO-5
LH0021C	6	5	200	500	100,000	1	3	±1000	±5	±18	$\pm V_s$	±30	40	0	TO-3
LH0022C	6	5	.005	.025	75,000	1	3	±10	±5	±22	$\pm V_s$	±30	24	0	TO-5 DIP F.P.
LH0024C	8	25	5 x 10^3	22 x 10^3	3500	50	400	±100	±9	±18	$\pm V_s$	±5	252	1	TO-5
LH032C	15	25	.02	.5	700	50	500	±100	±5	±20	$\pm V_s$	±30	220	2	TO-8
LH0033C	20	(Note 3)	(Note 3)	.15	.96 (Note 3)	100	1500	±100	±5	±20	$\pm V_s$	(Note 3)	240	0	TO-8 8 PIN J
LH0041C	6	5	200	500	100,000	1	3	±200	±5	±18	$\pm V_s$	±30	40	0	TO-8 8 PIN J
LH0042C	20	10	.01	.05	25,000	1	3	±10	±5	±22	$\pm V_s$	±30	28	0	TO-5 DIP F.P.
LH0052C	1	5	.0002	.005	75,000	1	3	±10	±5	±22	$\pm V_s$	±30	30	0	TO-5 DIP
LH0061C	10	5	200	200	25,000	15	70	±500	±5	±18	$\pm V_s$	(Note 4)	150	1	TO-3
LH0062C	15	10	.002	.065	25,000	15	70	±6	±5	±20	$\pm V_s$	±30	120	0	TO-5 DIP
LH0063C	50	(Note 3)	(Note 3)	.2	.96 (Note 3)	150	6000	±400	±5	±18	$\pm V_s$	(Note 3)	500	0	TO-3

Note 1: Specified for $A_V = -10$.
Note 2: Current booster.
Note 3: Voltage follower.
Note 4: Inputs have shunt-diode protection; current must be limited to ±10 mA.

Industrial Hybrid Op Amp Selection Guide

Industrial Op Amp Selection Guide

INDUSTRIAL TEMPERATURE RANGE: $-25°C \leq T_A \leq +85°C$

Device	Input Offset Voltage† Max (mV)	Input Offset Voltage Drift Max (μV/°C)	Input Offset Current† Max (nA)	Input Bias Current† Max (nA)	Voltage Gain† (Volts/V)	Bandwidth $A_V = 1$ Typ (MHz)	Slew Rate $A_V = 1$ Typ (V/μs)	Output Current Max (mA)	Supply Voltage Min Typ (V)	Supply Voltage Max (V)	Common Mode Range (V)	Differential Input Voltage (V)	Supply Current† Max (mA)	Compensation Components	Package Types
LM201A LH2201A (Note 1)	2	15	20	75	25k	1	.5	5	±3	±22	±12	±30	3	1	TO-5 DIP F.P.
LM202	10	15 typ	*	15	.999	10	10	1	±12	±18	±10	*	5.5	0	TO-5
LM207	2	20	20	75	25k	1	.5	5	±3	±22	±12	±30	3	0	TO-5 DIP F.P.
LM208 LH2208 (Note 1)	2	15	.2	2	50k	1	.3	1	±2	±20	±14	(Note 2)	.4	1	TO-5 DIP F.P.
LM208A LH2208A (Note 1)	.5	5	.2	2	80k	1	.3	1	±2	±20	±14	(Note 2)	.4	1	TO-5 DIP F.P.
LM210 LH2210 (Note 1)	4	*	*	3	.999	20	30	1	±5	±18	±10	*	5.5	0	TO-5 DIP F.P.
LM212	2	15	.2	2	50k	1	.3	1	±2	±20	±14	(Note 2)	.6	0	TO-5 DIP F.P.
LM216	10	*	.05	.15	10k	1	.3	1	±5	±20	±13	(Note 2)	.8	0	TO-5 DIP F.P.
LM216A	3	*	.015	.05	20k	1	.3	1	±5	±20	±13	(Note 2)	.6	0	TO-5 DIP F.P.
LM218	4	*	50	500	50k	15	50 min†	5	±5	±18	±11.5	(Note 2)	7.5	0	TO-5 DIP F.P.
LM224 (Quad)	7	*	50	500	100k	1	*	40	3 (±1.5)	30 (±15)	$V^+ - 1.5$	32	2	0	DIP
LM725B	1.5	10	20	100	500k	.5	.005	5	±3	±22	±13.5	±5	4	4	TO-5 DIP
LM2900 (Quad)	*	*	*	200	2.8k	2.5	20	18	4	36	*	*	10	0	DIP

*Not specified.
†Guaranteed at +25°C.

Note 1: Dual version of device.
Note 2: Inputs have shunt-diode protection; current must be limited.

COMMERCIAL TEMPERATURE RANGE: $0°C \leq T_A \leq +70°C$

Device	Input Offset Voltage† Max (mV)	Input Offset Voltage Drift Max (μV/°C)	Input Offset Current† Max (nA)	Input Bias Current† Max (nA)	Voltage Gain† (Volts/V)	Bandwidth $A_V = 1$ Typ (MHz)	Slew Rate $A_V = 1$ Typ (V/μs)	Output Current Max (mA)	Supply Voltage Min Typ (V)	Supply Voltage Max Typ (V)	Common Mode Range (V)	Differential Input Voltage (V)	Supply Current† Max (mA)	Compensation Components	Package Types
LH201	7.5	10	500	1500	20k	1	.5	5	±3	±22	±12	±30	3	0	TO-5 F.P.
LM201	7.5	10	500	1500	20k	1	.5	5	±3	±22	±12	±30	3	1	TO-5 F.P.
LM301A LH2301A (Note 1)	7.5	30	50	250	25k	1	.5	5	±3	±18	±12	±30	3	1	TO-5 DIP
LM302	15	20 typ	*	30	.9985	10	10	1	±12	±18	±10	*	5.5	0	TO-5
LM307	7.5	30	50	250	25k	1	.5	5	±3	±18	±12	±30	3	0	TO-5 DIP F.P.
LM308 LM2308 (Note 1)	7.5	30	1	7	25k	1	.3	1	±2	±18	±14	(Note 2)	.8	1	TO-5 DIP F.P.
LM308A LM2308A (Note 1)	.5	5	1	7	80k	1	.3	1	±2	±20	±14	(Note 2)	.8	1	TO-5 DIP F.P.
LM310 LH2310 (Note 1)	7.5	*	*	7	.999	20	30	1	±5	±18	±10	*	5.5	0	TO-5 DIP F.P.
LM312	7.5	30	1	7	25k	1	.3	1	±2	±18	±14	(Note 2)	.8	0	TO-5 DIP F.P.
LM316	10	*	.05	.15	20k	1	.3	1	±5	±20	±13	(Note 2)	.8	0	TO-5 DIP F.P.
LM316A	3	*	.015	.05	40k	1	.3	1	±5	±20	±13	(Note 2)	.6	0	TO-5 DIP F.P.
LM318	12	*	200	600	25k	15	50 min	5	±5	±18	±11.5	(Note 2)	10	0	TO-5 DIP
LM324 (Quad)	7	*	50	500	100k	1	*	40	3 (±1.5)	30 (±15)	$V^+ - 1.5$	32	2	0	DIP
LM709C	7.5	12	500	1500	25k	1	.3	5	±9	±18	±8	±5	6.6	3	TO-5 DIP
LM725C	2.5	2	35	125	250k	.5	.005	5	±3	±22	±13.5	±5	5	4	TO-5 DIP
LM741C	6	*	200	500	20k	1	.5	5	±3	±18	±12	±30	2.9	0	TO-5 DIP
LM747C	6	*	200	500	20k	1	.5	5	±3	±18	±12	±30	5.6	0	TO-5 DIP F.P.
LM748C	6	6	200	500	50k	1	.5	5	±3	±18	±12	±30	2.9	1	TO-5 DIP
LM1458 (Dual)	6	*	200	500	20k	1	.5	5	±3	±18	±12	±30	2.9	0	TO-5 DIP
LM3900 (Quad)	*	*	*	200	2.8k	2.5	20	10	4 (±2)	36 (±18)	*	*	10	0	DIP
LM4250C LH24250C (Note 1)	6	*	10	30	75k	.25	.16	.75	±1	±18	±12	±15	.03 set	0	TO-5 DIP

*Not specified.
†Guaranteed at +25°C.

Note 1: Dual version of device.
Note 2: Inputs have shunt-diode protection; current must be limited.

Commercial Op Amp Selection Guide

Fixed Voltage Regulator Guide

	Product Type No.	Input Voltage (V) Min	Input Voltage (V) Max	Output Voltage (V) Typ	Load Regulation (mV) Typ	Line Regulation (mV) Typ	Ripple Rejection (dB) Typ	Long Term Stability (mV) Max	Output Noise Voltage (μV) Typ	Quiescent Current (mA)	Operating Temperature Range (°C) Min	Operating Temperature Range (°C) Max	Output Current† (Amps)	Package Type
Positive Regulators	LM109K*	7	35	5	50	4	75	10	40	6	−55	125	>1	TO-3, TO-5
	LM209K*	7	35	5	50	4	75	10	40	6	−25	85	>1	TO-3, TO-5
	LM309K*	7	35	5	50	4	75	20	40	6	0	70	>1	TO-3, TO-5
	LM123K	7.5	20	5	50	4	75	10	40	6	−55	125	3	TO-3
	LM223K	7.5	20	5	50	4	75	10	40	6	−25	85	3	TO-3
	LM323K	7.5	20	5	50	4	75	20	40	6	0	70	3	TO-3
	LM340-05	7	35	5	100 max	100 max	70	20	40	6	0	70	>1	TO-3, TO-220
	LM340-06	8	35	6	120 max	120 max	65	24	45	6	0	70	>1	TO-3, TO-220
	LM340-08	10	35	8	160 max	160 max	62	32	52	6	0	70	>1	TO-3, TO-220
	LM340-12	14	35	12	240 max	240 max	61	48	75	6	0	70	>1	TO-3, TO-220
	LM340-15	17	35	15	300 max	300 max	60	60	90	6	0	70	>1	TO-3, TO-220
	LM340-18	20	35	18	360 max	360 max	59	72	110	6	0	70	>1	TO-3, TO-220
	LM340-24	26	40	24	480 max	480 max	56	96	170	6	0	70	.8	TO-3, TO-220
Negative Regulators	LM120K-5*	−6	−25	−5	50	10	67	50	150	2	−55	125	>1	TO-3, TO-5
	LM220K-5*	−6	−25	−5	50	10	67	50	150	2	−25	85	>1	TO-3, TO-5
	LM320K-5*	−6	−25	−5	50	10	67	50	150	2	0	70	>1	TO-3, TO-5
	LM120K-5.2*	−6.2	−25	−5.2	50	10	67	50	150	2	−55	125	>1	TO-3, TO-5
	LM220K-5.2*	−6.2	−25	−5.2	50	10	67	50	150	2	−25	85	>1	TO-3, TO-5
	LM320K-5.2*	−6.2	−25	−5.2	50	10	67	50	150	2	0	70	>1	TO-3, TO-5
	LM120K-12*	−13	−30	−12	30	4	80	120	400	4	−55	125	>1	TO-3, TO-5
	LM220K-12*	−13	−30	−12	30	4	80	120	400	4	−25	85	>1	TO-3, TO-5
	LM320K-12*	−13	−30	−12	30	4	80	120	400	4	0	70	>1	TO-3, TO-5
	LM120K-15*	−16	−30	−15	30	5	80	150	400	4	−55	125	>1	TO-3, TO-5
	LM220K-15*	−16	−30	−15	30	5	80	150	400	4	−25	85	>1	TO-3, TO-5
	LM320K-15*	−16	−30	−15	30	5	80	150	400	4	0	70	>1	TO-3, TO-5

*Ratings are for TO-3(K) package; device also available in TO-5(H) package.

†Max output current depends on package type, heat sinking, and input voltage differential.

Specifications Are Worst Case Over Operating Temperature Unless Noted.

	Product Type No.	Input Voltage Range (V) Min	Input Voltage Range (V) Max	Output Voltage Range (V) Min	Output Voltage Range (V) Max	Load Regulation (%) Typ.	Load Regulation I_L (mA)	Line Regulation $(\%V_{OUT}/\Delta V_{IN})$ Typ.	Ripple Rejection (%) Typ.	Input-Output Differential (V) Min	Input-Output Differential (V) Max	Temperature Stability (%)	Quiescent Current (mA) Typ.	Operating Temperature Range (°C) Min	Operating Temperature Range (°C) Max	Output Current* (mA)	Package Type
Positive Voltage Regulators	LM100	8.5	40	2.0	30	0.1	12	0.05	0.02	3	30	1.0	1.0	−55	125	20	TO-5, Flat Pack
	LM200	8.5	40	2.0	30	0.1	12	0.05	0.02	3	30	1.0	1.0	−25	85	20	TO-5, Flat Pack
	LM300	8.5	30	2.0	20	0.1	12	0.05	0.02	3	20	2.0	1.0	0	70	20	TO-5, Flat Pack
	LM105	8.5	50	4.5	40	0.02	12	0.015	0.003	3	30	1.0	0.8	−55	125	20	TO-5, Flat Pack
	LM205	8.5	50	4.5	40	0.02	12	0.015	0.003	3	30	1.0	0.8	−25	85	20	TO-5, Flat Pack
	LM305	8.5	40	4.5	30	0.02	12	0.015	0.003	3	30	1.0	0.8	0	70	20	TO-5, Flat Pack
	LM305A	8.5	50	4.5	40	0.02	45	0.015	0.003	3	30	1.0	0.8	0	70	45	TO-5
	LM376	9.0	40	5.0	37	0.2 max	25	0.03 max	0.1 max	3	30	–	2.5 max	0	70	25	Molded DIP
	LM723	9.5	40	2.0	37	0.03	50	0.01	0.02	3	38	0.015%/°C	1.3	−55	125	150	TO-5, Cavity DIP
	LM723C	9.5	40	2.0	37	0.03	50	0.01	0.02	3	38	0.015%/°C	1.3	0	70	150	TO-5, Cavity & Molded DIP
Negative Voltage Regulators	LM104	−50	−8	−40	−15 mV	0.01	20	.05	0.01	2	50	1.0	3.6	−55	125	20	TO-5, Flat Pack
	LM204	−50	−8	−40	−15 mV	0.01	20	.05	0.01	2	50	1.0	3.6	−25	85	20	TO-5, Flat Pack
	LM304	−40	−8	−30	−15 mV	0.01	20	.05	0.01	2	40	1.0	3.6	0	70	20	TO-5, Flat Pack
	LM723	−40	−9.5	−37	−2	0.03	50	0.01	0.02	3	38	0.015%/°C	1.3	−55	125	150	TO-5, Cavity & Molded DIP
	LM723C	−40	−9.5	−37	−2	0.03	50	0.01	0.02	3	38	0.015%/°C	1.3	0	70	150	TO-5, Cavity & Molded DIP

Note: The maximum power dissipation for the LM100, LM105 and LM104 regulators is 800 mW. For most cases of the LM100, LM105 and the LM104, output current will be limited by maximum junction temperature and thermal resistance as indicated.

Package	Thermal Resistance Junction to Air	Thermal Resistance Junction to Case
TO-5	150°C/W	45°C/W
Flat Pack	185°C/W Mounted	
Solid Kovar TO-5	150°C/W	15°C/W
TO-3	35°C/W	1.5°C/W

*The output currents given, as well as the load regulation for the LM100, LM105, LM723 and LM104 family of regulators can be increased by the addition of external transistors The increase will be roughly equal to the composite current gain of the added transistors

Voltage Comparator Guide

Device	Temperature Range*	DTL/TTL Fanout	Supply Voltage Typ (Volts)	Input Bias Current (+25°C) Max (μA)	Input Offset Current (+25°C) Max (μA)	Input Offset Voltage (+25°C) Max (mV)	Response Time† Typ (ns)	Voltage Gain Typ	Package Type	Comments
LM106	Military	10	$V^+ = +12$	20	3	2	40 max	40k	TO-5 F.P.	
LM206	Industrial	10	$V^- = -3$	20	3	2	40 max	40k	TO-5 F.P.	Single comparator with strobe, high speed and sensitivity, large fanout.
LM306	Commercial	10	To −12	25	5	5	40 max	40k	TO-5 F.P.	
LM111 LH2111 (Note 1)	Military	5	±15	.1	04	.7	200	200k	TO-5 DIP F.P.	
LM211 LH2211 (Note 1)	Industrial	5	To +5	.1	.04	.7	200	200k	TO-5 DIP F.P.	Single, with strobe, will work from single supply, low bias current.
LM311 LH2311 (Note 1)	Commercial	5	And GND	.25	.06	2	200	200k	TO-5 DIP F.P.	
LM119	Military	2 (each side)	±15	.5	.075	4	80	40k	TO-5 DIP F.P.	
LM219	Industrial	2 (each side)	To +5	.5	.075	4	80	40k	TO-5 DIP F.P.	High speed dual comparator.
LM319	Commercial	2 (each side)	And GND	1	.2	8	80	40k	TO-5 DIP	
LM139	Military	1	±1	.1	.025	5	1.3 μs	200k	DIP F.P.	
LM239	Industrial	1	To ±18	25	.050	5	1.3 μs	200k	DIP	Quad comparator designed for single supply operation; input common mode range includes ground.
LM339	Commercial	1	Or From	.25	.050	5	1.3 μs	200k	DIP	
LM139A	Military	1	+2	.1	025	2	1.3 μs	200k	DIP F.P.	
LM239A	Industrial	1	To +36	.25	.050	2	1.3 μs	200k	DIP	Low offset voltage Quad comparator with DTL/TTL logic levels.
LM339A	Commercial	1	And GND	.25	050	2	1.3 μs	200k	DIP	
LM160	Military	2	±4.5	10	2	2	16	3k	TO-5 DIP F.P.	
LM260	Industrial	2	To	10	2	2	16	3k	TO-5 DIP	Very high speed, outputs compatible with DTL/TTL logic levels.
LM360	Commercial	2	±6.5	15	4	4	16	3k	TO-5 DIP	
LM161	Military	2	±5	10	2	2	12	3k	TO-5 DIP F.P.	
LM261	Industrial	2	To ±15	10	2	2	12	3k	TO-5 DIP	Very high speed, with individual strobes, DTL/TTL compatible.
LM361	Commercial	2	And +5	15	4	4	12	3k	TO-5 DIP	
LM710	Military	1	$V^+ = +12$	20	3	2	40	1750	TO-5	Single, differential in, single output.
LM710C	Commercial	1	$V^- = -6$	25	5	5	40	1500	TO-5 DIP	
LM711	Military	1	$V^+ = +12$	75	10	3.5	40	1500	TO-5	Dual differential, common output, individual strobes.
LM711C	Commercial	1	$V^- = -6$	100	15	5	40	1500	TO-5 DIP	
LM1514	Military	1	$V^+ = +14$	20	3	3	30	1250	DIP	Dual LM710 with separate strobes, individual outputs.
LM1414	Commercial	1	$V^- = -7$	25	5	4	30	1000	DIP	

*Military −55°C to +125°C
Industrial −25°C to +85°C
Commercial 0°C to +70°C

†Response time is specified for 100 mV step input with 5 mV overdrive

Note 1: Dual version of device.

DEVICE NO.	PACKAGE	NATIONAL PIN FOR PIN EQUIVALENT	NEAREST NATIONAL EQUIVALENT
Analog Devices			
AD503J, K	TO-5	LH0042CH	
AD503S	TO-5	LH0042H	
AD506J, K, L	TO-5	LH0022CH	
AD506S	TO-5	LH0022H	
AD511	MOD		LH0042
AD513J, K	TO-5	LH0042CH	
AD513S	TO-5	LH0042H	
AD514J, K, L	TO-5		LH0042CH
AD514S	TO-5		LH0042H
AD516J, K	TO-5	LH0022CH	
AD516S	TO-5	LH0022H	
AD523J, K, L	TO-5		LH0052CH
AD528J, K	TO-5		LH0062CH
AD528S	TO-5		LH0062H
AD540J, K	TO-5		LH0042CH
AD540S	TO-5		LH0042H
ADP517	MOD		LH0042CH
M501A, B, C	TO-8		LH0022CH
40J, K	TO-8		LH0042CH
41J, K, L	MOD		LH0052CH
42J, K, L	MOD		LH0052CH
43J	MOD		LH0022CH
44J, K	MOD		LH0062CH
45J, K	MOD		LH0062CH
142A, B, C	MOD		LH0042CH
146J, K	MOD		LH0022CH
149J, K	MOD		LH0062CH
Bell and Howell			
20-008	MOD		LH0042CH
20-108	MOD		LH0042CH
20-208	TO-8		LH0022H
20-248	TO-8		LH0022CH
Burr-Brown			
3521L	TO-99		LH0022CH
3542J	TO-99	LH0042CH	
3542S	TO-99	LH0042H	
3542SQ	TO-99	LH0042H/883	
3506J	TO-99	LH0022CH	
3508J	TO-99	LH0062CH	
3348/03	DIL		LH0022CD
3349/03	DIL		LH0022CD
3350/03	DIL		LH0042CD
3503A	TO-99	LH0042CH	
3503B	TO-99	LH0042H	
3503C	TO-99	LH0022CH	
3503R	TO-99	LH0022H	
3503S	TO-99	LH0052CH	
3503T	TO-99	LH0052H	
Datel			
AM405-2	TO-99	LH0042CH	
AM406-2	TO-99	LH0042CH	
AM100A	MOD		LH0062H
AM100B	MOD		LH0062CH
AM102A	MOD		LH0062H
AM102B	MOD		LH0062CH
Fairchild			
U5B7740312 (μA740)	TO-5	LH740AH	
U5B7740393 (μA740C)	TO-5	LH740ACH	
Halex			
XH0032	TO-8	LH0032CG	
Harris			
HA2050	TO-99	LH0042H	
HA2055	TO-99	LH0042CH	
HA2050A	TO-99	LH0022H	
HA2055A	TO-99	LH0042CH	
HA2060	TO-99	LH0062H	
HA2065	TO-99	LH0062CH	
HA2060A	TO-99	LH0062H	
HA2065A	TO-99	LH0062CH	
Intech			
A-100	MOD		LH0042
A-101	MOD		LH0042C
A-102	MOD		LH0022CH
A-103	MOD		LH0022CH
A-122	MOD		LH0052CH
A-123	MOD		LH0052CH
A-125	MOD		LH0062CH
A-130	MOD		LH0062CH
A-131	MOD		LH0062CH
A-136	MOD		LH0062CH
A-137	MOD		LH0062CH
A-148A, B, C	MOD		LH0042CH
A-1026	MOD		LH0022CH
A-1027	MOD		LH0022CH
Intersil			
ICH8500	TO-5	LH0052H	
ICH8500A	TO-5	LH0052H	
ICH8500C	TO-5	LH0052CH	
ICH8007C	TO-5	LH0042CH	
ICH8007M	TO-5	LH0042H	
ICL8007AM	TO-5	LH0042H	
ICL8007AC	TO-5	LH0042CH	

FET Op Amp Cross Reference Guide

FET Op Amp Cross Reference Guide

DEVICE NO.	PACKAGE	NATIONAL PIN FOR PIN EQUIVALENT	NEAREST NATIONAL EQUIVALENT
Intronics			
FA530	MOD		LH0062CH
FA531	MOD		LH0062CH
FA540	MOD		LH0042CH
FA541	MOD		LH0042CH
Optical Electronics, Inc. (OEI)			
9712	MOD		LH0032CG
9725	MOD		LH0032CG
9731	MOD		LH0032G
9738	MOD		LH0032G
9718	MOD		LH0062CH
9726	MOD		LH0062CH
9727	MOD		LH0062CH
9715	MOD		LH0062CH
9721	MOD		LH0062CH
9723	MOD		LH0062CH
9733	MOD		LH0052CH
9720	MOD		LH0032CH
9729	MOD		LH0052CH
Signetics			
SU536T	TO-5	LH0042CH	
NE536T	TO-5	LH0042CH	
SU740T	TO-5	LH740ACH	
NE740T	TO-5	LH740ACH	
Siliconix			
L120A	TO-5		LH0042H
L120C	TO-5		LH0042CH
L137AA	TO-5		LH0022H
L137CA	TO-5		LH0022CH
Teledyne Philbrick Nexus			
QFT	MOD		LH0042CH
QFT-2	MOD		LH0042CH
QFT-2A	MOD		LH0022CH
QFT-2B	MOD		LH0052CH
QFT-5	MOD		LH0042CH
Q25AH	TO-8		LH0042CH
PP25A	MOD		LH0042CH

DEVICE NO.	PACKAGE	NATIONAL PIN FOR PIN EQUIVALENT	NEAREST NATIONAL EQUIVALENT
Teledyne Philbrick Nexus (Con't.)			
1003	MOD		LH0052CH
100301	MOD		LH0052CH
1006	MOD		LH0042CH
1008	MOD		LH0042CH
1009	MOD		LH0042CH
100901	MOD		LH0042CH
100902	MOD		LH0042CH
1011	MOD		LH0062CH
101101	MOD		LH0062CH
101102	MOD		LH0062CH
1021	MOD		LH0022CH
1023	MOD		LH0052CH
102301	MOD		LH0052CH
1025	MOD		LH0032CG
1408	MOD		LH0052CH
140801	MOD		LH0052CH
140802	MOD		LH0052CH
140810	TO-8		LH0052CH
1402	TO-8		LH0042CH
140201	TO-8		LH0042CH
140202	TO-8		LH0042CH
1407	TO-8		LH0042CH
140701	TO-8		LH0042CH
1414	MOD		LH0062CH
141410	DIP		LH0062CH
1421	TO-5		LH0042CH
Zeltex			
ZA801/M1/M2/M3	MOD		LH0042CH
ZA801T1	TO-8		LH0042CH
ZA801D1	DIL		LH0042CH
ZA801E1	DIL		LH0042CH
ZA802M1, M2	MOD		LH0022CH
ZA803M1	MOD		LH0042CH
ZA804M1, M2	MOD		LH0042CH
ZA903M1, M2	MOD		LH0042CH
ZA910M	MOD		LH0062CH
133	MOD		LH0022CH
133-03	MOD		LH0052CH
133-04	MOD		LH0022CH
134	MOD		LH0042CH
134D	MOD		LH0042CH
135	MOD		LH0062CH

TEXAS INSTRUMENTS DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
SN5510F		LM733H
SN5510L		LM733H
SN5511F		LM733H
SN5511L		LM733H
SN7510F		LM733CH
SN7510L		LM733CH
SN7511L		LM733CH
SN52101AJ	LM101AD	
SN52101AL	LM101AH	
SN52101AZ	LM101AF	
SN52107J	LM107D	
SN52107L	LM107H	
SN52107Z	LM107F	
SN52108J	LM108D	
SN52108AJ	LM108AD	
SN52514J	LM1514J	
SN52514N	LM1514N	
SN52555L	LM555H	
SN52558L	LM1558H	
SN52702AF		LM101AF
SN52702AL		LM101AH
SN52702AN		LM301AN
SN52702F		LM101AF
SN52702L		LM101AH
SN52702N		LM301AN
SN52702Z		LM101AF
SN52709AF		LM709AH
SN52709AL	LM709AH	
SN52709AN		LM709AH
SN52709F		LM709H
SN52709L	LM709H	
SN52709N		LM709H
SN52710J		LM710H
SN52710L	LM710H	
SN52710N		LM710H
SN52710S		LM710H
SN52710U		LM710H
SN52711J		LM711H
SN52711L	LM711H	
SN52711N		LM711H

TEXAS INSTRUMENTS DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
SN52711S		LM711H
SN52723L	LM723H	
SN52733L	LM733H	
SN52733N		LM733N
SN52741J	LM741D	
SN52741L	LM741H	
SN52741N	LM741CN-14	
SN52741Z	LM741F	
SN52747J	LM747D	
SN52747Z	LM747F	
SN52748J		LM748H
SN52748L	LM748H	
SN52748U		LM748CN
SN52748Z		LM748H
SN52770J		LM108D
SN52770L		LM108H
SN52770Z		LM108F
SN52771J		LM112D
SN52771L		LM112H
SN52771Z		LM112F
SN55709J		LM709CN
SN56514L		LM1496H
SN72301AJ	LM301AD	
SN72301AL	LM301AH	
SN72301AN		LM301AN
SN72301AP	LM301AN	
SN72301AZ	LM301AF	
SN72307J	LM307D	
SN72307L	LM307H	
SN72307N	LM307N	
SN72307P		LM307H
SN72307Z	LM307F	
SN72308L		LM308
SN72514J	LM1414J	
SN72514N	LM1414N	
SN72555L	LM555CH	
SN72555P	LM555CN	
SN72558L	LM1458H	
SN72558P	LM1458N	
SN72702F		LM301AF

TEXAS INSTRUMENTS DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
SN72702L		LM301AH
SN72702N		LM301AN
SN72709L	LM709CH	
SN72709N	LM709CN	
SN72709P		LM709CN
SN72709S		LM709CH
SN72710J		LM710CN
SN72710L	LM710CH	
SN72710N	LM710CN	
SN72710S		LM710CH
SN72711J		LM711CN
SN72711L	LM711CH	
SN72711N	LM711CN	
SN72811S		LM711CH
SN72720N	LM1414N	
SN72733L	LM733CH	
SN72733N	LM733CN	
SN72741J	LM741CD	
SN72741L	LM741CH	
SN72741N	LM741CN-14	
SN72741P	LM741CN	
SN72741Z	LM741CF	
SN72747J	LM747CD	
SN72747N	LM747CN	
SN72748N		LM748CN
SN72748P	LM748CN	
SN72748J		LM748CN
SN72748L	LM748CH	
SN72748Z		LM748H
SN72770J		LM308D
SN72770L		LM308H
SN72770N		LM308H
SN72770P		LM308H
SN72770Z		LM308F
SN72771L		LM312H
SN72771N		LM312D
SN72771P		LM312D
SN72771Z		LM312F
SN76514L		LM1496H
SN76514N		LM1496H

Texas Instruments Linear Cross Reference Guide

Motorola Linear Cross Reference Guide

MOTOROLA DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
MC1303L		LM1303N
MC1304P	LM1304N	
MC1305P	LM1305N	
MC1306P		LM380N
MC1307P	LM1307N	
MC1310P	LM1310N	
MC1326P		LM3067N
MC1326PQ		LM3067N
MC1328G		LM746N
MC1328P		LM746N
MC1328PQ		LM746N
MC1339P		LM382N
MC1350P		LM703L
MC1351P	LM1351N	
MC1357P	LM2111N	
MC1357PQ		LM2111N
MC1358P		LM3065N
MC1358PQ		LM3065N
MC1364G	LM3064H	
MC1364P	LM3064N	
MC1370P	LM3070N	
MC1371P	LM3071N	
MC1375P	LM3075N	
MC1380P		LM380N
MC1410G		LM733CH
MC1414F		LM1414N
MC1414L	LM1414J	
MC1414P	LM1414N	
MC1420G		LM733CH
MC1430F		LM301AF
MC1430G		LM301AH
MC1430P		LM301AN
MC1431F		LM301AF
MC1431G		LM301AH
MC1431P		LM301AN
MC1433F		LM301AF
MC1433G		LM301AH
MC1433L		LM301AN
MC1435F		LM1303N
MC1435G		LM1303N
MC1435L		LM1303N
MC1436CG	LM1436H	
MC1436G	LM1436H	
MC1437L		LM1458N-14
MC1437P		LM1458N-14
MC1438R		LH0002H
MC1439G		LM301AH
MC1439L		LM301AH
MC1439P1		LM218H
MC1439P2		LM301AH
MC1454G		LM380H
MC1455G	LM555CH	
MC1455P1	LM555N	
MC1456CG		LM308H
MC1456G		LM308H
MC1458CG	LM1458H	
MC1458CL		LM1458N-14
MC1458CP1	LM1458N	

MOTOROLA DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
MC1458CP2	LM1458N-14	
MC1458G	LM1458H	
MC1458L		LM1458N-14
MC1458P1	LM1458N	
MC1458P2	LM1458N-14	
MC1460G		LM305H
MC1460R		LM305H
MC1461G		LM305H
MC1461R		LM305H
MC1463G		LM304H
MC1463R		LM304H
MC1466L		LM304H
MC1469G		LM305H
MC1469R		LM305H
MC1488L	LM1488J	
MC1489AL	LM1489AJ	
MC1489L	LM1489J	
MC1496G	LM1496H	
MC1496L	LM1496N	
MC1509F		LM733H
MC1510F		LM733H
MC1510G		LM733H
MC1514F		LM1514N
MC1514L	LM1514J	
MC1519G		LM733H
MC1520F		LM733H
MC1520G		LM733H
MC1530F		LM101AF
MC1530G		LM101AH
MC1531F		LM101AF
MC1531G		LM101AH
MC1533F		LM101AF
MC1533G		LM101AH
MC1533L		LM101AD
MC1535F		LM1303N
MC1535G		LM1303N
MC1536G	LM1536H	
MC1537L		LM1458N-14
MC1538R		LH0002H
MC1539G		LM101AH
MC1539L		LM101AD
MC1550F		LM171H
MC1550G		LM171H
MC1552G		LM733H
MC1553G		LM733H
MC1554G		LM380N
MC1555G	LM555H	
MC1556G		LM108H
MC1558G	LM1558H	
MC1558L	LM1558D	
MC1560G		LM105H
MC1560R		LM105H
MC1561G		LM105H
MC1561R		LM105H
MC1563G		LM104H
MC1563R		LM104H
MC1566L		LM104H
MC1569G		LM105H

MOTOROLA DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
MC1569R		LM105H
MC1590G		LM170H
MC1596G	LM1596H	
MC15961		LM1596H
MC1709CF		LM709CH
MC1709CG	LM709CH	
MC1709CL		LM709CN
MC1709CP1	LM709CN	
MC1709CP2		LM709CN
MC1709F		LM709H
MC1709G	LM709H	
MC1709L		LM709H
MC1710CF		LM710CH
MC1710CG	LM710CH	
MC1710CL		LM710CH
MC1710CP	LM710CN	
MC1710F		LM710H
MC1710G	LM710H	
MC1710L		LM710H
MC1711CF		LM711CH
MC1711CG	LM711CH	
MC1711CL		LM711CH
MC1711CP		LM711CH
MC1711F		LM711H
MC1711G	LM711H	
MC1711L		LM711H
MC1712CF		LM733CH
MC1712CG		LM733CH
MC1712CL		LM733CH
MC1712F		LM733H
MC1712G		LM733H
MC1712L		LM733H
MC1723CG	LM723CH	
MC1723CL	LM723CD	
MC1723G	LM723H	
MC1723L	LM723D	
MC1733CG	LM733CH	
MC1733CL	LM733CD	
MC1733G	LM733H	
MC1733L	LM733D	
MC1741CF	LM741CF	
MC1741CG	LM741CH	
MC1741CL		LM741CH
MC1741CP1	LM741CN	
MC1741CP2	LM741CN-14	
MC1741F	LM741F	
MC1741G	LM741H	
MC1741L	LM741D	
MC1747CF	LM747CF	
MC1747CG	LM747CH	
MC1747CL	LM747CN	
MC1747F	LM747F	
MC1747G	LM747H	
MC1747L	LM747D	
MC1748CG	LM748CH	
MC1748G	LM748H	
MC1776G	LM4250H	
MC1776CG	LM4250CH	

MOTOROLA DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
MC3302P	LM339AN	
MC3401P	LM3900N	
MC7805CK	LM340K-5.0	
MC7805CP	LM340T-5.0	
MC7806CK	LM340K-6.0	
MC7806CP	LM340T-6.0	
MC7808CK	LM340K-8.0	
MC7808CP	LM340T-8.0	
MC7812CK	LM340K-12	
MC7812CP	LM340T-12	
MC7815CK	LM340K-15	
MC7815CP	LM340T-15	
MC7818CK	LM340K-18	
MC7818CP	LM340T-18	
MC7824CK	LM340K-24	
MC7824CP	LM340T-24	
MC7905CP	LM320T-05	
MC7905.2CP	LM320T-05.2	
MC7912CP	LM320T-12	
MC7915CP	LM320T-15	
MFC40000D		LM380N
MFC4010A		LM381N
MFC4050		LM380N
MFC4060		LM376N
MFC6010		LM2111N
MFC6030		LM376N
MFC6030A		LM376N
MFC6070		LM380N
MFC8000		LM703LN
MFC8001		LM703LN
MFC8002		LM703LN
MFC8010		LM380N
MFC8030		LM703LN
MFC8040		LM381N
MFC9020		LM380N
MLM101AG	LM101AH	
MLM104G	LM104H	
MLM105G	LM105H	
MLM107G	LM107H	
MLM109G	LM109H	
MLM109K	LM109K	
MLM110G	LM110H	
MLM201AG	LM201AH	
MLM201AP1	LM201AN	
MLM204G	LM204H	
MLM205G	LM205H	
MLM207G	LM207H	
MLM209K	LM209K	
MLM210G	LM210H	
MLM301AG	LM301AH	
MLM301AP1	LM301AN	
MLM304G	LM304H	
MLM305G	LM305H	
MLM307G	LM307H	
MLM309G	LM309H	
MLM309K	LM309K	
MLM310G	LM310H	

SIGNETICS DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
N5201A		LM301AD
N5307T	LM307H	
N5308T	LM308H	
N53A1T	LM301AH	
N53A1V	LM301AN	
N53A8T	LM308AH	
N5556V		LM307N
N5558F	LM1458N	
N5558T	LM1458H	
N5596K	LM1496H	
N5596K		LM1496N
N5709A	LM709CN	
N5709T	LM709CH	
N5709V		LM709CN
N5710A	LM710CN	
N5710T	LM710CH	
N5711A	LM711CN	
N5711K	LM711CH	
N5723A	LM723CN	
N5723L	LM723CH	
N5733A	LM733CN	
N5733K	LM733CH	
N5740T	LH740CH	
N5741A	LM741CN-14	
N5741T	LM741CH	
N5741V	LM741CN	
N5747A	LM747CN	
N5747F	LM747CD	
N5747K	LM747CH	
N5748A		LM748CH
N5748T	LM748CH	
N5748V	LM748CN	
NE501G		LM733CH
NE501K		LM733CH
NE510A		LM371H
NE510J		LM371H
NE515A		LM733CN
NE515G		LM733CH
NE515K		LM733CH
NE518A		LM306H

SIGNETICS DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
NE518G		LM306H
NE518K		LM306H
NE526A		LM306H
NE526G		LM306H
NE526K		LM306H
NE529K	LM361H	
NE529A	LM361N	
NE531G		LM318H
NE531T		LM318H
NE531V		LM318H
NE533G		LM4250CH
NE533T		LM4250CH
NE533V		LM4250CH
NE536T		LM316H
NE537G		LM308H
NE537T		LM308H
NE540L		LH0021CK
NE546		LM1820
NE550A		LM723CH
NE550L		LM723CH
NE555V	LM555CN	
NE555T	LM555CH	
NE565A	LM565CN	
NE565K	LM565CH	
NE566T	LM566CH	
NE566V	LM566CN	
NE567T	LM567CH	
NE567V	LM567CN	
NE592A	LM733CN	
NE592K	LM733CH	
PA239A		LM381N
S5101T	LM101H	
S5107T	LM107H	
S5108T	LM108H	
S51A1T	LM101AH	
S51A8T	LM108AH	
S5556L		LM107H
S5558T	LM1558H	
S5596K	LM1596H	
S5709T	LM709H	

SIGNETICS DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
S5710T	LM710H	
S5711K	LM711H	
S5711T		LM711H
S5723L	LM723H	
S5733F	LM733D	
S5733K	LM733H	
S5740T	LM740H	
S5741T	LM741H	
S5747K	LM747H	
S5748T	LM748H	
SE501G		LM733H
SE501K		LM733H
SE510A		LM171H
SE510J		LM171H
SE515G		LM733H
SE515K		LM733H
SE518A		LM106H
SE518G		LM106H
SE518K		LM106H
SE526A		LM106H
SE526G		LM106H
SE526K		LM106H
SE529K	LM161H	
SE531G		LM118H
SE533G		LM4250CH
SE533T		LM4250H
SE537G		LM108H
SE537T		LM108H
SE540L		LH0021K
SE550L		LM723H
SE555T	LM555H	
SE555V	LM555N	
SE565A	LM565N	
SE565K	LM565H	
SE566T	LM566H	
SE567T	LM567H	
SE592A	LM733N	
SE592K	LM733H	
SU536G		LM216H
SU536T		LM216H

Signetics Linear Cross Reference Guide

FAIRCHILD DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
LM101AD	LM101AD	
LM101AF	LM101AF	
LM101AH	LM101AH	
LM101D	LM101J	
LM101H	LM101H	
LM102H	LM102H	
LM104H	LM104H	
LM105H	LM105H	
LM107H	LM107H	
LM108AD	LM108AD	
LM108AF	LM108AF	
LM108AH	LM108AH	
LM108D	LM108D	
LM108F	LM108F	
LM108H	LM108H	
LM109K	LM109K	
LM110H	LM110H	
LM111H	LM111H	
LM201AH	LM201AH	
LM201AD	LM201AD	
LM201AF	LM201AF	
LM207H	LM207H	
LM208AD	LM208AD	
LM208AF	LM208AF	
LM208AH	LM208AH	
LM208D	LM208D	
LM208F	LM208F	
LM208H	LM208H	
LM209K	LM209K	
LM301AH	LM301AH	
LM301AN	LM301AN	
LM302H	LM302H	
LM304H	LM304H	
LM305AH	LM305AH	
LM305H	LM305H	
LM307H	LM307H	
LM307N	LM307N	
LM308AD	LM308AD	
LM308AH	LM308AH	
LM308D	LM308D	
LM308H	LM308H	
LM309K	LM309K	
LM310H	LM310H	
LM376N	LM376N	
703	LM703LH	
709AHM	LM709AH	

FAIRCHILD DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
709HM	LM709H	
710DC	LM710CN	
710H	LM710H	
710HC	LM710CH	
711HM	LM711H	
720PC	LM1820N	
723DC	LM723CN	
723DM	LM723D	
723HC	LM723CH	
723HM	LM723H	
725AHM	LM725AH	
726		LM114A
727		LM121H
732PC	LM1304N	
733DC	LM733CD	
733DM	LM733D	
733HC	LM733CH	
733HM	LM733H	
739		LM381N
740HC	LH740ACH	
740HM	LH740AH	
741DC	LM741CN-14	
741FM	LM741F	
741HC	LM741CH	
741HM	LM741H	
741TC	LM741CN	
746PC	LM746N	
747DC	LM747CN	
747DM	LM747D	
747HC	LM747CH	
747HM	LM747H	
748HC	LM748CH	
747HM	LM748H	
748TC	LM748CN	
749		LM1303N
750		LM711H
758		LM1800
760		LM361
767		LM1304
768PC		LM1304
769		LM1304
771		LM725
776HC	LM4250CH	
776HM	LM4250H	
777		LM108
780DC	LM3070N	

FAIRCHILD DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
786		LM3067
796HC	LM1496H	
MC1458G	LM1458H	
MC1458P1	LM1458N	
MC1558G	LM1558H	
CA3018	LM3018H	
CA3018A	LM3018AH	
CA3019	LM3019H	
CA3026	LM3026H	
CA3039	LM3039H	
CA3045	LM3045D	
CA3046	LM3046N	
CA3054	LM3054N	
CA3064T	LM3064H	
CA3065D	LM3065N	
CA3065E	LM3065N	
CA3066D	LM3066N	
CA3066E	LM3066N	
CA3067D	LM3067N	
CA3067E	LM3067N	
CA3075D	LM3075N	
CA3075E	LM3075N	
CA3086	LM3086N	
7805KM		LM340K-5.0
7805UC		LM340T-5.0
7806KM		LM340K-6.0
7806UC		LM340T-6.0
7808KM		LM340K-8.0
7808UC		LM340T-8.0
7812KM		LM340K-12
7812UC		LM340T-12
7815KM		LM340K-15
7815UC		LM340T-15
7818KM		LM340T-18
7818UC		LM340T-18
7824KM		LM340K-24
7824UC		LM340T-24
78M05HC		LM340T-5.0
78M06HC		LM340T-6.0
78M08HC		LM340T-8.0
78M12HC		LM340T-12
78M15HC		LM340T-15
78M24HC		LM340T-24
78N05.2GJ	LM120K-5.2	
SH3002		AHO162
TBA510		LM3066

Voltage Regulators

LM100/LM200/LM300 voltage regulator

general description

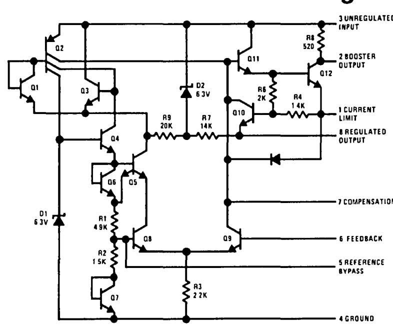
The LM100, LM200 and LM300 are integrated voltage regulators designed for a wide range of applications from digital power supplies to precision regulators for analog circuitry. Built on a single silicon chip, these devices are encapsulated in either an 8-lead, low profile TO-5 header or a 1/4 x 1/4 metal flat package. Outstanding characteristics are:

- Output voltage adjustable from 2V to 30V (LM300 adjustable from 2V to 20V)
- Better than one percent load and line regulation
- One percent temperature stability
- Adjustable short-circuit limiting
- Output currents in excess of 5A possible by adding external transistors
- Can be used as either a linear or high-efficiency switching regulator.

Additional features are fast response to both load and line transients, small standby power dissipation, freedom from oscillations with varying resistive and reactive loads, and the ability to start reliably on any load within rating.

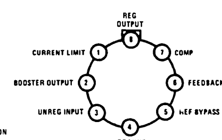
The LM100 is specified for operation over the −55°C to +125°C military temperature range. The LM200 and LM300 are low cost, commercial-industrial versions of the LM100. They are identical to the LM100 except that they are specified for operation from −25°C to 85°C and from 0°C to 70°C respectively.

schematic and connection diagrams



Pin connections shown are for TO-5 package

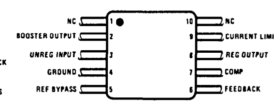
Metal Can



Note: Pin 4 connected to case.
TOP VIEW

Order Number LM100H or LM200H or LM300H
See Package 11

Flat Package

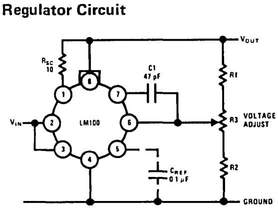


Note: Pin 4 connected to bottom of package.
TOP VIEW

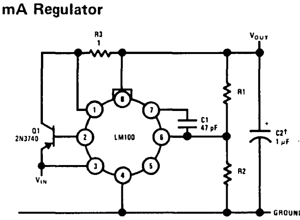
Order Number LM100F or LM200F or LM300F
See Package 3

typical applications

Basic Regulator Circuit

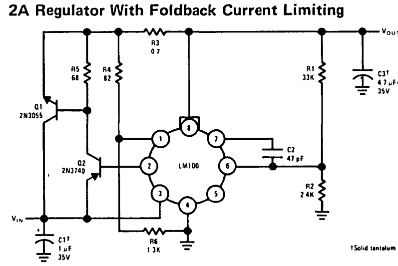


200 mA Regulator



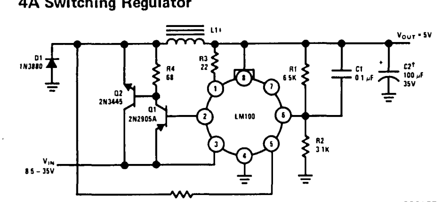
†Solid tantalum.

2A Regulator With Foldback Current Limiting



†Solid tantalum.

4A Switching Regulator



‡ 60 turns = 20 on Arnold Engineering A930157-2 molybdenum permalloy core.
† Solid tantalum.

absolute maximum ratings

Input Voltage	
LM100, LM200	40V
LM300	35V
Input-Output Voltage Differential	
LM100, LM200	40V
LM300	30V
Power Dissipation (Note 1)	
LM100, LM200	800 mW
LM300	500 mW
Operating Temperature Range	
LM100, LM200	-55°C to +125°C
LM300	0°C to 70°C
Storage Temperature Range	-65°C to 150°C
Lead Temperature (soldering, 10 sec)	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range					
LM100/LM200		8.5		40	V
LM300		8.5		30	
Output Voltage Range					
LM100/LM200		2.0		30	V
LM300				20	
Output-Input Voltage Differential					
LM100/LM200		3.0		30	V
LM300				20	
Load Regulation (Note 3)	$R_{SC} = 0, I_O < 12$ mA		0.1	0.5	%
Line Regulation	$V_{IN} - V_{OUT} \leq 5V$		0.1	0.2	%/V
	$V_{IN} - V_{OUT} \geq 5V$		0.05	0.1	%/V
Temperature Stability					
LM100	$-55°C \leq T_A \leq +125°C$		0.3	1.0	
LM200	$-25°C \leq T_A \leq 85°C$		0.3	1.0	%
LM300	$0°C \leq T_A \leq 70°C$		0.3	2.0	
Feedback Sense Voltage		1.63	1.7	1.81	V
Output Noise Voltage	$10 Hz \leq f \leq 10 kHz$				
	$C_{REF} = 0$		0.005		%
	$C_{REF} = 0.1\ \mu F$		0.002		%
Long Term Stability			0.1	1.0	%
Standby Current Drain					
LM100/LM200	$V_{IN} = 40V$		1.0	3.0	mA
LM300	$V_{IN} = 30V$				
Minimum Load Current					
LM100/LM200	$V_{IN} - V_{OUT} = 30V$		1.5	3.0	mA
LM300	$V_{IN} - V_{OUT} = 20V$				

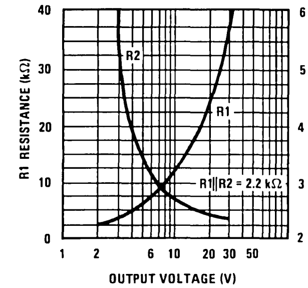
Note 1: The maximum junction temperature of the LM100 is 150°C, while that of the LM200 is 100°C, and the LM300 is 85°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W junction to ambient or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick, epoxy-glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. Peak dissipations to 1.0W are allowable providing the dissipation rating is not exceeded with the power averaged over a five second interval for the LM100 and LM200, and a two second interval for the LM300.

Note 2: These specifications apply for an operating temperature between –55°C to +125°C for the LM100, between –25°C to 85°C for the LM200 and between 0°C to 70°C for the LM300 devices for input and output voltages within the ranges given, and for a divider impedance seen by the feedback terminal of 2 kΩ, unless otherwise specified. The load and line regulation specifications are for constant junction temperature. Temperature drift effects must be taken into account separately when the unit is operating under conditions of high dissipation.

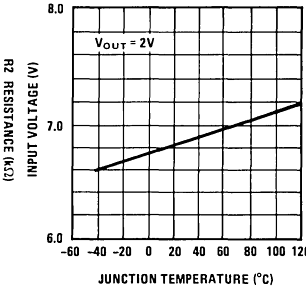
Note 3: The output currents given, as well as the load regulation, can be increased by the addition of external transistors. The improvement factor will be roughly equal to the composite current gain of the added transistors.

typical performance characteristics

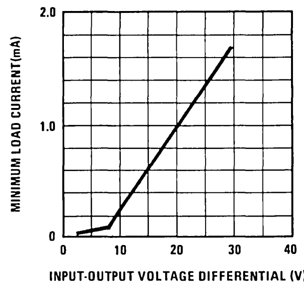
Optimum Divider Resistance Values vs Output Voltage



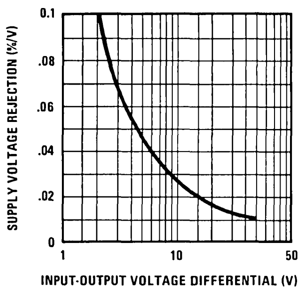
Minimum Input Voltage vs Junction Temperature



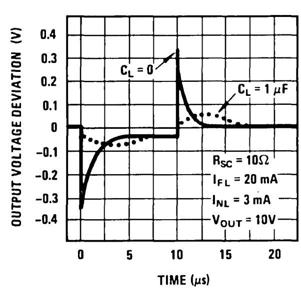
Minimum Load Current vs Input-Output Voltage Differential



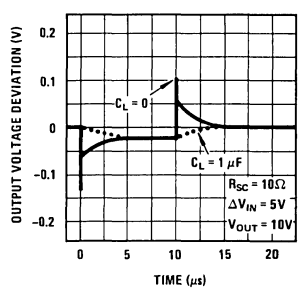
Supply Voltage Rejection vs Input-Output Voltage Differential



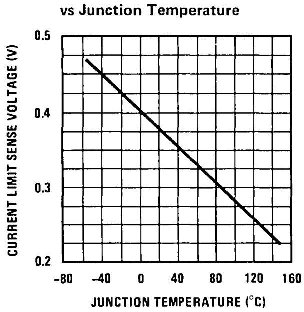
Load Transient Response



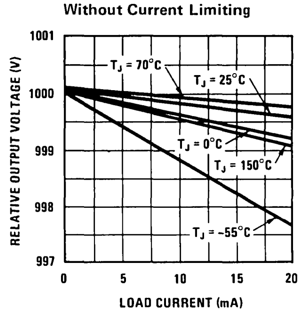
Line Transient Response



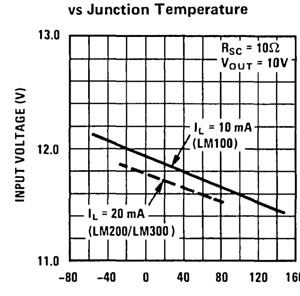
Current Limit Sense Voltage vs Junction Temperature



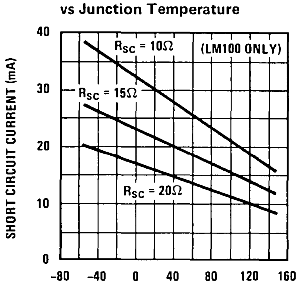
Regulation Characteristics Without Current Limiting



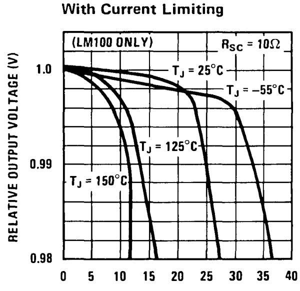
Regulator Dropout Voltage vs Junction Temperature



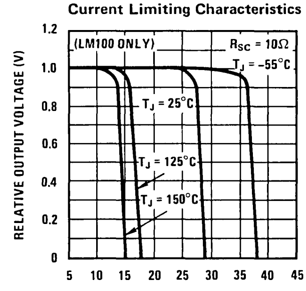
Short Circuit Current vs Junction Temperature



Regulation Characteristics With Current Limiting



Current Limiting Characteristics



Voltage Regulators

LM103 regulator diode **

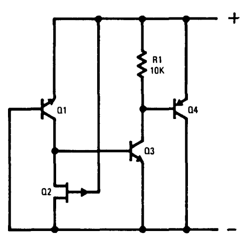
general description

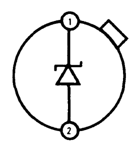
The LM103 is a two-terminal monolithic regulator diode electrically equivalent to a breakdown diode. The device makes use of the reverse punch-through of double-diffused transistors, combined with active circuitry, to produce a breakdown characteristic which is ten times sharper than single-junction zener diodes at low voltages. Breakdown voltages from 1.8V to 5.6V are available; and, although the design is optimized for operation between 100 μA and 1 mA, it is completely specified from 10 μA to 10 mA. Noteworthy features of the device are:

- Exceptionally sharp breakdown
- Low dynamic impedance from 10 μA to 10 mA
- Performance guaranteed over full military temperature range
- Planar, passivated junctions for stable operation
- Low capacitance.

The LM103, packaged in a hermetically sealed, modified TO-46 header is useful in a wide range of circuit applications from level shifting to simple voltage regulation. It can also be employed with operational amplifiers in producing breakpoints to generate nonlinear transfer functions. Finally, its unique characteristics recommend it as a reference element in low voltage power supplies with input voltages down to 4V.

schematic and connection diagrams



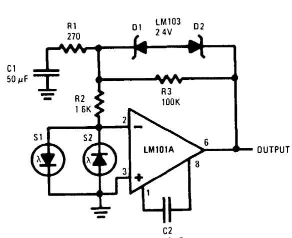


Note: Pin 2 connected to case.
TOP VIEW

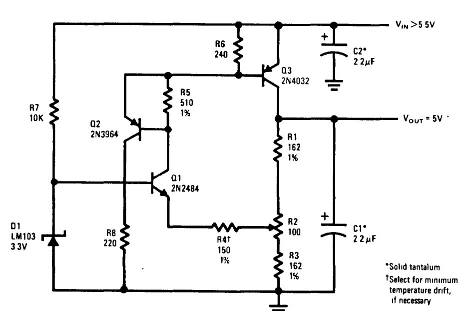
Order Number LM103H
See Package 8

typical applications

Saturating Servo Preamplifier with Rate Feedback



200 mA Positive Regulator



**Covered by U.S. Patent Number 3,571,630.

absolute maximum ratings

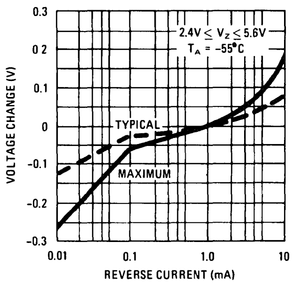
Power Dissipation (note 1)	250 mW
Reverse Current	20 mA
Forward Current	100 mA
Operating Temperature Range	−55°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (soldering, 60 sec)	300°C

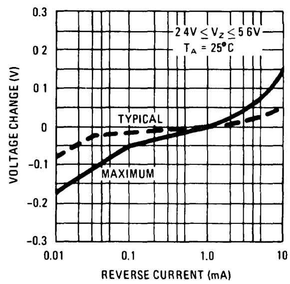
electrical characteristics (Note 2)

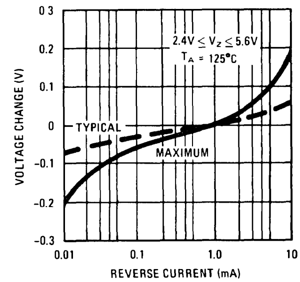
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
Reverse Breakdown Voltage Change	$10\ \mu A \leq I_R \leq 100\ \mu A$		60	120	mV
	$100\ \mu A \leq I_R \leq 1\ mA$		15	50	mV
	$1\ mA \leq I_R \leq 10\ mA$		50	150	mV
Reverse Dynamic Impedance (Note 3)	$I_R = 3\ mA$		5	25	Ω
	$I_R = 0.3\ mA$		15	60	Ω
Reverse Leakage Current	$V_R = V_Z - 0.2V$		2	5	μA
Forward Voltage Drop	$I_F = 10\ mA$	0.7	0.8	1.0	V
Peak-to-Peak Broadband Noise Voltage	$10\ Hz \leq f \leq 100\ kHz$, $I_R = 1\ mA$		300		μV
Reverse Breakdown Voltage Change (Note 4)	$10\ \mu A \leq I_R \leq 100\ \mu A$			200	mV
	$100\ \mu A \leq I_R \leq 1\ mA$			60	mV
	$1\ mA \leq I_R \leq 10\ mA$			200	mV
Breakdown Voltage Temperature Coefficient (Note 4)	$100\ \mu A \leq I_R \leq 1\ mA$		−5.0		mV/°C

NOTE 1: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 80°C/W junction to case or 440°C/W junction to ambient (see curve).
NOTE 2: These specifications apply for $T_A = 25°C$ and $1.8V < V_Z < 5.6V$ unless stated otherwise. The diode should not be operated with shunt capacitances between 100 pF and 0.01 μF, unless isolated by at least a 50Ω resistor, as it may oscillate at some currents.
NOTE 3: Measured with the peak-to-peak change of reverse current equal to 10 percent of the dc reverse current.
NOTE 4: These specifications apply for $-55°C < T_A < 125°C$.

guaranteed reverse characteristics

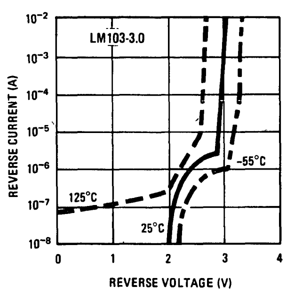




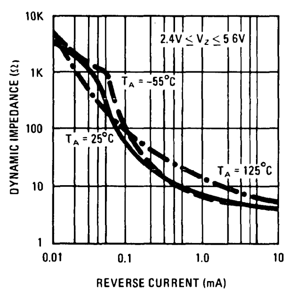


typical performance characteristics

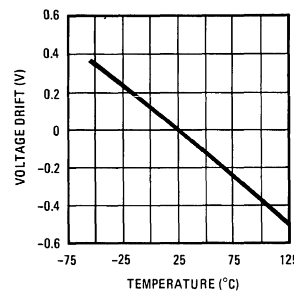
Reverse Characteristics



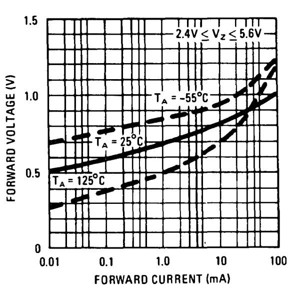
Reverse Dynamic Impedance



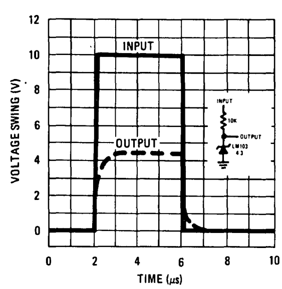
Temperature Drift



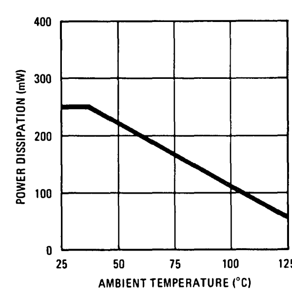
Forward Characteristics



Response Time



Maximum Power Dissipation



BREAKDOWN VOLTAGE*	PART NUMBER
1.8	LM103H-1.8
2.0	LM103H-2.0
2.2	LM103H-2.2
2.4	LM103H-2.4
2.7	LM103H-2.7
3.0	LM103H-3.0
3.3	LM103H-3.3
3.6	LM103H-3.6
3.9	LM103H-3.9
4.3	LM103H-4.3
4.7	LM103H-4.7
5.1	LM103H-5.1
5.6	LM103H-5.6

*Measured at I_R = 1 mA.
Standard tolerance is ±10%.

Voltage Regulators

LM104/LM204 negative regulator general description

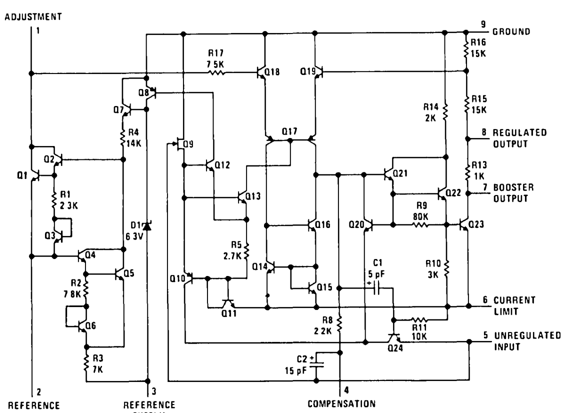
The LM104 and LM204 are precision voltage regulators which can be programmed by a single external resistor to supply any voltage from 40V down to zero while operating from a single unregulated supply. They can also provide 0.01-percent regulation in circuits using a separate, floating bias supply, where the output voltage is limited only by the breakdown of external pass transistors. Although designed primarily as linear, series regulators, the circuits can be used as switching regulators, current regulators or in a number of other control applications. Typical performance characteristics are:

- 1 mV regulation no load to full load
- 0.01%/V line regulation
- 0.2 mV/V ripple rejection
- 0.3% temperature stability over military temperature range

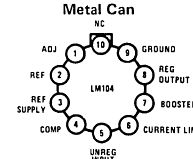
The LM104 and LM204 are complements of the LM100 and LM105 positive regulators, intended for systems requiring regulated negative voltages which have a common ground with the unregulated supply. By themselves, they can deliver output currents to 25 mA, but external transistors can be added to get any desired current. The output voltage is set by external resistors, and either constant or foldback current limiting is made available.

The LM104 is specified for operation over the −55°C to +125°C military temperature range. The LM204 is specified for operation over the −25°C to +85°C temperature range.

schematic and connection diagrams



Metal Can

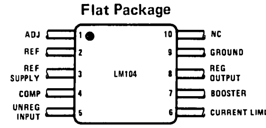


Note: Pin 5 connected to case.

TOP VIEW

Order Number LM104H or LM204H
See Package 12

Flat Package



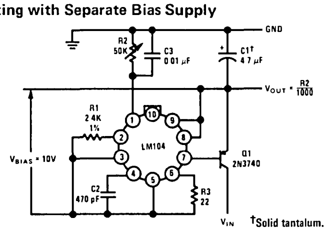
Note: Pin 5 connected to bottom of package.

TOP VIEW

Order Number LM104F or LM204F
See Package 3

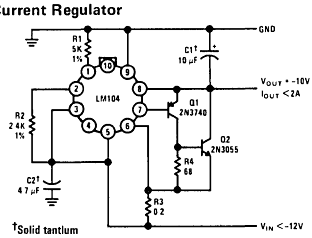
typical applications

Operating with Separate Bias Supply



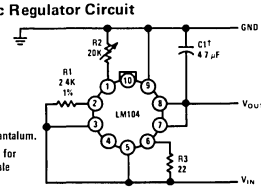
†Solid tantalum.

High Current Regulator



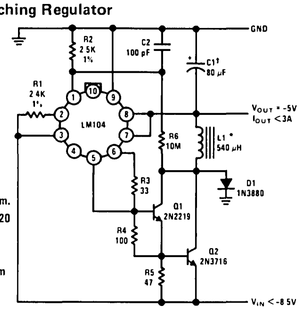
†Solid tantlum

Basic Regulator Circuit



†Solid tantalum.
Trim R1 for exact scale factor.

Switching Regulator



†Solid tantlum.
*60 Turns #20 on Arnold Engineering A930157-2 Molybdenum Permalloy Core.

absolute maximum ratings

Input Voltage	50V
Input-Output Voltage Differential	50V
Power Dissipation (Note 1)	500 mW
Operating Temperature Range	
LM104	−55°C to 125°C
LM204	−25°C to 85°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range		−50		−8	V
Output Voltage Range		−40		−0.015	V
Output-Input Voltage Differential (Note 3)	I_O = 20 mA	2.0		50	V
	I_O = 5 mA	0.5		50	V
Load Regulation (Note 4)	$0 \leq I_O \leq 20$ mA, R_{SC} = 15Ω		1	5	mV
Line Regulation (Note 5)	$V_{OUT} \leq -5V$, $\Delta V_{IN} = 0.1\ V_{IN}$		0.056	0.1	%
Ripple Rejection	C_{19} = 10 μF, f = 120 Hz				
	$V_{IN} < -15V$		0.2	0.5	mV/V
	$-7V \geq V_{IN} \geq -15V$		0.5	1.0	mV/V
Output Voltage Scale Factor	R_{23} = 2.4k	1.8	2.0	2.2	V/kΩ
Temperature Stability	$V_O \leq -1V$		0.3	1.0	%
Output Noise Voltage	$10\ Hz \leq f \leq 10\ kHz$				
	$V_O \leq -5V$, $C_{19} = 0$		0.007		%
	C_{19} = 10 μF		15		μV
Standby Current Drain	I_L = 5 mA, V_O = 0		1.7	2.5	mA
	V_O = −40V		3.6	5.0	mA
Long Term Stability	$V_O \leq -1V$		0.1	1.0	%

Note 1: The maximum junction temperature of the LM104 is 150°C, while that of the LM204 is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors.

Note 2: These specifications apply for junction temperatures between −55°C and 150°C (between −25°C and 100°C for the LM204) and for input and output voltages within the ranges given, unless otherwise specified. The load and line regulation specifications are for constant junction temperature. Temperature drift effects must be taken into account separately when the unit is operating under conditions of high dissipation.

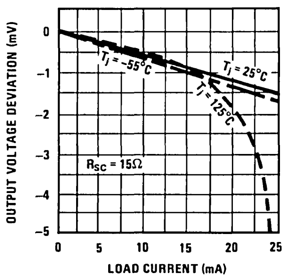
Note 3: When external booster transistors are used, the minimum output-input voltage differential is increased, in the worst case, by approximately 1V.

Note 4: The output currents given, as well as the load regulation, can be increased by the addition of external transistors. The improvement factor will be roughly equal to the composite current gain of the added transistors.

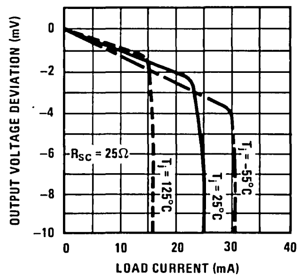
Note 5: With zero output, the dc line regulation is determined from the ripple rejection. Hence, with output voltages between 0V and −5V, a dc output variation, determined from the ripple rejection, must be added to find the worst-case line regulation.

typical performance characteristics

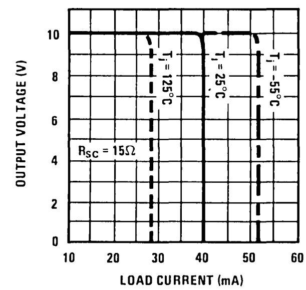
Load Regulation



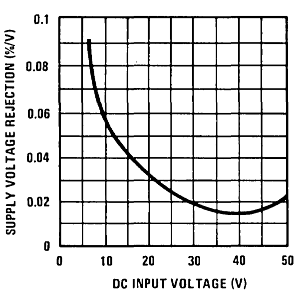
Load Regulation



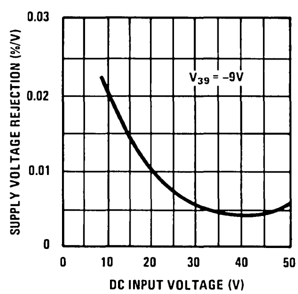
Current Limiting



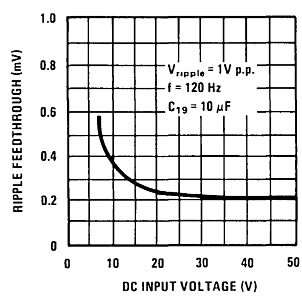
Supply Voltage Rejection



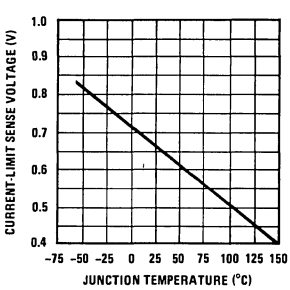
Supply Voltage Rejection With Preregulated Reference Supply



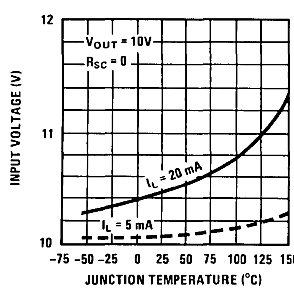
Ripple Rejection



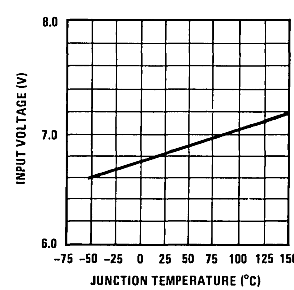
Current Limit Sense Voltage



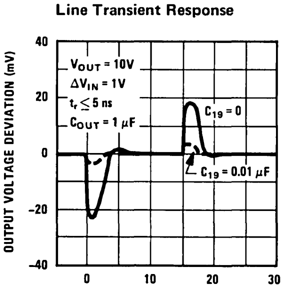
Regulator Dropout Voltage



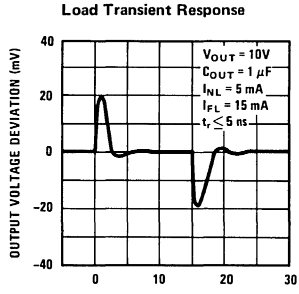
Minimum Input Voltage



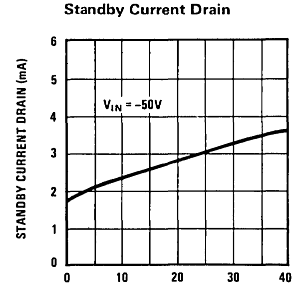
Line Transient Response



Load Transient Response



Standby Current Drain



Voltage Regulators

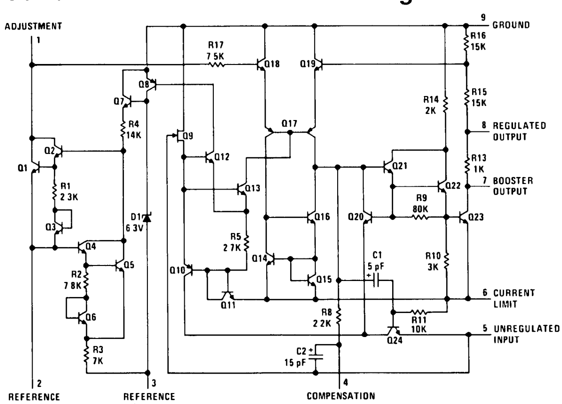
LM304 negative regulator general description

The LM304 is a precision voltage regulator which can be programmed by a single external resistor to supply any voltage from 30V down to zero while operating from a single unregulated supply. It can also provide 0.01-percent regulation in circuits using a separate, floating bias supply, where the output voltage is limited only by the breakdown of external pass transistors. Although designed primarily as a linear, series regulator, the circuit can be used as a switching regulator, a current regulator or in a number of other control applications. Typical performance characteristics are:

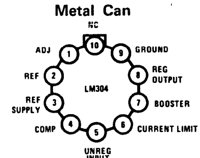
- 1 mV regulation no load to full load
- 0.01%/V line regulation
- 0.2 mV/V ripple rejection

The LM304 is a complement of the LM300 and LM305 positive regulators, intended for systems requiring regulated negative voltages which have a common ground with the unregulated supply. By itself, it can deliver output currents to 25 mA, but external transistors can be added to get any desired current. The output voltage is set by external resistors, and either constant or foldback current limiting is made available. The LM304 is a commercial/industrial version of the LM104 and LM204.

schematic and connection diagrams



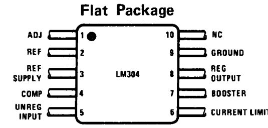
Metal Can



Note: Pin 5 connected to case.
TOP VIEW

Order Number LM304H
See Package 12

Flat Package

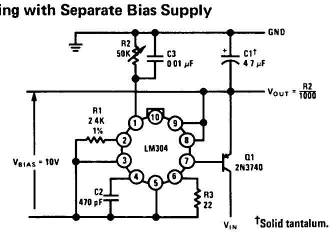


Note: Pin 5 connected to bottom of package.
TOP VIEW

Order Number LM304F
See Package 3

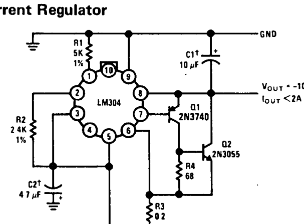
typical applications

Operating with Separate Bias Supply



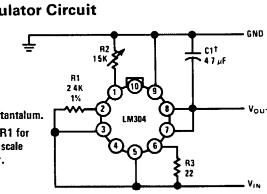
†Solid tantalum.

High Current Regulator



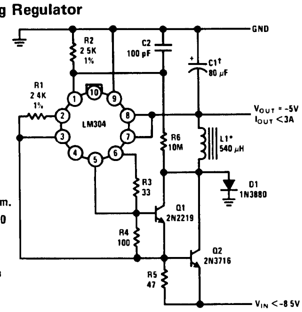
†Solid tantalum.

Basic Regulator Circuit



†Solid tantalum.
Trim R1 for exact scale factor.

Switching Regulator



†Solid tantalum.
*60 Turns # 20 on Arnold Engineering A930157-2 Molybdenum Permalloy Core.

absolute maximum ratings

Input Voltage	40V
Input-Output Voltage Differential	40V
Power Dissipation (Note 1)	500 mW
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range		−40		−8	V
Output Voltage Range		−30		−0.035	V
Output-Input Voltage Differential (Note 3)	I_O = 20 mA	2.0		40	V
	I_O = 5 mA	0.5		40	V
Load Regulation (Note 4)	$0 \leq I_O \leq 20$ mA				
	R_{SC} = 15Ω		1	5	mV
Line Regulation (Note 5)	$V_{OUT} \leq -5V$				
	$\Delta V_{IN} = 0.1\ V_{IN}$		0.056	0.1	%
Ripple Rejection	C_{19} = 10 µF, f = 120 Hz				
	$V_{IN} < -15V$		0.2	0.5	mV/V
	$-7V \geq V_{IN} \geq -15V$		0.5	1.0	mV/V
Output Voltage Scale Factor	R_{23} = 2.4K	1.8	2.0	2.2	V/KΩ
Temperature Stability	$V_O \leq -1V, 0°C \leq T_A \leq 70°C$		0.3	1.0	%
Output Noise Voltage	10 Hz ≤ f ≤ 10 KHz				
	$V_O \leq -5V, C_{19} = 0$		0.007		%
	C_{19} = 10 µF		15		µV
Standby Current Drain	I_L = 5 mA, V_O = 0		1.7	2.5	mA
	V_O = −30V		3.6	5.0	mA
Long Term Stability	$V_O \leq -1V$		0.1	1.0	%

Note 1: For operating at elevated temperatures, the device must be derated based on an 85°C maximum junction temperature and a thermal resistance of 45°C/W junction to case or 150°C/W junction to ambient. Peak dissipations to 1.0W are allowable providing the dissipation rating is not exceeded with the power averaged over a two second interval.

Note 2: These specifications apply for junction temperatures between 0°C and 85°C and for input and output voltages within the ranges given, unless otherwise specified. The load and line regulation specifications are for constant junction temperature. Temperature drift effects must be taken into account separately when the unit is operating under conditions of high dissipation.

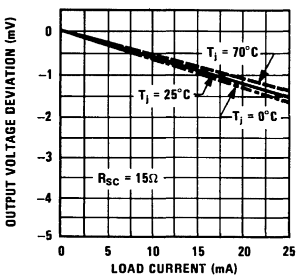
Note 3: When external booster transistors are used, the minimum output-input voltage differential is increased, in the worst case, by approximately 1V.

Note 4: The output currents given, as well as the load regulation, can be increased by the addition of external transistors. The improvement factor will be roughly equal to the composite current gain of the added transistors.

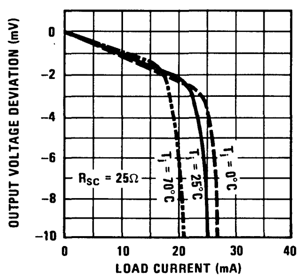
Note 5: With zero output, the dc line regulation is determined from the ripple rejection. Hence, with output voltages between 0V and −5V, a dc output variation, determined from the ripple rejection, must be added to find the worst-case line regulation.

typical performance characteristics

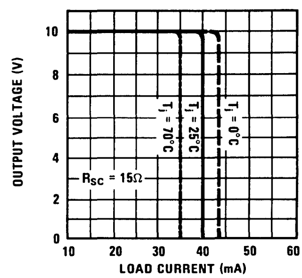
Load Regulation



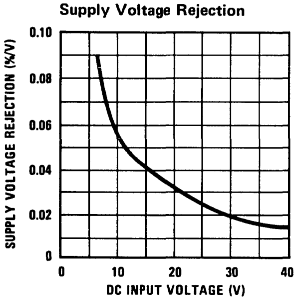
Load Regulation



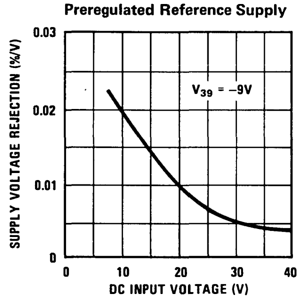
Current Limiting



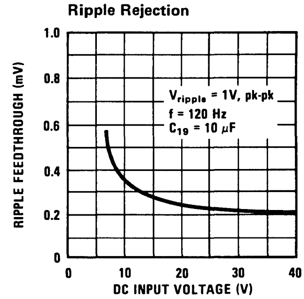
Supply Voltage Rejection



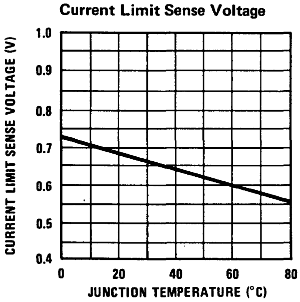
Supply Voltage Rejection With Preregulated Reference Supply



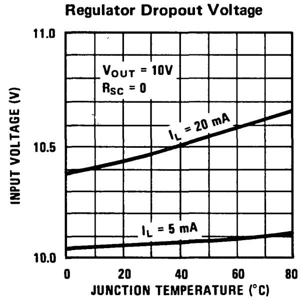
Ripple Rejection



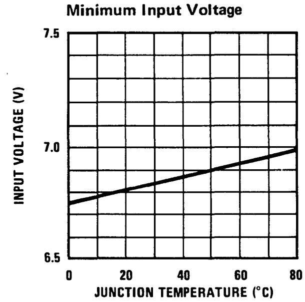
Current Limit Sense Voltage



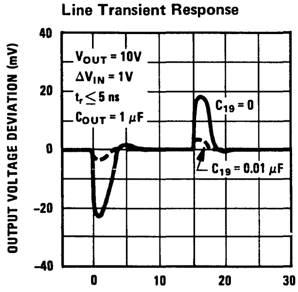
Regulator Dropout Voltage



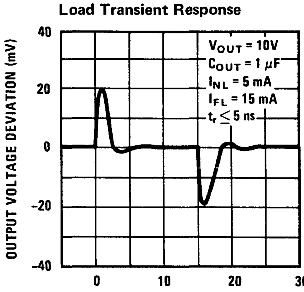
Minimum Input Voltage



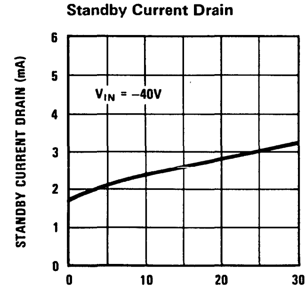
Line Transient Response



Load Transient Response



Standby Current Drain



Voltage Regulators

LM105/LM205/LM305 voltage regulator

general description

The LM105, LM205 and LM305 are positive voltage regulators similar to the LM100, except that an extra gain stage has been added for improved regulation. A redesign of the biasing circuitry removes any minimum load current requirement and at the same time reduces standby current drain, permitting higher voltage operation. They are direct, plug-in replacements for the LM100 in both linear and switching regulator circuits with output voltages greater than 4.5V. Important characteristics of the circuits are:

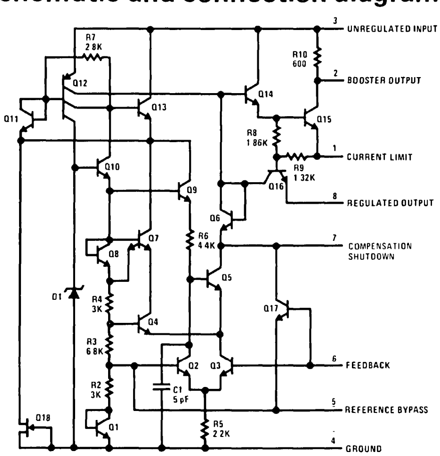
- Output voltage adjustable from 4.5V to 40V
- Output currents in excess of 10A possible by adding external transistors
- Load regulation better than 0.1%, full load with current limiting
- DC line regulation guaranteed at 0.03%/V
- Ripple rejection of 0.01%/V

Like the LM100, they also feature fast response to both load and line transients, freedom from oscillations with varying resistive and reactive loads and the ability to start reliably on any load within rating. The circuits are built on a single silicon chip and are supplied in either an 8-lead, TO-5 header or a 1/4" x 1/4" metal flat package.

The LM205 is identical to the LM105 except that it is specified for operation from −25°C to 85°C.

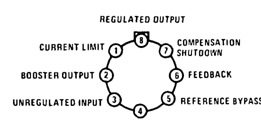
The LM305 is specified for operation from 0°C to 70°C and for output voltages to 30V.

schematic and connection diagrams



Pin connections shown are for metal can.

Metal Can

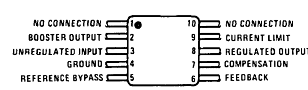


Note: Pin 4 connected to case.

TOP VIEW

Order Number LM105H, LM205H or LM305H
See Package 11

Flat Package

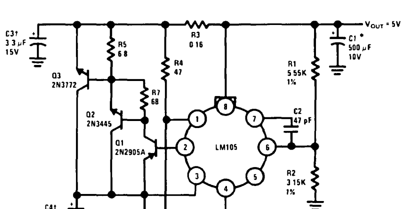


Note: Pin 4 connected to bottom of package.

Order Number LM105F, LM205F or LM305F
See Package 3

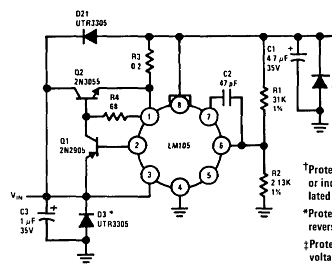
typical applications

10A Regulator with Foldback Current Limiting



†Solid tantalum.
*Electrolytic.

1.0A Regulator with Protective Diodes



†Protects against shorted input or inductive loads on unregulated supply.
*Protects against input voltage reversal.
‡Protects against output voltage reversal.

absolute maximum ratings

Input Voltage	
LM105, LM205	50V
LM305	40V
Input-Output Voltage Differential	40V
Power Dissipation (Note 1)	
LM105, LM205	800 mW
LM305	500 mW
Operating Temperature Range	0°C to 70°C
LM105	-55°C to +125°C
LM205	-25°C to +85°C
LM305	0°C to 70°C
Storage Temperature Range	-65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range					
LM105, LM205		8.5		50	V
LM305		8.5		40	V
Output Voltage Range					
LM105, LM205		4.5		40	V
LM305		4.5		30	V
Output-Input Voltage Differential		3.0		30	V
Load Regulation (Note 3)					
LM105	$0 \leq I_O \leq 12$ mA				
	$R_{SC} = 10\Omega$, $T_A = 25°C$		0.02	0.05	%
	$R_{SC} = 10\Omega$, $T_A = 125°C$		0.03	0.1	%
	$R_{SC} = 10\Omega$, $T_A = -55°C$		0.03	0.1	%
LM205	$0 \leq I_o \leq 12$ mA				
	$R_{SC} = 10\Omega$, $T_A = 25°C$		0.02	0.05	%
	$R_{SC} = 10\Omega$, $T_A = 85°C$		0.03	0.1	%
	$R_{SC} = 10\Omega$, $T_A = -25°C$		0.03	0.1	%
LM305	$0 \leq I_O \leq 12$ mA				
	$R_{SC} = 10\Omega$, $T_A = 25°C$		0.02	0.05	%
	$R_{SC} = 15\Omega$, $T_A = 70°C$		0.03	0.1	%
	$R_{SC} = 10\Omega$, $T_A = 0°C$		0.03	0.1	%
Line Regulation	$V_{IN} - V_{OUT} \leq 5V$		0.025	0.06	%/V
	$V_{IN} - V_{OUT} > 5V$		0.015	0.03	%/V
Ripple Rejection	$C_{REF} = 10\,\mu F$, f = 120 Hz		0.003	0.01	%/V
Temperature Stability					
LM105	$-55°C \leq T_A \leq 125°C$		0.3	1.0	%
LM205	$-25°C \leq T_A \leq 85°C$		0.3	1.0	%
LM305	$0°C \leq T_A \leq 70°C$		0.3	1.0	%
Feedback Sense Voltage		1.63	1.7	1.81	V
Output Noise Voltage	$10\text{ Hz} \leq f \leq 10\text{ kHz}$				
	$C_{REF} = 0$		0.005		%
	$C_{REF} > 0.1\,\mu F$		0.002		%
Current Limit Sense Voltage	$R_{SC} = 10\Omega$, $T_A = 25°C$, $V_{OUT} = 0V$	225	300	375	mV
Standby Current Drain					
LM105, LM205	$V_{IN} = 50V$		0.8	2.0	mA
LM305	$V_{IN} = 40V$		0.8	2.0	mA
Long Term Stability			0.1	1.0	%

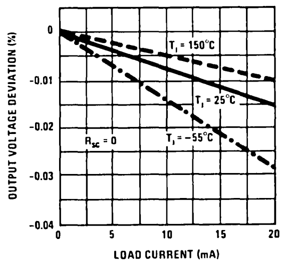
Note 1: The maximum junction temperature of the LM105 is 150°C, while that for the LM205 is 100°C, and that for the LM305 is 85°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. Peak dissipations to 1W are allowable providing the dissipation rating is not exceeded with the power averaged over a five second interval for the LM105 and LM205, and averaged over a two second interval for the LM305.

Note 2: These specifications apply for input and output voltages within the ranges given, and for a divider impedance seen by the feedback terminal of 2 kΩ, unless otherwise specified. The load and line regulation specifications are for constant junction temperature. Temperature drift effects must be taken into account separately when the unit is operating under conditions of high dissipation. Unless otherwise specified, $T_A = 25°C$.

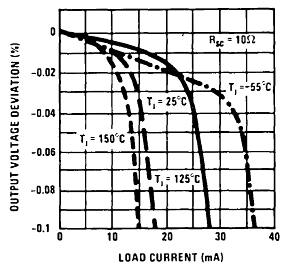
Note 3: The output currents given, as well as the load regulation, can be increased by the addition of external transistors. The improvement factor will be roughly equal to the composite current gain of the added transistors.

typical performance characteristics

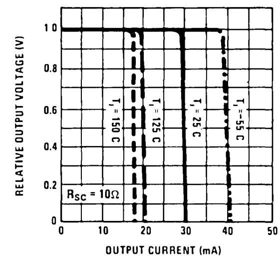
Load Regulation



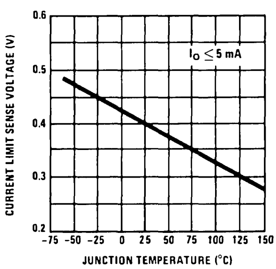
Load Regulation



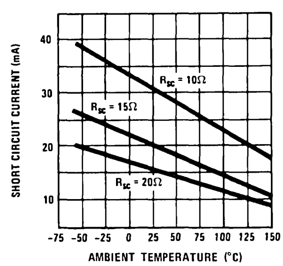
Current Limiting Characteristics



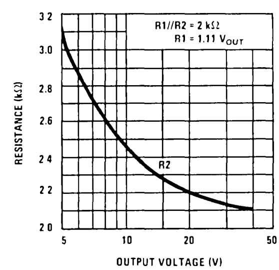
Current Limit Sense Voltage



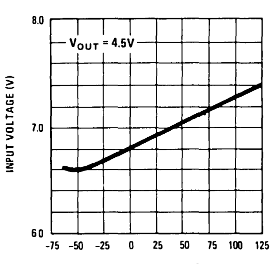
Short Circuit Current



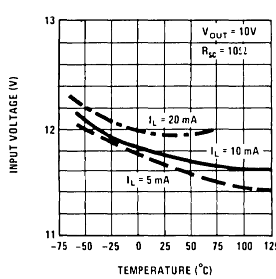
Optimum Divider Resistance Values



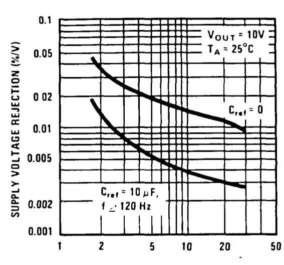
Minimum Input Voltage



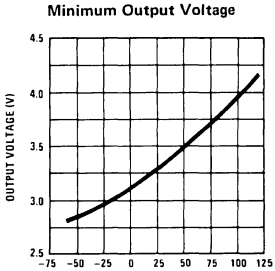
Regulator Dropout Voltage



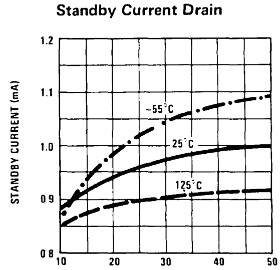
Supply Voltage Rejection



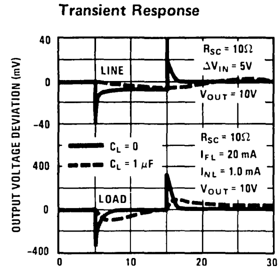
Minimum Output Voltage



Standby Current Drain



Transient Response



Voltage Regulators

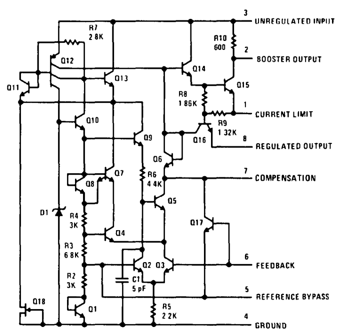
LM305A voltage regulator general description

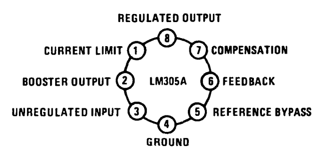
The LM305A is a positive voltage regulator designed primarily for commercial series regulator applications. By itself, it will supply output currents up to 45 mA; but external transistors can be added to provide any desired load current. The circuit features extremely low standby current drain, and provision is made for either linear or foldback current limiting. Important characteristics are:

- 45 mA output current without external pass transistor
- Output currents in excess of 10A possible by adding external transistors
- Maximum input voltage = 50V
- Output voltage adjustable from 4.5V to 40V
- Can be used as either a linear or a switching regulator

The LM305A is also useful in a wide range of other applications such as a shunt regulator, a current regulator or a temperature controller.

schematic and connection diagrams



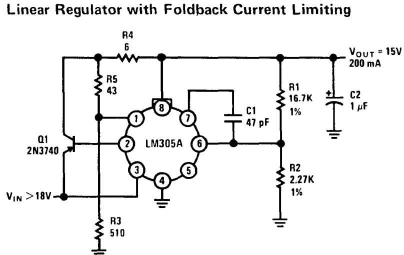


Note: Pin 4 connected to case.

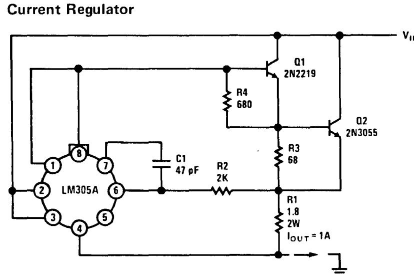
Order Number LM305AH
See Package 11

typical applications

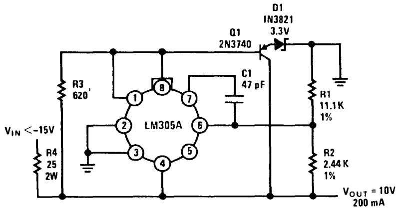
Linear Regulator with Foldback Current Limiting



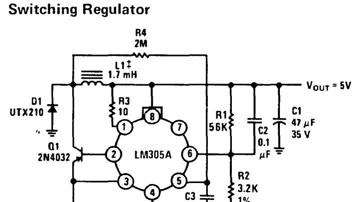
Current Regulator



Shunt Regulator



Switching Regulator



†Solid tantalum.
‡125 turns #22 on Arnold Engineering A262123-2 molybdenum permally core.

absolute maximum ratings

Input Voltage	50V
Input-Output Voltage Differential	40V
Power Dissipation (Note 1)	800 mW
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 60 sec)	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range		8.5		50	V
Output Voltage Range		4.5		40	V
Output-Input Voltage Differential		3.0		30	V
Load Regulation (Note 3)	$0 \leq I_O \leq 45$ mA				
	$R_{SC} = 0\Omega$, $T_A = 25°C$		0.02	0.2	%
	$R_{SC} = 0\Omega$, $T_A = 70°C$		0.03	0.4	%
	$R_{SC} = 0\Omega$, $T_A = 0°C$		0.03	0.4	%
Line Regulation	$V_{IN} - V_{OUT} \leq 5V$		0.025	0.06	%/V
	$V_{IN} - V_{OUT} > 5V$		0.015	0.03	%/V
Ripple Rejection	$C_{REF} = 10\ \mu F$, f = 120 Hz		0.003		%/V
Temperature Stability	$0°C \leq T_A \leq 70°C$		0.3	1.0	%
Feedback Sense Voltage		1.55	1.7	1.85	V
Output Noise Voltage	10 Hz $\leq f \leq$ 10 kHz				
	$C_{REF} = 0$		0.005		%
	$C_{REF} > 0.1\ \mu F$		0.002		%
Current Limit Sense Voltage (Note 4)	$R_{SC} = 10\Omega$, $T_A = 25°C$, $V_{OUT} = 0V$	225	300	375	mV
Standby Current Drain	$V_{IN} = 50V$		0.8	2.0	mA
Long Term Stability			0.1	1.0	%

Note 1: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 45°C/W junction to case or 150°C/W junction to ambient.

Note 2: These specifications apply for an operating temperature between 0°C and 70°C, for input and output voltages within the ranges given, and for a divider impedance seen by the feedback terminal of 2 KΩ, unless otherwise specified. The load and line regulation specifications are for constant junction temperature. Temperature drift effects must be taken into account separately when the unit is operating under conditions of high dissipation.

Note 3: The output currents given, as well as the load regulation, can be increased by the addition of external transistors. The improvement factor will be roughly equal to the composite current gain of the added transistors.

Note 4: With no external pass transistor.

Voltage Regulators

LM109/LM209 five-volt regulator

general description

The LM109 and LM209 are complete 5V regulators fabricated on a single silicon chip. They are designed for local regulation on digital logic cards, eliminating the distribution problems associated with single-point regulation. The devices are available in two common transistor packages. In the solid-kovar TO-5 header, it can deliver output currents in excess of 200 mA, if adequate heat sinking is provided. With the TO-3 power package, the available output current is greater than 1A.

The regulators are essentially blow-out proof. Current limiting is included to limit the peak output current to a safe value. In addition, thermal shutdown is provided to keep the IC from overheating. If internal dissipation becomes too great, the regulator will shut down to prevent excessive heating.

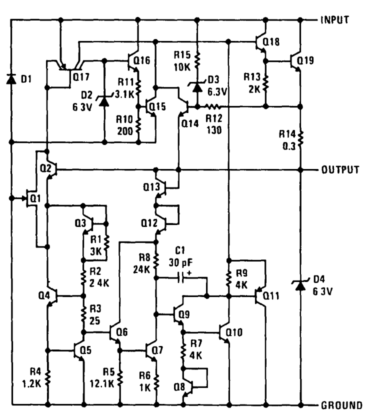
Considerable effort was expended to make these devices easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response somewhat. Input bypassing is needed, however, if the regulator is located very far from the filter capacitor of the power supply. Stability is also achieved by methods that provide very good rejection of load or line transients as are usually seen with TTL logic.

Although designed primarily as a fixed-voltage regulator, the output of the LM109 and LM209 can be set to voltages above 5V, as shown below. It is also possible to use the circuits as the control element in precision regulators, taking advantage of the good current-handling capability and the thermal overload protection.

To summarize, outstanding features of the regulator are:

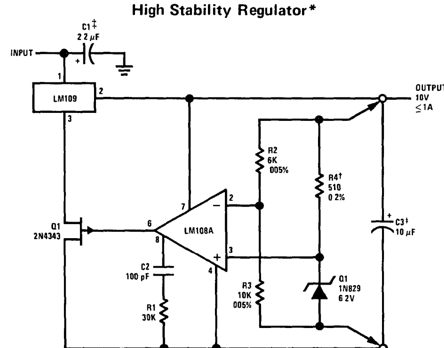
- Specified to be complete, worst case, with TTL and DTL
- Output current in excess of 1A
- Internal thermal overload protection
- No external components required

schematic diagram



typical application

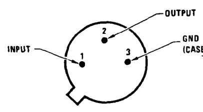
High Stability Regulator*



*Regulation better than 0.01%, load, line and temperature, can be obtained.
†Determines zener current. May be adjusted to minimize thermal drift.
‡Solid tantalum.

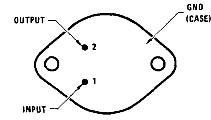
connection diagrams

TO-5 (H)



Order Number LM109H or LM209H
See Package 9

TO-3 (K)



Order Number LM109K or LM209K
See Package 18

absolute maximum ratings

Input Voltage	35V
Power Dissipation	Internally Limited
Operating Junction Temperature Range	−55°C to 150°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 1)

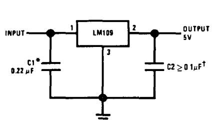
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	$T_j = 25°C$	4.7	5.05	5.3	V
Line Regulation	$T_j = 25°C$ $7V \leq V_{IN} \leq 25V$		4	50	mV
Load Regulation	$T_j = 25°C$				
LM109H	$5\ mA \leq I_{OUT} \leq 0.5A$		20	50	mV
LM109K	$5\ mA \leq I_{OUT} \leq 1.5A$		50	100	mV
Output Voltage	$7V \leq V_{IN} \leq 25V$ $5\ mA \leq I_{OUT} \leq I_{max}$ $P < P_{max}$	4.6		5.4	V
Quiescent Current	$7V \leq V_{IN} \leq 25V$		5.2	10	mA
Quiescent Current Change	$7V \leq V_{IN} \leq 25V$			0.5	mA
	$5\ mA \leq I_{OUT} \leq I_{max}$			0.8	mA
Output Noise Voltage	$T_A = 25°C$ $10\ Hz \leq f \leq 100\ kHz$		40		μV
Long Term Stability				10	mV
Thermal Resistance Junction to Case (Note 2)					
LM109H			15		°C/W
LM109K			3		°C/W

Note 1: Unless otherwise specified, these specifications apply for $-55°C \leq T_j \leq 150°C$ ($-25°C \leq T_j \leq 150°C$ for the LM209), $V_{IN} = 10V$ and $I_{OUT} = 0.1A$ for the TO-5 package or $I_{OUT} = 0.5A$ for the TO-3 package. For the TO-5 package, $I_{max} = 0.2A$ and $P_{max} = 2.0W$. For the TO-3 package, $I_{max} = 1.0A$ and $P_{max} = 20W$.

Note 2: Without a heat sink, the thermal resistance of the TO-5 package is about 150°C/W, while that of the TO-3 package is approximately 35°C/W. With a heat sink, the effective thermal resistance can only approach the values specified, depending on the efficiency of the sink.

typical applications(con't)

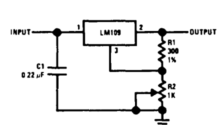
Fixed 5V Regulator



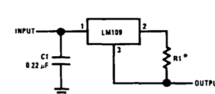
*Required if regulator is located an apprecible distance from power supply filter.

†Although no output capacitor is needed for stability, it does improve transient response.

Adjustable Output Regulator



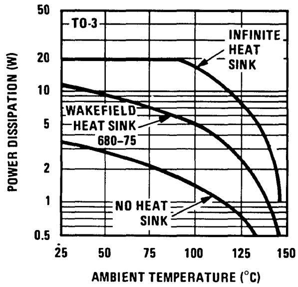
Current Regulator



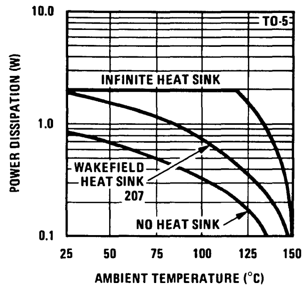
*Determines output current.

typical performance characteristics

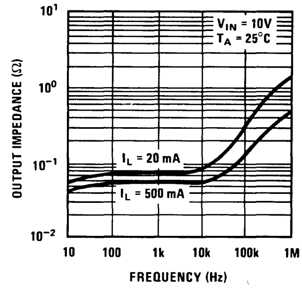
Maximum Average Power Dissipation



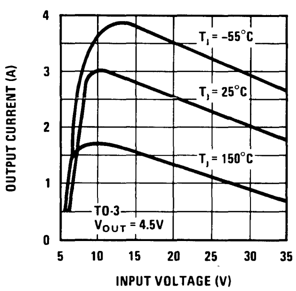
Maximum Average Power Dissipation



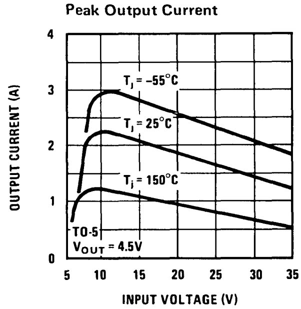
Output Impedance



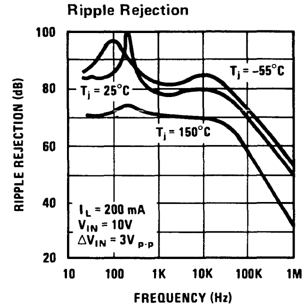
Peak Output Current



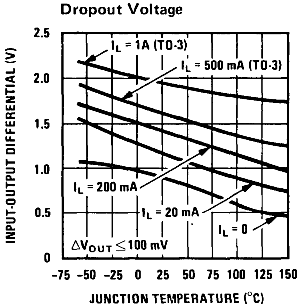
Peak Output Current



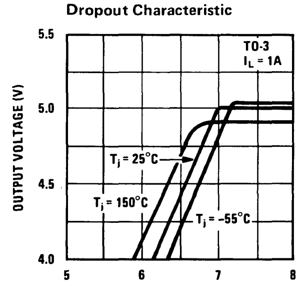
Ripple Rejection



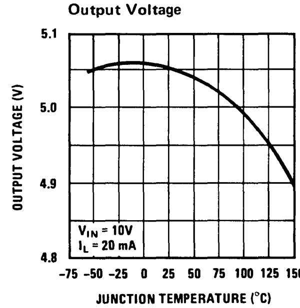
Dropout Voltage



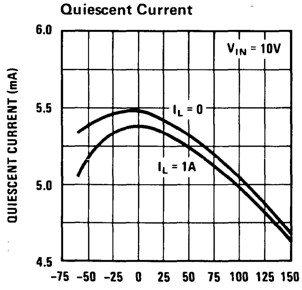
Dropout Characteristic



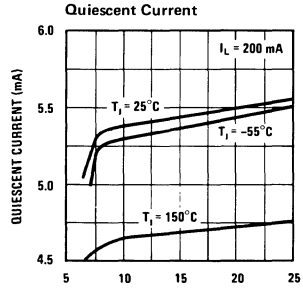
Output Voltage



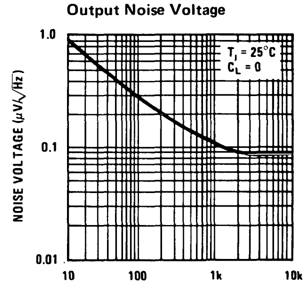
Quiescent Current



Quiescent Current



Output Noise Voltage



Voltage Regulators

LM309 five-volt regulator general description

The LM309 is a complete 5V regulator fabricated on a single silicon chip. It is designed for local regulation on digital logic cards, eliminating the distribution problems associated with single-point regulation. The device is available in two common transistor packages. In the solid-kovar TO-5 header, it can deliver output currents in excess of 200 mA, if adequate heat sinking is provided. With the TO-3 power package, the available output current is greater than 1A.

The regulator is essentially blow-out proof. Current limiting is included to limit the peak output current to a safe value. In addition, thermal shutdown is provided to keep the IC from overheating. If internal dissipation becomes too great, the regulator will shut down to prevent excessive heating.

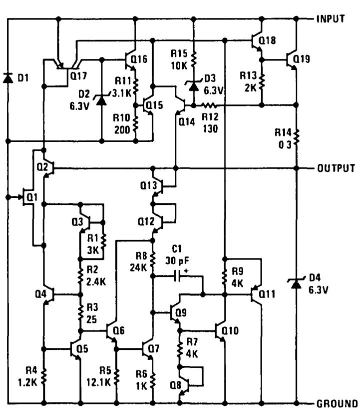
Considerable effort was expended to make the LM309 easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response somewhat. Input bypassing is needed, however, if the regulator is located very far from the filter capacitor of the power supply. Stability is also achieved by methods that provide very good rejection of load or line transients as are usually seen with TTL logic.

Although designed primarily as a fixed-voltage regulator, the output of the LM309 can be set to voltages above 5V, as shown below. It is also possible to use the circuit as the control element in precision regulators, taking advantage of the good current-handling capability and the thermal overload protection.

To summarize, outstanding features of the regulator are:

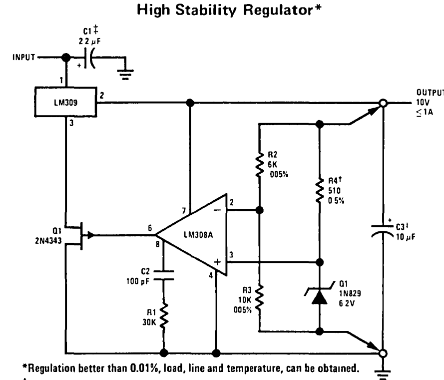
- Specified to be compatible, worst case, with TTL and DTL
- Output current in excess of 1A
- Internal thermal overload protection
- No external components required

schematic diagram



typical application

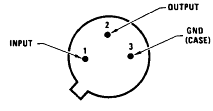
High Stability Regulator*



*Regulation better than 0.01%, load, line and temperature, can be obtained.
†Determines zener current. May be adjusted to minimize thermal drift.
‡Solid tantalum.

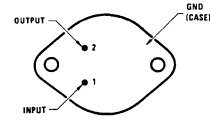
connection diagrams

TO-5 (H)



Order Number LM309H
See Package 9

TO-3 (K)



Order Number LM309K
See Package 18

absolute maximum ratings

Input Voltage	35V
Power Dissipation	Internally Limited
Operating Junction Temperature Range	0°C to 125°C
Storage Temperature Range	-65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 1)

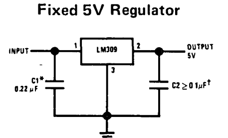
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	$T_j = 25°C$	4.8	5.05	5.2	V
Line Regulation	$T_j = 25°C$ $7V \leq V_{IN} \leq 25V$		4.0	50	mV
Load Regulation	$T_j = 25°C$				
LM309H	$5\ mA \leq I_{OUT} \leq 0.5A$		20	50	mV
LM309K	$5\ mA \leq I_{OUT} \leq 1.5A$		50	100	mV
Output Voltage	$7V \leq V_{IN} \leq 25V$ $5\ mA \leq I_{OUT} \leq I_{max}$ $P < P_{max}$	4.75		5.25	V
Quiescent Current	$7V \leq V_{IN} \leq 25V$		5.2	10	mA
Quiescent Current Change	$7V \leq V_{IN} \leq 25V$ $5\ mA \leq I_{OUT} \leq I_{max}$			0.5 0.8	mA mA
Output Noise Voltage	$T_A = 25°C$ $10\ Hz \leq f \leq 100\ kHz$		40		µV
Long Term Stability				20	mV
Thermal Resistance Junction to Case (Note 2)					
LM309H			15		°C/W
LM309K			3.0		°C/W

Note 1: Unless otherwise specified, these specifications apply for $0°C \leq T_j \leq 125°C$, $V_{IN} = 10V$ and $I_{OUT} = 0.1A$ for the LM309H or $I_{OUT} = 0.5A$ for the LM309K. For the LM309H, $I_{max} = 0.2A$ and $P_{max} = 2.0W$. For the LM309K, $I_{max} = 1.0A$ and $P_{max} = 20W$.

Note 2: Without a heat sink, the thermal resistance of the TO-5 package is about 150°C/W, while that of the TO-3 package is approximately 35°C/W. With a heat sink, the effective thermal resistance can only approach the values specified, depending on the efficiency of the sink.

typical applications(con't)

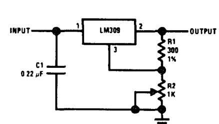
Fixed 5V Regulator



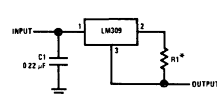
*Required if regulator is located an apprecible distance from power supply filter.

†Although no output capacitor is needed for stability, it does improve transient response.

Adjustable Output Regulator



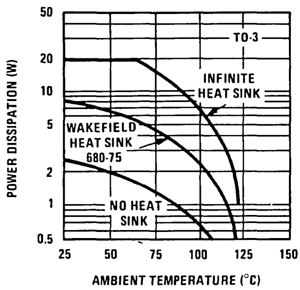
Current Regulator



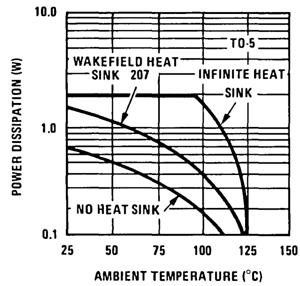
*Determines output current.

typical performance characteristics

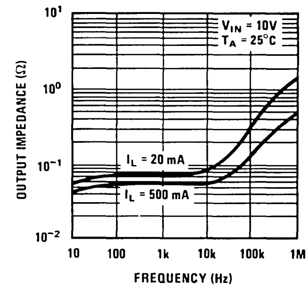
Maximum Average Power Dissipation



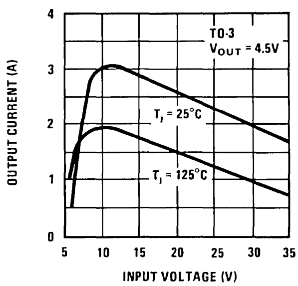
Maximum Average Power Dissipation



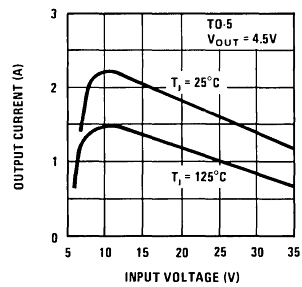
Output Impedance



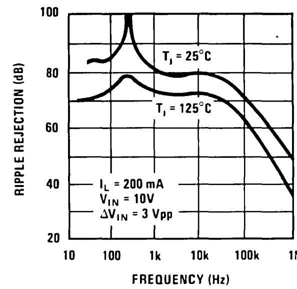
Peak Output Current



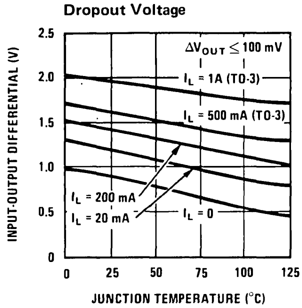
Peak Output Current



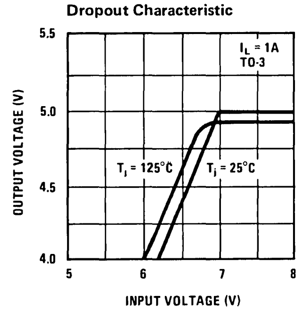
Ripple Rejection



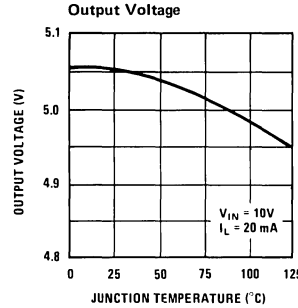
Dropout Voltage



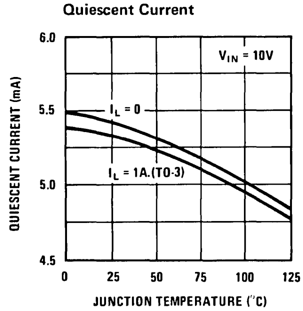
Dropout Characteristic



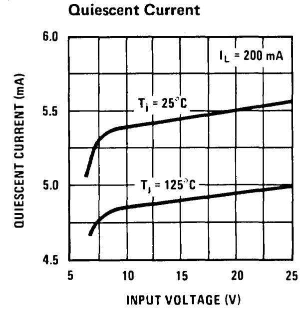
Output Voltage



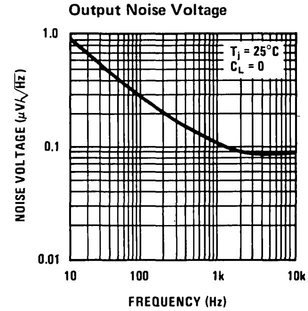
Quiescent Current



Quiescent Current



Output Noise Voltage



1

Voltage Regulators

LM113 reference diode

general description

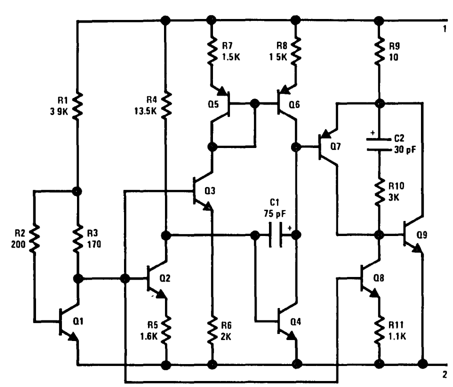
The LM113 is a temperature-compensated, low-voltage reference diode. It features extremely-tight regulation over a wide range of operating currents in addition to an unusually-low breakdown voltage and good temperature stability.

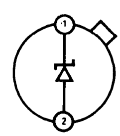
The diode is synthesized using transistors and resistors in a monolithic integrated circuit. As such, it has the same low noise and long term stability as modern IC op amps. Further, output voltage of the reference depends only on highly-predictable properties of components in the IC; so it can be manufactured and supplied to tight tolerances. Outstanding features include:

- Low breakdown voltage: 1.220V
- Dynamic impedance of 0.3Ω from 500 μA to 20 mA
- Temperature stability typically 1% over −55°C to 125°C range
- Tight tolerance: ±5% standard, ±2% and ±1% on special order.

The characteristics of this reference recommend it for use in bias-regulation circuitry, in low-voltage power supplies or in battery powered equipment. The fact that the breakdown voltage is equal to a physical property of silicon—the energy-band-gap voltage—makes it useful for many temperature-compensation and temperature-measurement functions.

schematic and connection diagrams



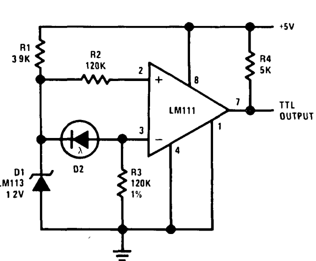


Note: Pin 2 connected to case.
TOP VIEW

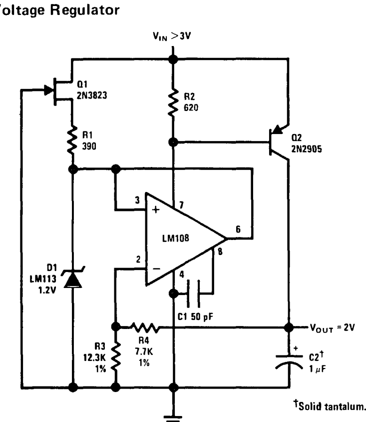
Order Number LM113H
See Package 8

typical applications

Level Detector for Photodiode



Low Voltage Regulator



†Solid tantalum.

absolute maximum ratings

Power Dissipation (Note 1)	100 mW
Reverse Current	50 mA
Forward Current	50 mA
Operating Temperature Range	−55°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (soldering, 10 sec)	300°C

electrical characteristics (Note 2)

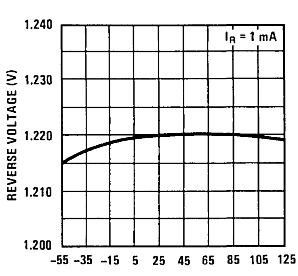
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Reverse Breakdown Voltage	I_R = 1 mA	1.160	1.220	1.280	V
Reverse Breakdown Voltage Change	0.5 mA $\le I_R \le$ 20 mA		6.0	15	mV
Reverse Dynamic Impedance	I_R = 1 mA I_R = 10 mA		0.2 0.25	1.0 0.8	Ω Ω
Forward Voltage Drop	I_F = 1.0 mA		0.67	1.0	V
RMS Noise Voltage	10 Hz $\le$ f $\le$ 10 kHz I_R = 1 mA		5		μV
Reverse Breakdown Voltage Change	0.5 mA $\le I_R \le$ 10 mA −55°C $\le T_A \le$ 125°C			15	mV
Breakdown Voltage Temperature Coefficient	1.0 mA $\le I_R \le$ 10 mA −55°C $\le T_A \le$ 125°C		0.01		%/°C

Note 1: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction and a thermal resistance of 80°C/W junction to case or 440°C/W junction to ambient.

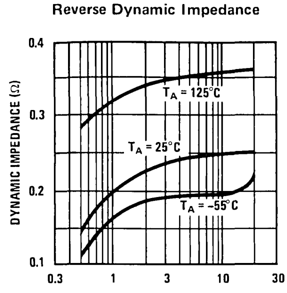
Note 2: These specifications apply for T_A = 25°C, unless stated otherwise. At high currents, breakdown voltage should be measured with lead lengths less than 1/4 inch. Kelvin contact sockets are also recommended. The diode should not be operated with shunt capacitances between 200 pF and 0.1 μF, unless isolated by at least a 100 Ω resistor, as it may oscillate at some currents.

typical performance characteristics

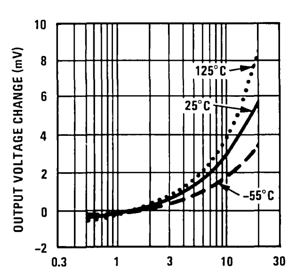
Temperature Drift



Reverse Dynamic Impedance

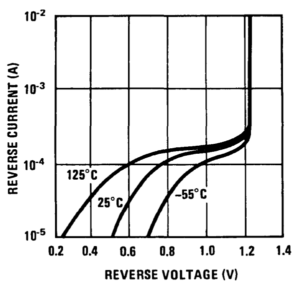


Reverse Characteristics

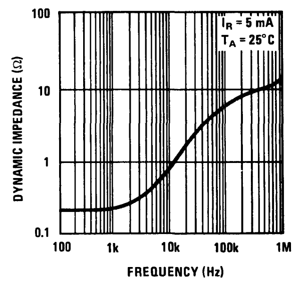


typical performance characteristics (con't)

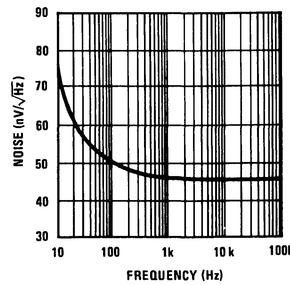
Reverse Characteristics



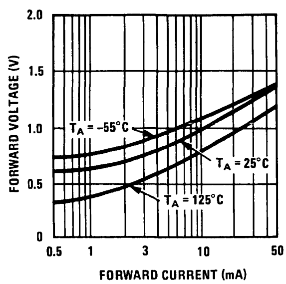
Reverse Dynamic Impedance



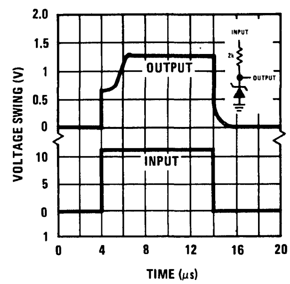
Noise Voltage



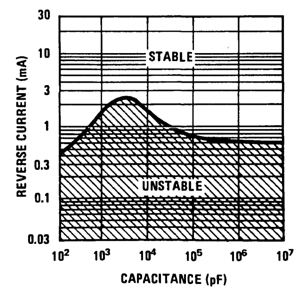
Forward Characteristics



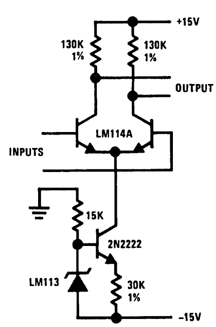
Response Time



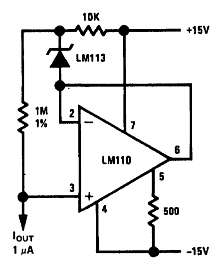
Maximum Shunt Capacitance



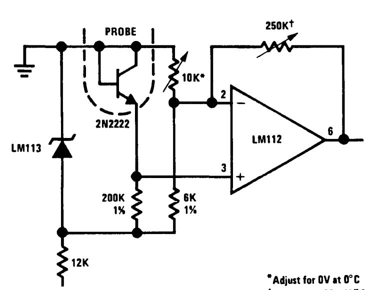
typical applications (con't)



Amplifier Biasing for Constant Gain with Temperature



Constant Current Source



Thermometer

Voltage Regulators

LM120 series three-terminal negative regulators

general description

The LM120 Series are three-terminal negative regulators with a fixed output voltage of –5V, –5.2V, –12V, and –15V and up to 1.5A load current capability. These devices need only one external component – a compensation capacitor at the output, making them easy to apply. Worst case guarantees on output voltage deviation due to any combination of line, load or temperature variation assure satisfactory system operation.

Exceptional effort has been made to make the LM120 Series immune to overload conditions. The regulators have current limiting which is independent of temperature, combined with thermal overload protection. Internal current limiting protects against momentary faults while thermal shutdown prevents junction temperatures from exceeding safe limits during prolonged overloads.

Although primarily intended for fixed output voltage applications, the LM120 Series may be programmed for higher output voltages with a simple resistive divider. The low quiescent drain current of the devices allows this technique to be used with good regulation.

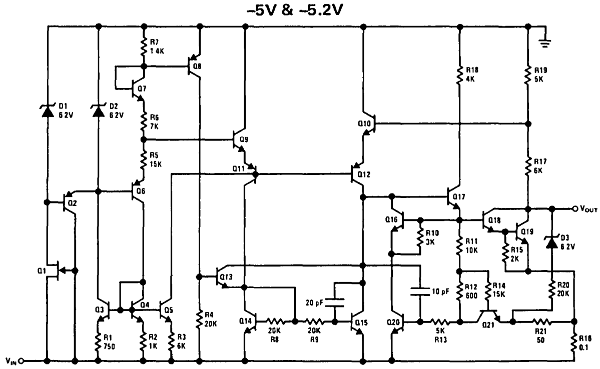
The LM120 Series is available in TO-5 and TO-3 packages. The TO-5 is rated at 200 mA and 2W; the TO-3 at 1A and 20W.

features

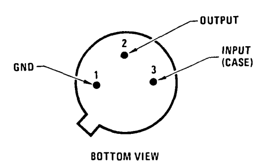
- Preset output voltage error less than ±3%
- Preset current limit
- Internal thermal shutdown
- Operates with input-output voltage differential down to 1V
- Excellent ripple rejection
- 50 mV load regulation

schematic and connection diagrams

–5V & –5.2V

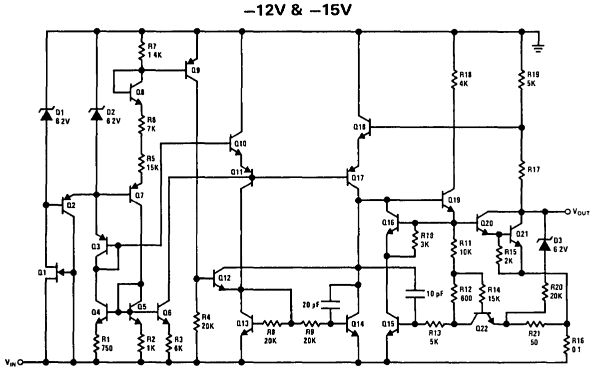


TO-5 (H)

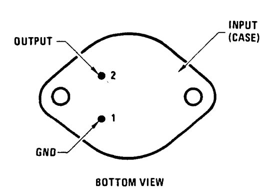


Order Numbers:
LM120H-5.0 LM120H-5.2 LM120H-12 LM120H-15
LM220H-5.0 LM220H-5.2 LM220H-12 LM220H-15
LM320H-5.0 LM320H-5.2 LM320H-12 LM320H-15
See Package 9

–12V & –15V



TO-3 (K)



Order Numbers:
LM120K-5.0 LM120K-5.2 LM120K-12 LM120K-15
LM220K-5.0 LM220K-5.2 LM220K-12 LM220K-15
LM320K-5.0 LM320K-5.2 LM320K-12 LM320K-15
See Package 18

absolute maximum ratings

Device Type	Input Voltage	Input-Output Differential
LM120 Series/-5.0V	−25V	25V
LM120 Series/-5.2V	−25V	25V
LM120 Series/-12V	−35V	30V
LM120 Series/-15V	−40V	30V

Power Dissipation	Internally Limited
Operating Junction Temperature Range	
LM120	-55°C to +150°C
LM220	-25°C to +150°C
LM320	0°C to +125°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering 10 sec)	300°C

electrical characteristics (-5V & -5.2V) (Note 1)

PARAMETER	CONDITIONS	LM120 LM220 MIN	LM120 LM220 MAX	TYP	LM320 MIN	LM320 MAX	UNITS
Output Voltage	T_j = 25°C -5V	-5.1	-4.9	-5.0	-5.2	-4.8	V
	-5.2V	-5.3	-5.1	-5.2	-5.4	-5.0	V
Line Regulation (Note 2)	T_j = 25°C $-25V \leq V_{IN} \leq -7V$		25	10		50	mV
Load Regulation (Note 2)	T_j = 25°C						
H Package	$5\ mA \leq I_{OUT} \leq 0.5A$		50	20		50	mV
K Package	$5\ mA \leq I_{OUT} \leq 1.5A$		75	50		100	mV
Output Voltage	$-25V \leq V_{IN} \leq -7V$ $5\ mA \leq I_{OUT} \leq I_{MAX}$						
	$P \leq P_{MAX}$ -5V	-5.20	-4.80		-5.25	-4.75	V
	-5.2V	-5.40	-5.00		-5.45	-4.95	V
Quiescent Current	$-25V \leq V_{IN} \leq -7V$		2.0	1.0		2.0	mA
Quiescent Current Change	T_A = 25°C						
	$-25V \leq V_{IN} \leq -7V$		0.4	0.1		0.4	mA
	$5\ mA \leq I_{OUT} \leq I_{MAX}$		0.4	0.1		0.4	mA
Output Noise Voltage	T_A = 25°C, C_L = 1 μF 10 Hz ≤ f ≤ 100 kHz			150			μV
Long Term Stability			50	5		50	mV
Thermal Resistance Junction to Case							
H Package				15			°C/W
K Package				3			°C/W

electrical characteristics (−12V) (Note 1)

PARAMETER	CONDITIONS	LM120 LM220 MIN	LM120 LM220 MAX	TYP	LM320 MIN	LM320 MAX	UNITS
Output Voltage	T_j = 25°C	−12.3	−11.7	−12	−12.4	−11.6	V
Line Regulation (Note 2)	T_j = 25°C $-32V \leq V_{IN} \leq -14V$		10	4		20	mV
Load Regulation	T_j = 25°C						
H Package (Note 2)	$5\ mA \leq I_{OUT} \leq 0.2A$		25	10		40	mV
K Package (Note 2)	$5\ mA \leq I_{OUT} \leq 1.0A$		80	30		80	mV
Output Voltage	$-32V \leq V_{IN} \leq -14V$ $5\ mA \leq I_{OUT} \leq I_{MAX}$ $P \leq P_{MAX}$	−12.5	−11.5		−12.6	−11.4	V
Quiescent Current	$-32V \leq V_{IN} \leq -14V$		4	2		4	mA
Quiescent Current Change	T_j = 25°C						
	$-32V \leq V_{IN} \leq -14V$			0.1			mA
	$5\ mA \leq I_{OUT} \leq I_{MAX}$			0.1			mA
Output Noise Voltage	T_A = 25°C 10 Hz ≤ f ≤ 100 kHz			400			μV
Long Term Stability			120	15		120	mV

electrical characteristics (–15V) (Note 1)

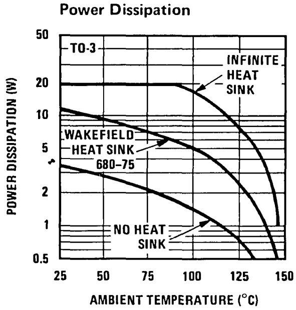
PARAMETER	CONDITIONS	LM120 LM220 MIN	LM120 LM220 MAX	TYP	LM320 MIN	LM320 MAX	UNITS
Output Voltage	$T_j = 25°C$	–15.3	–14.7	–15	–15.4	–14.6	V
Line Regulation (Note 2)	$T_j = 25°C$ $-35V \leq V_{IN} \leq -17V$		10	5		20	mV
Load Regulation	$T_j = 25°C$						
H Package (Note 2)	$5\ mA \leq I_{OUT} \leq 0.2A$		25	10		40	mV
K Package (Note 2)	$5\ mA \leq I_{OUT} \leq 1.0A$		80	30		80	mV
Output Voltage	$-35V \leq V_{IN} \leq -17V$ $5\ mA \leq I_{OUT} \leq I_{MAX}$ $P \leq P_{MAX}$	15.5	14.5		15.6	14.4	V
Quiescent Current	$-35V \leq V_{IN} \leq -17V$		4	2		4	mA
Quiescent Current Change	$T_j = 25°C$ $-35V \leq V_{IN} \leq -17V$ $5\ mA \leq I_{OUT} \leq I_{MAX}$			 0.1 0.1			mA
Output Noise Voltage				400			μV
Long Term Stability			150	15		150	mV

Note 1: Unless otherwise specified, these specifications apply: $-55°C \leq T_j \leq 150°C$ for the LM120; $-25°C \leq T_j \leq 150°C$ for the LM220, and $0°C \leq T_j \leq 125°C$ for the LM320; $V_{IN} = (V_{OUT} + 5V)$ and $I_{OUT} = 0.1A$ for the TO-5 package and $I_{OUT} = 0.5A$ for the TO-3 package. For the TO-5 package, $I_{MAX} = 0.2A$ and $P_{MAX} = 2.0W$. For the TO-3 package, $I_{MAX} = 1.0A$ and $P_{MAX} = 20W$. Although power dissipation is internally limited, electrical specifications apply only for power levels up to P_{MAX}. For calculations of junction temperature rise due to power dissipation, use a thermal resistance of 150°C/W for the TO-5 and 35°C/W for the TO-3. With an infinite heat sink, the thermal resistance is 15°C/W and 3°C/W respectively.

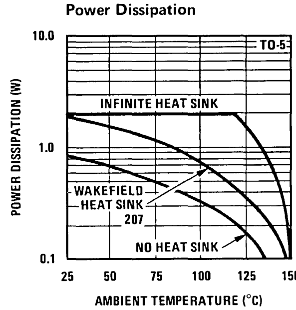
Note 2: Regulation is measured at constant junction temperature. Changes in output voltage due to heating effects must be taken into account separately. To ensure constant junction temperature, pulse testing with a low duty cycle is used.

typical performance characteristics

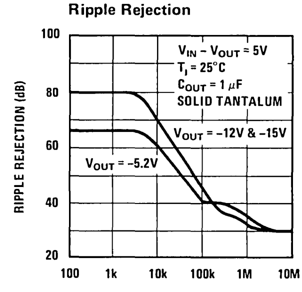
Maximum Average Power Dissipation



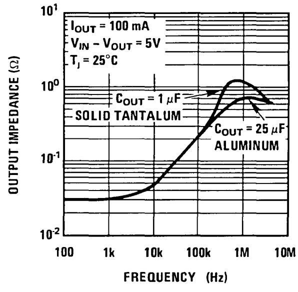
Maximum Average Power Dissipation



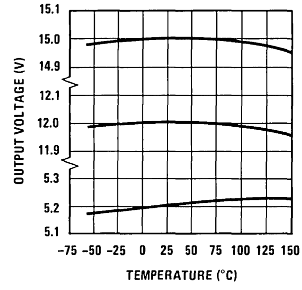
Ripple Rejection



Output Impedance

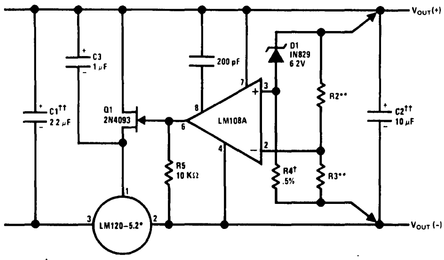


Output Voltage



1

typical applications



†Determines zener current. May be adjusted to minimize temperature drift.

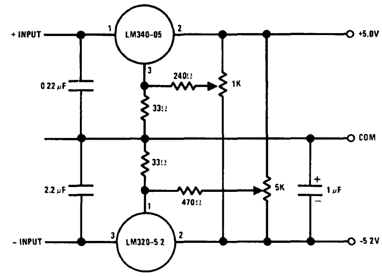
††Solid tantalum.

*An LM120-12 or LM120-15 may be used to permit higher input voltages, but the regulated output voltage must be at least −15V when using the LM120-12 and −18V for the LM120-15.

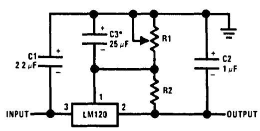
**Select resistors to set output voltage. 1 PPM/°C tracking suggested.

Load and line regulation < 0.01% temperature stability < 0.1%.

High Stability 1 Amp Regulator



Dual Trimmed Supply



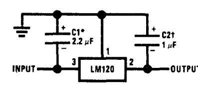
*Optional. Improves transient response and ripple rejection.

$$V_{OUT} = V_{SET}\ \frac{R1 + R2}{R2}$$

Select R2 as follows:

LM120-5 – 300Ω
LM120-5.2 – 300Ω
LM120-12 – 750Ω
LM120-15 – 1 KΩ

Variable Output

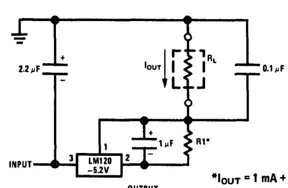


*Required if regulator is separated from filter capacitor. For value given, capacitor must be solid tantalum. 25μF aluminum electrolytic may be substituted.

†Required for stability. For value given, capacitor must be solid tantalum. 25μF aluminum electrolytic may be substituted. Values given may be increased without limit.

For output capacitance in excess of 100μF. A high current diode from input to output (1N4001, etc.) will protect the regulator from momentary input shorts.

Fixed Regulator



$$*I_{OUT} = 1\text{ mA} + \frac{5.2V}{R1}$$

Current Source

Voltage Regulators

LM320T series three-terminal negative regulators

general description

The LM320T Series are three-terminal negative regulators with a fixed output voltage of −5V, −5.2V, −6V, −8V, −12V, −15V, −18V, −24V and up to 1.5A load current capability. These devices need only one external component—a compensation capacitor at the output, making them easy to apply. Worst case guarantees an output voltage deviation due to any combination of line, load or temperature variation assure satisfactory system operation.

Exceptional effort has been made to make the LM320T Series immune to overload conditions. The regulators have current limiting which is independent of temperature, combined with thermal overload protection. Internal current limiting protects against momentary faults while thermal shutdown prevents junction temperatures from exceeding safe limits during prolonged overloads.

Although primarily intended for fixed output voltage applications, the LM320T Series may be programmed for higher output voltages with a simple resistive divider. The low quiescent drain current of the devices allows this technique to be used with good regulation.

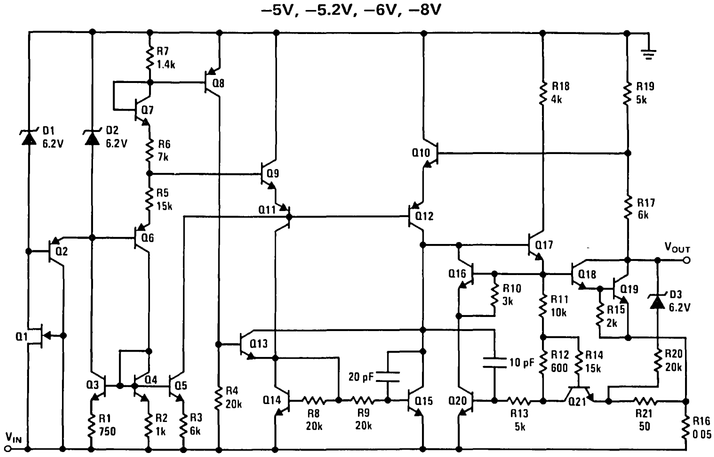
The LM320T Series is packaged in the easy to use Epoxy B TO-220 rated at 15 watts dissipation.

features

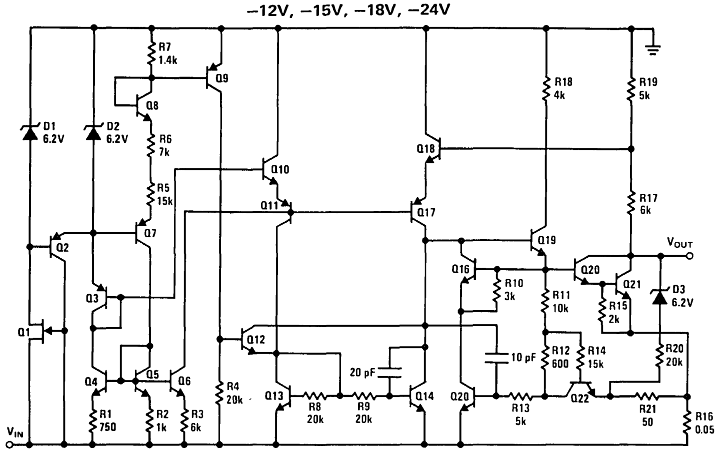
- Preset output voltage
- Current limit constant with temperature
- Internal thermal shutdown
- Operates with input-output voltage differential down to 1V
- Excellent ripple rejection
- Easily adjustable to higher output voltage

schematic diagrams

−5V, −5.2V, −6V, −8V

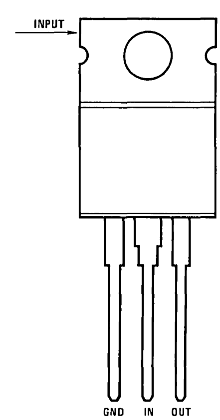


−12V, −15V, −18V, −24V



connection diagram

TO-220 (T)



Order Numbers:
LM320T-5.0
LM320T-5.2
LM320T-6.0
LM320T-8.0
LM320T-12
LM320T-15
LM320T-18
LM320T-24
See Package 26

absolute maximum ratings

Device Type	Input Voltage	Input-Output Differential
LM320T 5V, 5.2V, 6V, 8V	−25V	25V
LM320T 12V, 15V, 18V	−35V	30V
LM320T 24V	−40V	35V
Power Dissipation		Internally Limited
Operating Junction Temperature Range		0°C to +125°C
Storage Temperature Range		−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)		230°C

electrical characteristics (−5V and −5.2V) (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	$T_j = 25°C$, −5V −5.2V	−5.2 −5.4	−5.0 −5.2	−4.8 −5.0	V V
Line Regulation (Note 2)	$T_j = 25°C$, $-25V \le V_{IN} \le -7.5V$		10	40	mV
Load Regulation (Note 2)	$T_j = 25°C$, $5\ mA \le I_{OUT} \le 1.5A$		70	120	mV
Output Voltage	$-25V \le V_{IN} \le -7V$ $5\ mA \le I_{OUT} \le 1.0A$ $P \le 15W$, −5V −5.2V	 −5.25 −5.45		 −4.75 −4.95	 V V
Quiescent Current			1.0	3	mA
Quiescent Current Change	$T_A = 25°C$, $-25V \le V_{IN} \le -7.5V$ $5\ mA \le I_{OUT} \le 1.0A$		0.1 0.1	0.5 0.5	mA mA
Output Noise Voltage	$T_A = 25°C$, $C_L = 1\mu F$, $10\ Hz \le f \le 100\ kHz$		150		μV
Long Term Stability			10		mV
Thermal Resistance Junction to Case			5		°C/W

electrical characteristics (−6V) (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	$T_j = 25°C$	−6.25	−6	−5.75	V
Line Regulation (Note 2)	$T_j = 25°C$, $-25V \le V_{IN} \le -8.5V$		12	40	mV
Load Regulation (Note 2)	$T_j = 25°C$, $5\ mA \le I_{OUT} \le 1.5A$		70	120	mV
Output Voltage	$-25V \le V_{IN} \le -8.5V$ $5\ mA \le I_{OUT} \le 1.0A$, $P \le 15W$	−6.3		−5.7	V
Quiescent Current			1	3	mA
Quiescent Current Change	$T_j = 25°C$, $-25V \le V_{IN} \le -8.5V$ $5\ mA \le I_{OUT} \le 1.0A$		0.1 0.1	0.5 0.5	mA mA
Output Noise Voltage	$T_A = 25°C$, $10\ Hz \le f \le 100\ kHz$		180		μV
Long Term Stability			12		mV

Note 1: Unless otherwise specified, these specifications apply: $0°C \le T_j \le 125°C$; $V_{IN} = (V_{OUT} + 5V)$ and $I_{OUT} = 5\ mA$. Although power dissipation is internally limited, electrical specifications apply only for power levels up to 15W. For calculations of junction temperature rise due to power dissipation, use a thermal resistance of 50°C/W (no heat sink). With an infinite heat sink, the thermal resistance is 5°C/W.

Note 2: Regulation is measured at constant junction temperature. Changes in output voltage due to heating effects must be taken into account separately. To ensure constant junction temperature, pulse testing with a low duty cycle is used.

electrical characteristics (−8V) (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	$T_j = 25°C$	−8.3	−8.0	−7.7	V
Line Regulation (Note 2)	$T_j = 25°C$, $-25V \le V_{IN} \le -10.5V$		15	40	mV
Load Regulation (Note 2)	$T_j = 25°C$, $5\ mA \le I_{OUT} \le 1.5A$		70	120	mV
Output Voltage	$-25V \le V_{IN} \le -10.5V$ $5\ mA \le I_{OUT} \le 1.0A$, $P \le 15W$	−8.4		−7.6	V
Quiescent Current			1	3	mA
Quiescent Current Change	$T_j = 25°C$, $-25V \le V_{IN} \le -10.5V$ $5\ mA \le I_{OUT} \le 1.0A$		0.1 0.1	0.5 0.5	mA mA
Output Noise Voltage			250		μV
Long Term Stability			15		mV

electrical characteristics (−12V) (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	$T_j = 25°C$	−12.5	−12	−11.5	V
Line Regulation (Note 2)	$T_j = 25°C$, $-32V \le V_{IN} \le -14.5V$		4	24	mV
Load Regulation (Note 2)	$T_j = 25°C$, $5\ mA \le I_{OUT} \le 1.0A$		40	120	mV
Output Voltage	$-32V \le V_{IN} \le -14.5V$ $5\ mA \le I_{OUT} \le 1.0A$, $P \le 15W$	−12.6		−11.4	V
Quiescent Current			2	4	mA
Quiescent Current Change	$T_j = 25°C$, $-32V \le V_{IN} \le -14.5V$ $5\ mA \le I_{OUT} \le 1.0A$		0.1 0.1	0.5 0.5	mA mA
Output Noise Voltage	$T_A = 25°C$, $10\ Hz \le f \le 100\ kHz$		400		μV
Long Term Stability			25		mV

electrical characteristics (−15V) (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	$T_j = 25°C$	−15.6	−15	−14.4	V
Line Regulation (Note 2)	$T_j = 25°C$, $-35V \le V_{IN} \le -17.5V$		5	30	mV
Load Regulation (Note 2)	$T_j = 25°C$, $5\ mA \le I_{OUT} \le 1.0A$		50	120	mV
Output Voltage	$-35V \le V_{IN} \le -17.5V$ $5\ mA \le I_{OUT} \le 1.0A$, $P \le 15W$	−15.7		−14.3	V
Quiescent Current			2	4	mA
Quiescent Current Change	$T_j = 25°C$, $-35V \le V_{IN} \le -17.5V$ $5\ mA \le I_{OUT} \le 1.0A$		0.1 0.1	0.5 0.5	mA mA
Output Noise Voltage			400		μV
Long Term Stability			30		mV

Note 1: Unless otherwise specified, these specifications apply: $0°C \le T_j \le 125°C$; $V_{IN} = (V_{OUT} + 5V)$ and $I_{OUT} = 5\ mA$. Although power dissipation is internally limited, electrical specifications apply only for power levels up to 15W. For calculations of junction temperature rise due to power dissipation, use a thermal resistance of 50°C/W (no heat sink). With an infinite heat sink, the thermal resistance is 5°C/W.

Note 2: Regulation is measured at constant junction temperature. Changes in output voltage due to heating effects must be taken into account separately. To ensure constant junction temperature, pulse testing with a low duty cycle is used.

electrical characteristics (−18V) (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	$T_j = 25°C$	−18.7	−18	−17.3	V
Line Regulation (Note 2)	$T_j = 25°C$, $-35V \leq V_{IN} \leq -21V$		8	36	mV
Load Regulation (Note 2)	$T_j = 25°C$, $5\ mA \leq I_{OUT} \leq 1.0A$		50	120	mV
Output Voltage	$-3.5V \leq V_{IN} \leq -21V$ $5\ mA \leq I_{OUT} \leq 1.0A$, $P \leq 15W$	−18.9		−17.1	V
Quiescent Current			2	4	mA
Quiescent Current Change	$T_j = 25°C$, $-35V \leq V_{IN} \leq -21V$ $5\ mA \leq I_{OUT} \leq 1.0A$		0.1 0.1	0.5 0.5	mA mA
Output Noise Voltage	$T_A = 25°C$, $10\ Hz \leq f \leq 100\ kHz$		500		μV
Long Term Stability			35		mV

electrical characteristics (−24V) (Note 1)

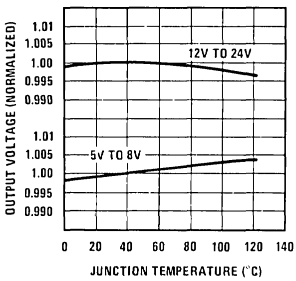
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	$T_j = 25°C$	−25	−24	−23	V
Line Regulation (Note 2)	$T_j = 25°C$, $-35V \leq V_{IN} \leq -27V$		12	50	mV
Load Regulation (Note 2)	$T_j = 25°C$, $5\ mA \leq I_{OUT} \leq 1.0A$		50	120	mV
Output Voltage	$-40V \leq V_{IN} \leq -27V$ $5\ mA \leq I_{OUT} \leq 1.0A$, $P \leq 15W$	−25.2		−22.8	V
Quiescent Current			2	4	mA
Quiescent Current Change	$T_j = 25°C$, $-40V \leq V_{IN} \leq -27V$ $5\ mA \leq I_{OUT} \leq 1.0A$		0.1 0.1	0.5 0.5	mA mA
Output Noise Voltage			700		μV
Long Term Stability			50		mV

Note 1: Unless otherwise specified, these specifications apply: $0°C \leq T_j \leq 125°C$; $V_{IN} = (V_{OUT} + 5V)$ and $I_{OUT} = 5\ mA$. Although power dissipation is internally limited, electrical specifications apply only for power levels up to 15W. For calculations of junction temperature rise due to power dissipation, use a thermal resistance of 50°C/W (no heat sink). With an infinite heat sink, the thermal resistance is 5°C/W.

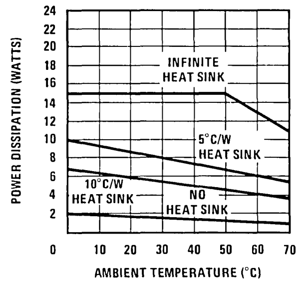
Note 2: Regulation is measured at constant junction temperature. Changes in output voltage due to heating effects must be taken into account separately. To ensure constant junction temperature, pulse testing with a low duty cycle is used.

typical performance characteristics

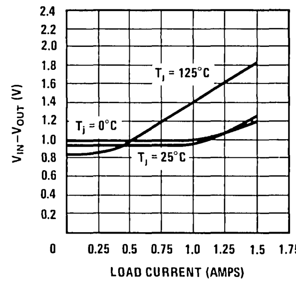
Output Voltage vs Temperature



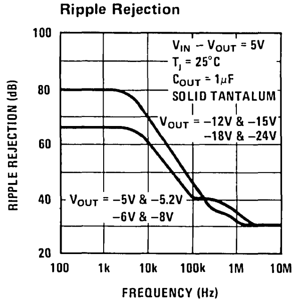
Maximum Power Dissipation



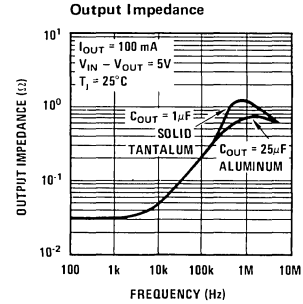
Minimum Input-Output Differential



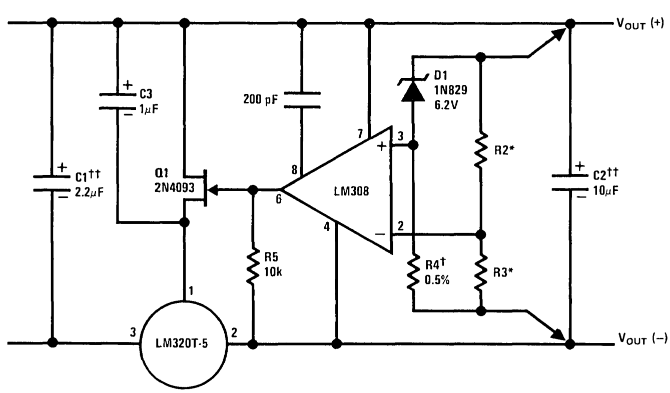
Ripple Rejection



Output Impedance



typical applications



Load and line regulation <0.01% temperature stability <0.1%

†Determines Zener current. May be adjusted to minimize temperature drift.

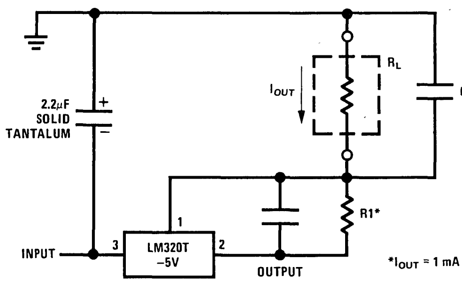
††Solid tantalum.

An LM320T-12 or LM320T-15 may be used to permit higher input voltages, but the regulated output voltage must be at least –15V when using the LM320T-12 and –18V for the LM320T-15.

**Select resistors to set output voltage. 1 ppm/°C tracking suggested.

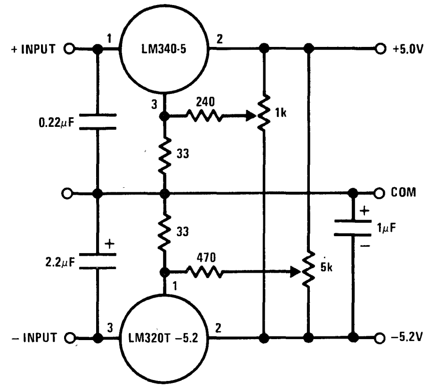
High Stability 1 Amp Regulator

typical applications (con't)

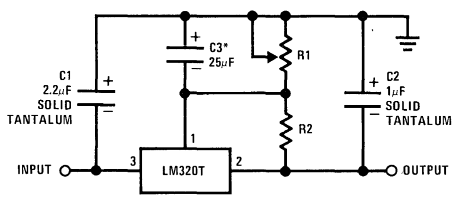


$*I_{OUT} = 1\ mA + \frac{5V}{R1}$

Current Source



Dual Trimmed Supply



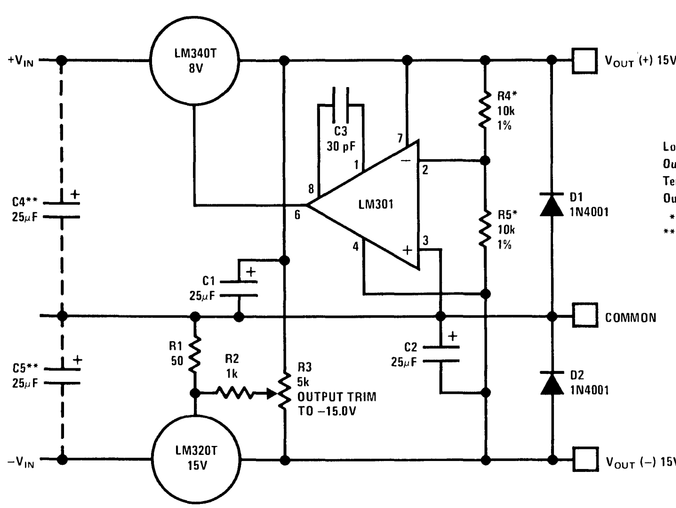
*Improves transient response and ripple rejection. Do not increase beyond 50μF

$V_{OUT} = V_{SET} \left(\frac{R1 + R2}{R2}\right)$

SELECT R2 AS FOLLOWS

LM320T-5/5.2/6	300
LM320T-8	470
LM320T-12	750
LM320T-15	1k
LM320T-18	1.2k
LM320T-24	1.5k

Variable Output



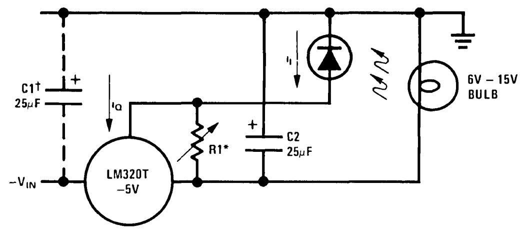
Performance (Typical)

	(−15)	(+15)
Load Regulation at $\Delta I_L = 1A$	40 mV	2 mV
Output Ripple, $C_{IN} = 3000\mu F$, $I_L = 1A$	100μVrms	100μVrms
Temperature Stability	·50 mV	·50 mV
Output Noise 10 Hz ≤ f ≤ 10 kHz	150μVrms	150μVrms

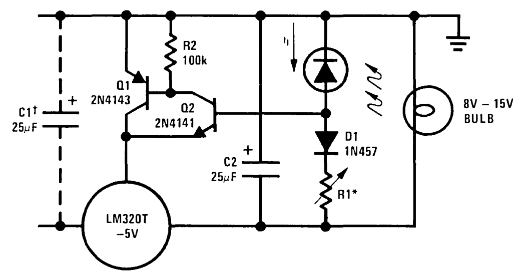
*Resistor tolerance of R4 and R5 determine matching of (+) and (−) outputs.
**Necessary only if raw supply filter capacitors are more than 2" from regulators.

±15V, 1 Amp Tracking Regulators

typical applications (con't)

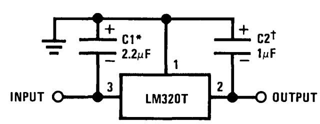


*Lamp brightness increases until $I_l = I_Q$ (≈ 1 mA) + 5V/R1.
†Necessary only if raw supply filter capacitor is more than 2" from LM320T.



*Lamp brightness increases until I_l = 5V/R1 (I_l can be set as low as 1μA).
†Necessary only if raw supply filter capacitor is more than 2" from LM320T.

Light Controllers Using Silicon Photo Cells



*Required if regulator is separated from filter capacitor by more than 3". For value given, capacitor must be solid tantalum. 25μF aluminum electrolytic may be substituted.

†Required for stability. For value given, capacitor must be solid tantalum. 25μF aluminum electrolytic may be substituted. Values given may be increased without limit.

For output capacitance in excess of 100μF, a high current diode from input to output (1N4001, etc.) will protect the regulator from momentary input shorts.

Fixed Regulator

Voltage Regulators

LM123/LM223/LM323 3 amp - 5 volt positive regulator

general description

The LM123 is a three-terminal positive regulator with a preset 5V output and a load driving capability of 3 amps. New circuit design and processing techniques are used to provide the high output current without sacrificing the regulation characteristics of lower current devices.

The 3 amp regulator is virtually blowout proof. Current limiting, power limiting, and thermal shutdown provide the same high level of reliability obtained with these techniques in the LM109 1 amp regulator.

No external components are required for operation of the LM123. If the device is more than 4 inches from the filter capacitor, however, a 1μF solid tantalum capacitor should be used on the input. A 0.1μF or larger capacitor may be used on the output to reduce load transient spikes created by fast switching digital logic, or to swamp out stray load capacitance.

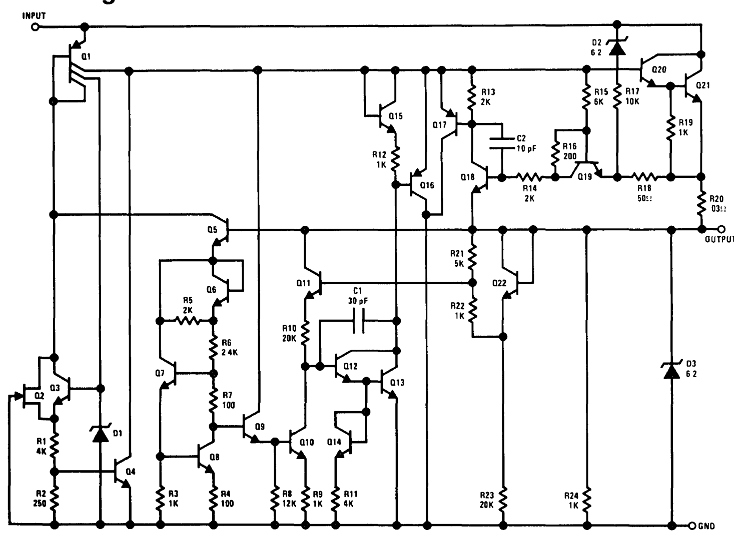
An overall worst case specification for the combined effects of input voltage, load currents, ambient temperature, and power dissipation ensure that the LM123 will perform satisfactorily as a system element.

Operation is guaranteed over the junction temperature range −55°C to +150°C. An electrically identical LM223 operates from −25°C to +150°C and the LM323 is specified from 0°C to +125°C junction temperature. A hermetic TO-3 package is used for high reliability and low thermal resistance.

features

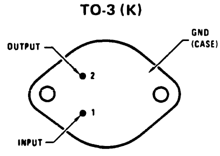
- 3 amp output current
- Internal current and thermal limiting
- 0.01Ω typical output impedance
- 7.5 minimum input voltage
- 30W power dissipation

schematic diagram



connection diagram

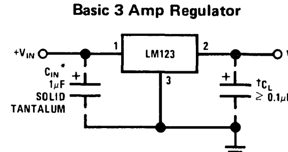
TO-3 (K)



Order Number LM123K, LM223K or LM323K
See Package 18

typical applications

Basic 3 Amp Regulator



*Required if LM123 is more than 4" from filter capacitor.
†Regulator is stable with no load capacitor into resistive loads.

absolute maximum ratings

Input Voltage	20V
Power Dissipation	Internally Limited
Operating Junction Temperature Range	
LM123	−55°C to +150°C
LM223	−25°C to +150°C
LM323	0°C to +125°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 1)

PARAMETER	CONDITIONS	LM123/LM223			LM323			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	T_j = 25°C V_{IN} = 7.5V, I_{OUT} = 0	4.7	5	5.3	4.8	5	5.2	V
Output Voltage	7.5V ≤ V_{IN} ≤ 15V 0 ≤ I_{OUT} ≤ 3A, P ≤ 30W	4.6		5.4	4.75		5.25	V
Line Regulation (Note 3)	T_j = 25°C 7.5V ≤ V_{IN} ≤ 15V		5	25		5	25	mV
Load Regulation (Note 3)	T_j = 25°C, V_{IN} = 7.5V, 0 ≤ I_{OUT} ≤ 3A		25	100		25	100	mV
Quiescent Current	7.5V ≤ V_{IN} ≤ 15V, 0 ≤ I_{OUT} ≤ 3A		12	20		12	20	mA
Output Noise Voltage	T_j = 25°C 10 Hz ≤ f ≤ 100 kHz		40			40		µVrms
Short Circuit Current Limit	T_j = 25°C V_{IN} = 15V V_{IN} = 7.5V		 3 4	 4.5 5		 3 4	 4.5 5	 A A
Long Term Stability				35			35	mV
Thermal Resistance Junction to Case (Note 2)			2			2		°C/W

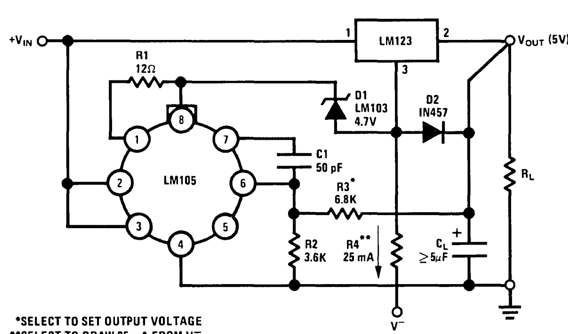
Note 1: Unless otherwise noted, specifications apply for −55°C ≤ T_j ≤ +150°C for the LM123, −25°C ≤ T_j ≤ +150°C for the LM223, and 0°C ≤ T_j ≤ +125°C for the LM323. Although power dissipation is internally limited, specifications apply only for P ≤ 30W.

Note 2: Without a heat sink, the thermal resistance of the TO-3 package is about 35°C/W. With a heat sink, the effective thermal resistance can only approach the specified values of 2°C/W, depending on the efficiency of the heat sink.

Note 3: Load and line regulation are specified at constant junction temperature. Pulse testing is required with a pulse width ≤ 1 ms and a duty cycle ≤ 5%.

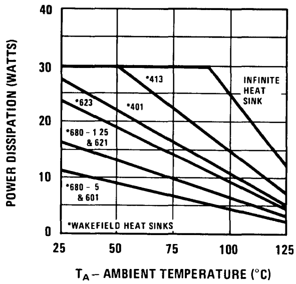
typical applications (con't)

Adjustable Output 5V – 10V 0.1% Regulation

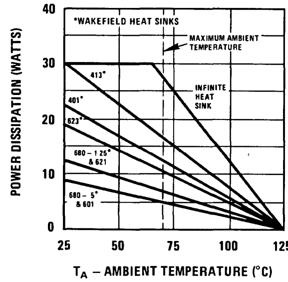


typical performance characteristics

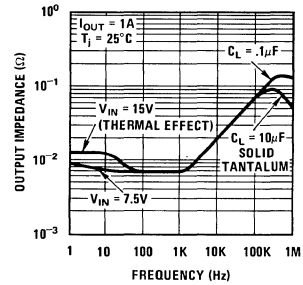
Maximum Average Power Dissipation For LM123; LM223



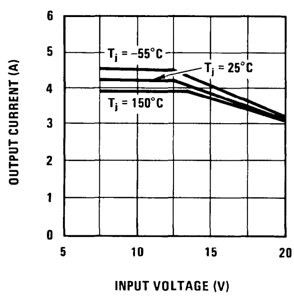
Maximum Average Power Dissipation For LM323



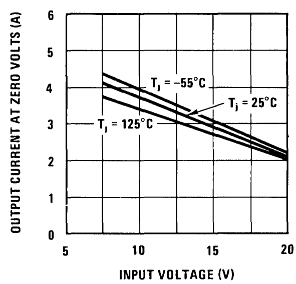
Output Impedance



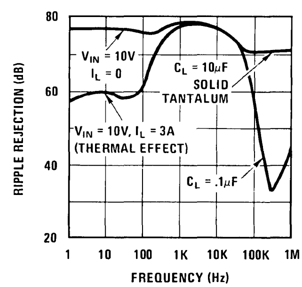
Peak Available Output Current



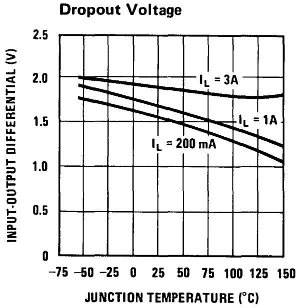
Short Circuit Current



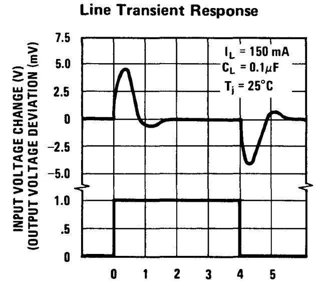
Ripple Rejection



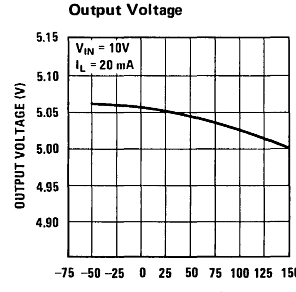
Dropout Voltage



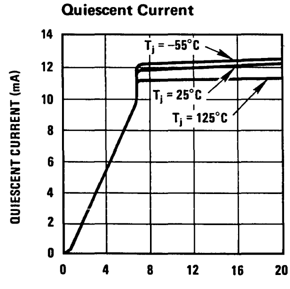
Line Transient Response



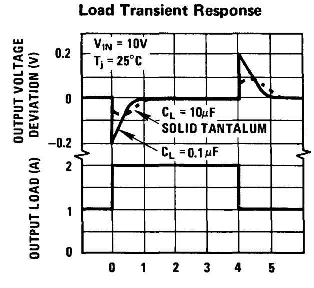
Output Voltage



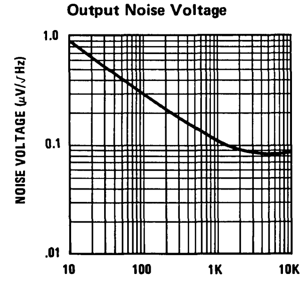
Quiescent Current



Load Transient Response

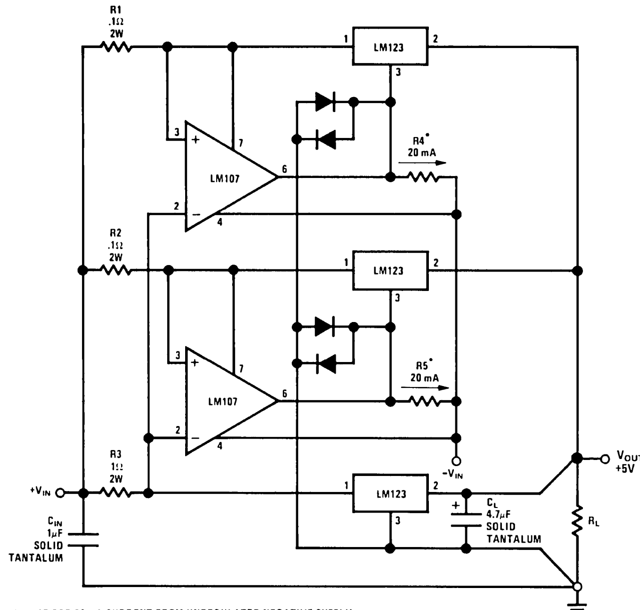


Output Noise Voltage



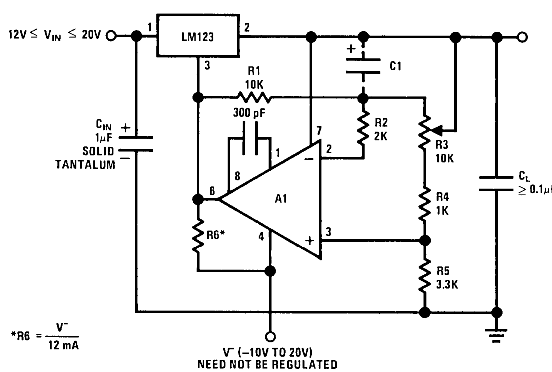
typical applications (con't)

10 Amp Regulator With Complete Overload Protection



*SELECT FOR 20 mA CURRENT FROM UNREGULATED NEGATIVE SUPPLY

Adjustable Regulator 0—10V @ 3A

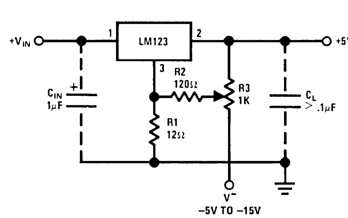


$$*R6 = \frac{V^-}{12\text{ mA}}$$

A_1 – LM101A

C_1 – 2μF OPTIONAL – IMPROVES RIPPLE REJECTION, NOISE, AND TRANSIENT RESPONSE

Trimming Output to 5V



Voltage Regulators

LM125/LM225/LM325/LM325A voltage regulators

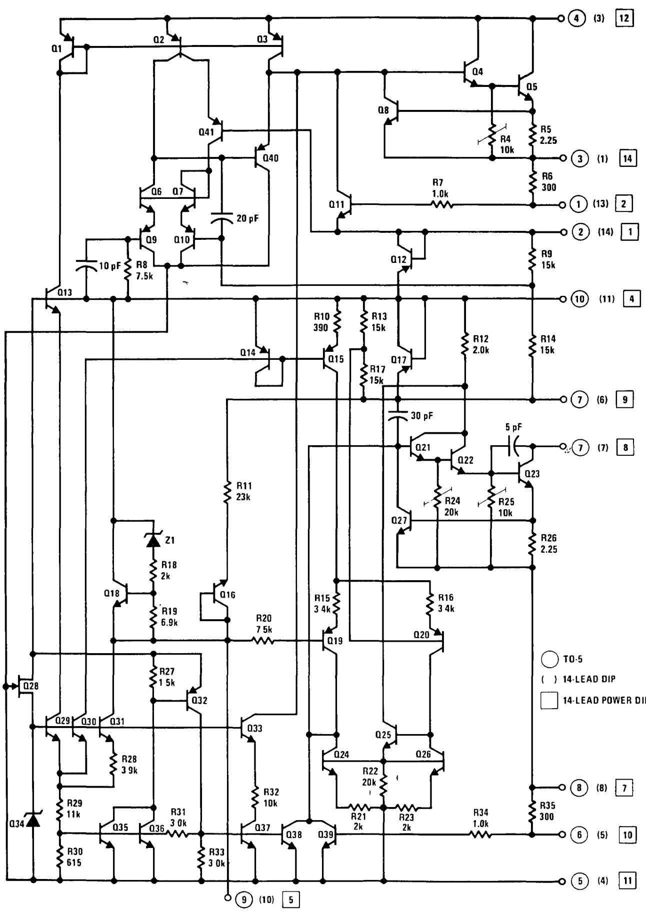
general description

The LM125/LM225/LM325 and LM325A are dual polarity tracking regulators designed to provide balanced positive and negative output voltages at currents up to 100 mA. Internally, the device is set for ±15V outputs. Input voltages up to ±30V can be used and there is provision for adjustable current limiting. The device is available in three package types to accommodate various power requirements and temperature ranges.

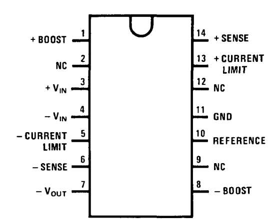
features

- ±15V tracking outputs
- Output currents to 100 mA
- Output voltages balanced to within 1% (LM125, LM325A)
- Line and load regulation of 0.06%
- Internal thermal overload protection
- Standby current drain of 3 mA
- Externally adjustable current limit
- Internal current limit

schematic and connection diagrams



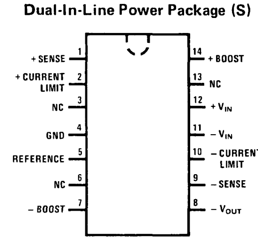
Dual-In-Line Package (N)



TOP VIEW

Order Number LM325N or LM325AN
See Package 22

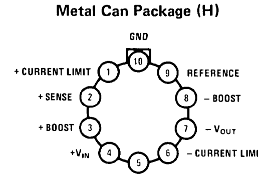
Dual-In-Line Power Package (S)



BOTTOM VIEW

Order Number LM325S or LM325AS
See Package 39

Metal Can Package (H)



TOP VIEW
Note: Pin 5 connected to case.

Order Number LM125H, LM225H or LM325H
See Package 13

absolute maximum ratings

Input Voltage	±30V
Forced V_O^+ (min) (Note 1)	−0.5V
Forced V_O^- (max) (Note 1)	+0.5V
Power Dissipation (Note 2)	P_{MAX}
Output Short-Circuit Duration (Note 3)	Indefinite

operating conditions

Operating Temperature Range	
LM125	−55°C to +125°C
LM225	−25°C to +85°C
LM325, LM325A	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C				
LM125, LM225, LM325A		14.8	15	15.2	V
LM325		14.5	15	15.5	V
Input-Output Differential		2.0			V
Line Regulation	V_{IN} = 18V to 30V, I_L = 20 mA, T_j = 25°C		2.0	10	mV
Line Regulation Over Temperature Range	V_{IN} = 18V to 30V, I_L = 20 mA		2.0	20	mV
Load Regulation	I_L = 0 to 50 mA, V_{IN} = ±30V,				
V_O+	T_j = 25°C		3.0	10	mV
V_O−			5.0	10	mV
Load Regulation Over Temperature Range	I_L = 0 to 50 mA, V_{IN} = ±30V				
V_O+			4.0	20	mV
V_O−			7.0	20	mV
Output Voltage Balance	T_j = 25°C				
LM125/LM225/LM325A				±150	mV
LM325				±300	mV
Output Voltage Over Temperature Range	$P \leq P_{MAX}$, $0 \leq I_O \leq 50$ mA, $18V \leq \lvert V_{IN} \rvert \leq 30$				
LM125/LM325A		14.65		15.35	V
LM225		14.57		15.43	V
LM325		14.27		15.73	V
Temperature Stability of V_O			±0.3		%
Short Circuit Current Limit	T_j = 25°C		260		mA
Output Noise Voltage	T_j = 25°C, BW = 100 − 10 kHz		150		μVrms
Positive Standby Current	T_j = 25°C		1.75	3.0	mA
Negative Standby Current	T_j = 25°C		3.1	5.0	mA
Long Term Stability			0.2		%/kHr
Thermal Resistance Junction to Case (Note 4)					
LM125H, LM225H, LM325H			45		°C/W
LM325AS, LM325S			12		°C/W
Junction to Ambient					
LM325AN, LM325N			150		°C/W

Note 1: See Definition of Terms.

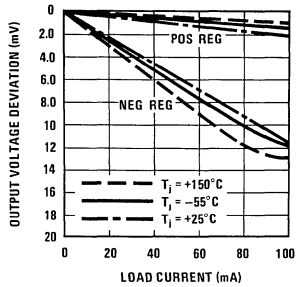
Note 2: Unless otherwise specified, these specifications apply for T_j = −55°C to +150°C on LM125, T_j = −25°C to +150°C on LM225, T_j = 0°C to +125°C on LM325A, T_j = 0°C to +125°C on LM325, V_{IN} = ±20V, I_L = 0 mA. I_{MAX} = 100 mA, P_{MAX} = 2.0W for the TO-5 H Package. I_{MAX} = 100 mA, P_{MAX} = 5.0W for the DIP S Package. I_{MAX} = 100 mA, P_{MAX} = 1.0W for the DIP N Package.

Note 3: If the junction temperature exceeds 150°C, the output short circuit duration is 60 seconds.

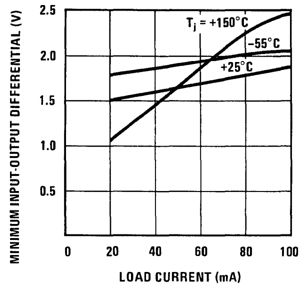
Note 4: Without a heat sink, the thermal resistance junction to ambient of the TO-5 Package is about 150°C/W, while that of the S Package is approximately 55°C/W. With a heat sink, the effective thermal resistance can only approach the values specified, depending on the efficiency of the sink.

typical performance characteristics (V_{IN} = ±20V, I_L = 0 mA, T_j = 25°C, unless otherwise noted)

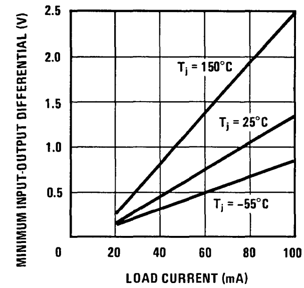
Load Regulation



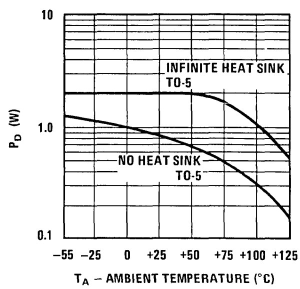
Regulator Dropout Voltage for Positive Regulator



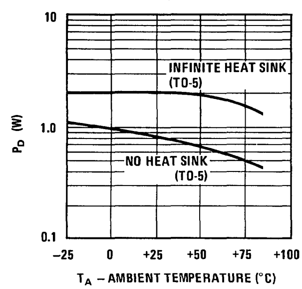
Regulator Dropout Voltage for Negative Regulator



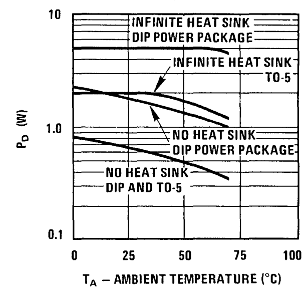
LM125 Maximum Average Power Dissipation vs Ambient Temperature



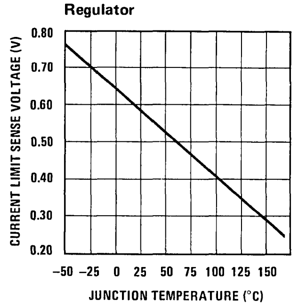
LM225 Maximum Average Power Dissipation vs Ambient Temperature



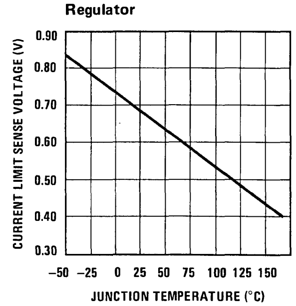
LM325A, LM325 Maximum Average Power Dissipation vs Ambient Temperature



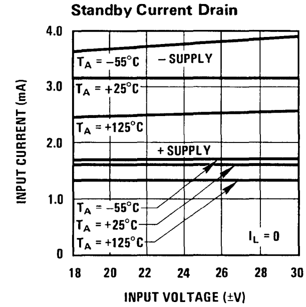
Current Limit Sense Voltage vs Temperature for Negative Regulator



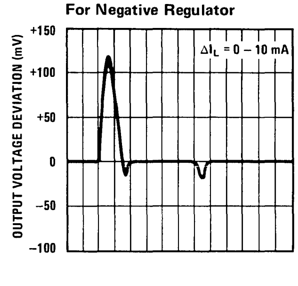
Current Limit Sense Voltage vs Temperature for Positive Regulator



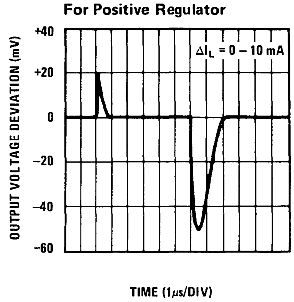
Standby Current Drain



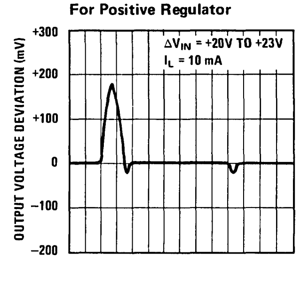
Load Transient Response For Negative Regulator



Load Transient Response For Positive Regulator

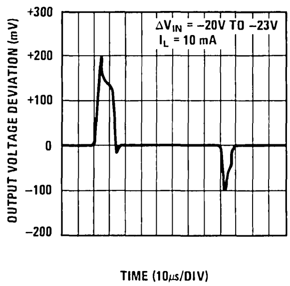


Line Transient Response For Positive Regulator

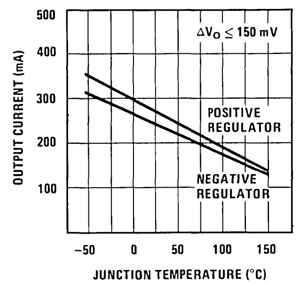


typical performance characteristics (con't)

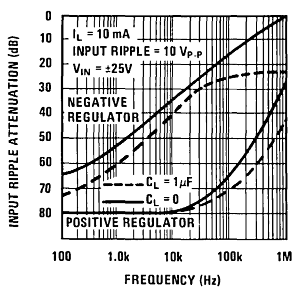
Line Transient Response For Negative Regulator



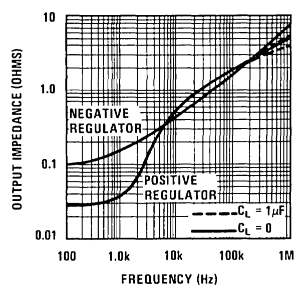
Peak Output Current vs Junction Temperature



Ripple Rejection



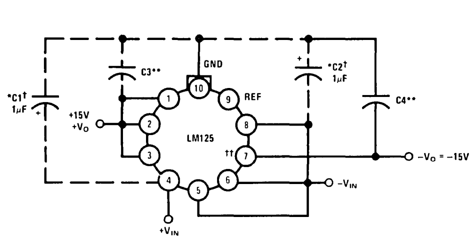
Output Impedance vs Frequency



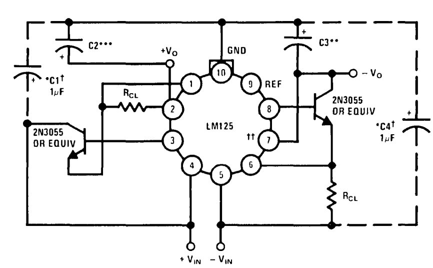
typical applications

(NOTE: Metal Can (H) packages shown. Short pins 6 and 7 on DIP (N) and 8 and 9 on Power DIP (S).)

Basic Regulator†††



2.0 Amp Boosted Regulator With Current Limit



$$I_{CL} = \frac{\text{Current limit sense voltage (see curve)}}{R_{CL}}$$

†Solid tantalum.

††Short pins 6 and 7 on DIP or 8 and 9 on power DIP.

†††R_{CL} can be added to the basic regulator between pins 6 and 5, 1 and 2 to reduce current limit.

*Required if regulator is located an appreciable distance from power supply filter.

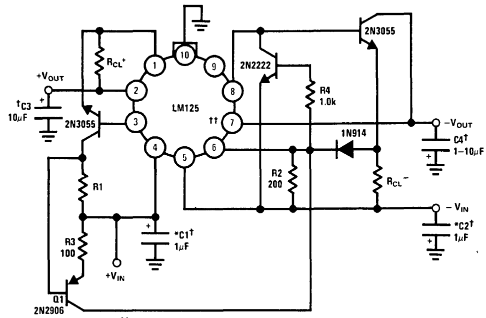
**Although no capacitor is needed for stability, it does help transient response. (If needed use 1μF electrolytic.)

***Although no capacitor is needed for stability, it does help transient response. (If needed use 10μF electrolytic.)

typical applications (con't)

(NOTE: Metal Can (H) packages shown. Short pins 6 and 7 on DIP (N) and 8 and 9 on Power DIP (S).)

Positive Current Dependent Simultaneous Current Limiting

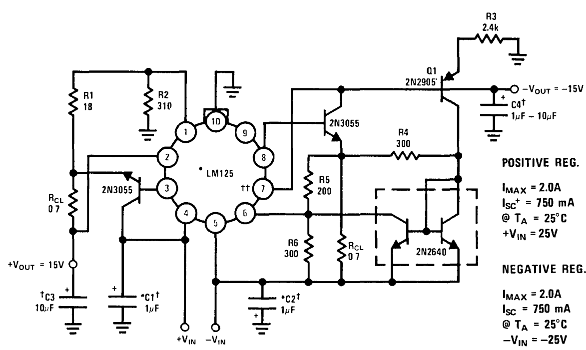


$$I_{CL}^{+} = \frac{\frac{V_{SENSE\ NEG}}{2} + V_{BEQ1}}{R1} \qquad R_{CL}^{+} = \frac{V_{SENSE}^{+}}{1.1\ I_{CL}^{+}}$$

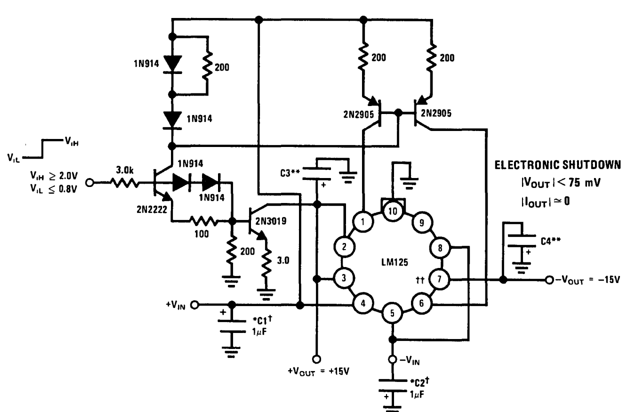
$$I_{CL}^{-} = \frac{V_{SENSE\ NEG} + V_{DIODE}}{R_{CL}^{-}}$$

I_{CL}^{+} controls both sides of the regulator.

Boosted Regulator With Foldback Current Limit



Electronic Shutdown



†Solid tantalum.
††Short pins 6 and 7 on DIP or 8 and 9 on power DIP.
*Required if regulator is located an appreciable distance from power supply filter.
**Although no capacitor is needed for stability, it does help transient response. (If needed use 1µF electrolytic.)

Voltage Regulators

LM126/LM226/LM326 voltage regulators

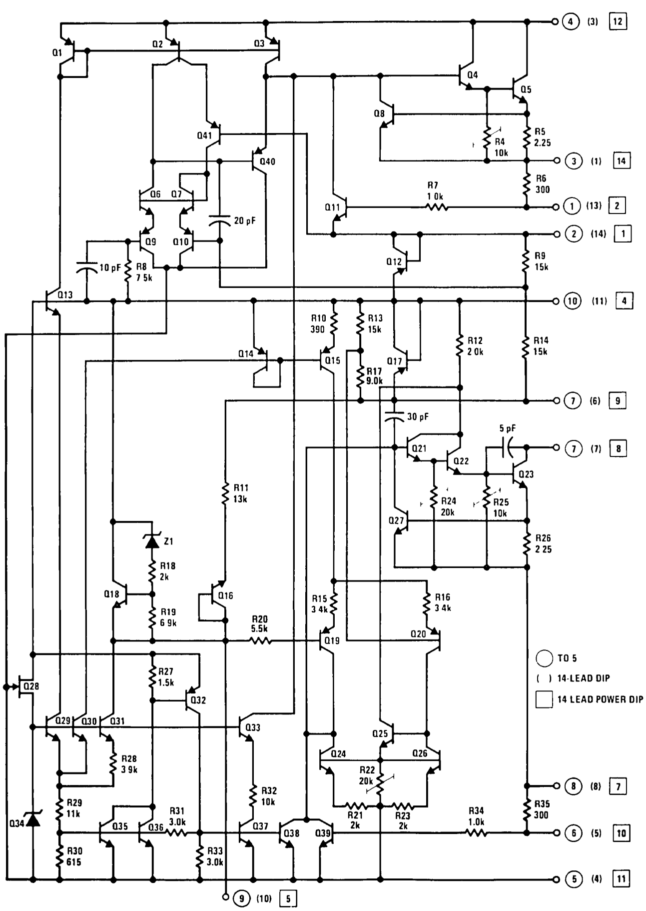
general description

The LM126/LM226 and LM326 are dual polarity tracking regulators designed to provide balanced positive and negative output voltages at currents up to 100 mA. Internally, the device is set for ±12V outputs. Input voltages up to ±30V can be used and there is provision for adjustable current limiting. The device is available in three package types to accommodate various power requirements and temperature ranges.

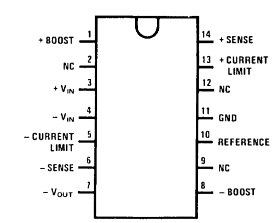
features

- ±12V tracking outputs
- Output currents to 100 mA
- Output voltage balanced to within 1% (LM126)
- Line and load regulation of 0.08%
- Internal thermal overload protection
- Standby current drain of 3 mA
- Externally adjustable current limit
- Internal current limit
- Specified to be compatible, worst case, with high threshold MOS

schematic and connection diagrams



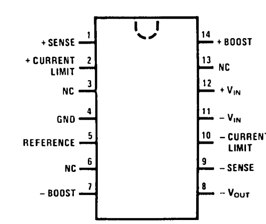
Dual-In-Line Package



TOP VIEW

Order Number LM326N
See Package 22

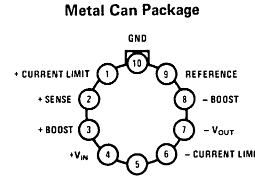
Dual-In-Line Power Package



BOTTOM VIEW

Order Number LM326S
See Package 39

Metal Can Package



TOP VIEW

Note: Pin 5 connected to case.

Order Number LM126H, LM226H or LM326H
See Package 13

absolute maximum ratings

Input Voltage	±30V
Forced V_O^+ (Min) (Note 1)	−0.5V
Forced V_O^- (Max) (Note 1)	+0.5V
Power Dissipation (Note 2)	Internally Limited
Output Short-Circuit Duration (Note 3)	Indefinite
Operating Temperature Range	
LM126	−55°C to +125°C
LM226	−25°C to +85°C
LM326	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C				
LM126, LM226		11.8	12	12.2	V
LM326		11.5		12.5	V
Input-Output Differential		2.0			V
Line Regulation	V_{IN} = 15V to 30V, I_L = 20 mA, T_j = 25°C		2.0	10	mV
Line Regulation Over Temperature Range	V_{IN} = 15V to 30V, I_L = 20 mA		2.0	20	mV
Load Regulation	I_L = 0 to 50 mA, V_{IN} = ±30V, T_j = 25°C				
V_O^+			3.0	10	mV
V_O^-			5.0	10	mV
Load Regulation Over Temperature Range	I_L = 0 to 50 mA, V_{IN} = ±30V				
V_O^+			4.0	20	mV
V_O^-			7.0	20	mV
Output Voltage Balance	T_j = 25°C				
LM126, LM226				±125	mV
LM326				±250	mV
Output Voltage Over Temperature Range	$P \leq P_{MAX}$, $0 \leq I_O \leq 50$ mA, $15V \leq \|V_{IN}\| \leq 30V$				
LM126		11.68		12.32	V
LM226		11.62		12.38	V
LM326		11.32		12.68	V
Temperature Stability of V_O			±0.3		%
Short Circuit Current Limit	T_j = 25°C		260		mA
Output Noise Voltage	T_j = 25°C, BW = 100 − 10 kHz		100		μVrms
Positive Standby Current	T_j = 25°C, I_L = 0		1.75	3.0	mA
Negative Standby Current	T_j = 25°C, I_L = 0		3.1	5.0	mA
Long Term Stability			0.2		%/kHr
Thermal Resistance Junction to Case (Note 4)					
LM126H/LM226H/LM326H			45		°C/W
LM326S			12		°C/W
Junction to Ambient LM326N			150		°C/W

Note 1: See Definition of Terms.

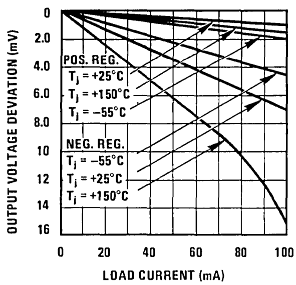
Note 2: Unless otherwise specified, these specifications apply for T_j = −55°C to +150°C on LM126, T_j = −25°C to +150°C on LM226, T_j = 0°C to +125°C on LM326, V_{IN} = ±20V, I_L = 0 mA. I_{MAX} = 100 mA, P_{MAX} = 2.0W for the TO-5 H Package I_{MAX} = 100 mA, P_{MAX} = 5.0W for the DIP S Package. I_{MAX} = 100 mA, P_{MAX} = 1.0W for the DIP N Package.

Note 3: If the junction temperature exceeds 150°C the output short circuit duration is 60 seconds.

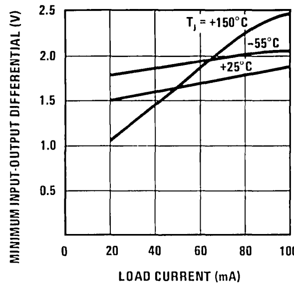
Note 4: Without a heat sink, the thermal resistance of the TO-5 Package is about 150°C/W, while that of the S Package is approximately 55°C/W. With a heat sink, the effective thermal resistance can only approach the values specified, depending on the efficiency of the sink.

typical performance characteristics (V_{IN} = ±20V, I_L = 0 mA, T_j = 25°C, unless otherwise noted.)

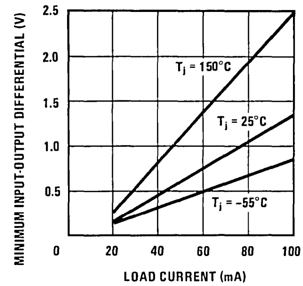
Load Regulation



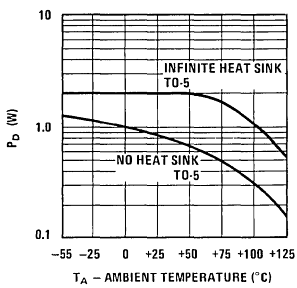
Regulator Dropout Voltage for Positive Regulator



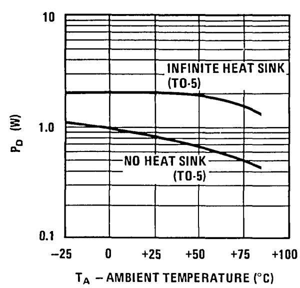
Regulator Dropout Voltage for Negative Regulator



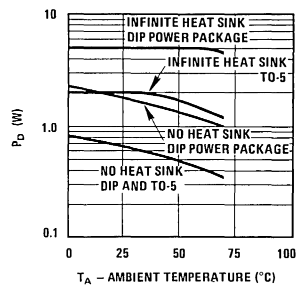
LM126 Maximum Average Power Dissipation vs Ambient Temperature



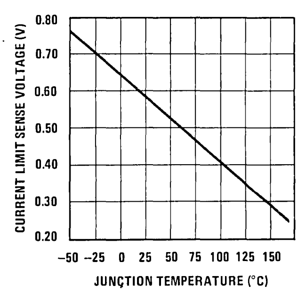
LM226 Maximum Average Power Dissipation vs Ambient Temperature



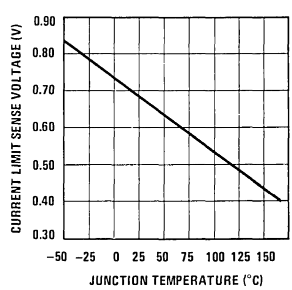
LM326 Maximum Average Power Dissipation vs Ambient Temperature



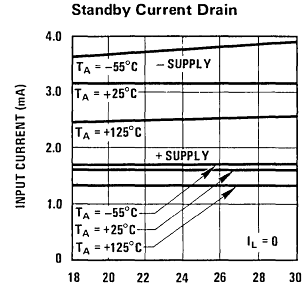
Current Limit Sense Voltage vs Temperature for Negative Regulator



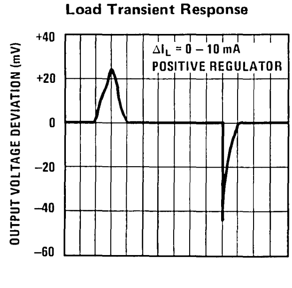
Current Limit Sense Voltage vs Temperature for Positive Regulator



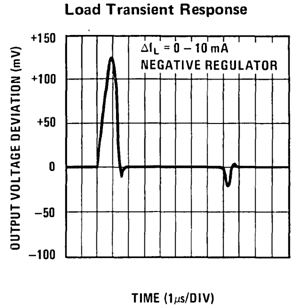
Standby Current Drain



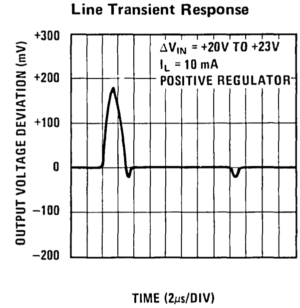
Load Transient Response



Load Transient Response

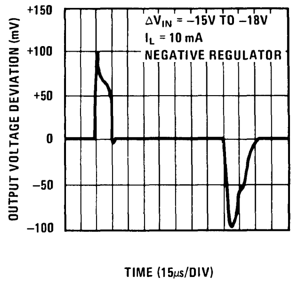


Line Transient Response

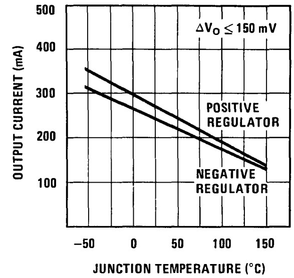


typical performance characteristics (con't)

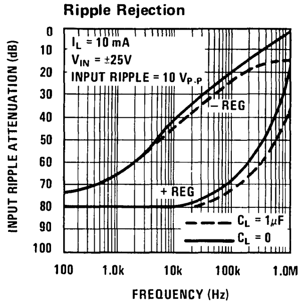
Line Transient Response



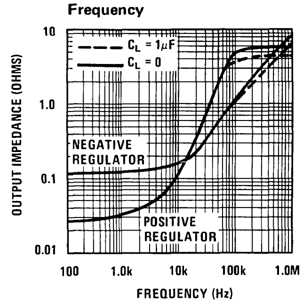
Peak Output Current vs Junction Temperature



Ripple Rejection



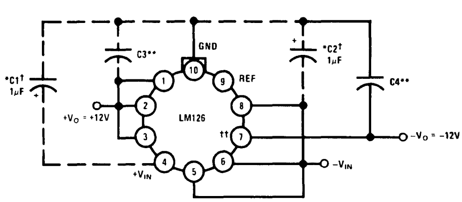
Output Impedance vs Frequency



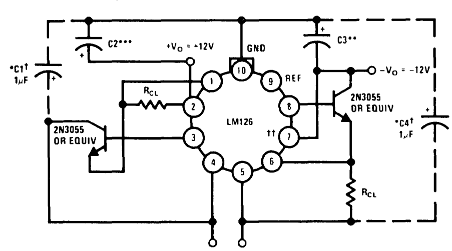
typical applications

(NOTE: Metal Can (H) packages shown. Short pins 6 and 7 on DIP (N) and 8 and 9 on Power DIP (S).)

Basic Regulator†††



2.0 Amp Boosted Regulation With Current Limit



$$I_{CL} = \frac{\text{Current limit sense voltage (see curve)}}{R_{CL}}$$

†Solid tantalum.

††Short pins 6 and 7 on DIP or 8 and 9 on power DIP.

†††R_{CL} can be added to the basic regulator between pins 6 and 5, 1 and 2 to reduce current limit.

*Required if regulator is located an appreciable distance from power supply filter.

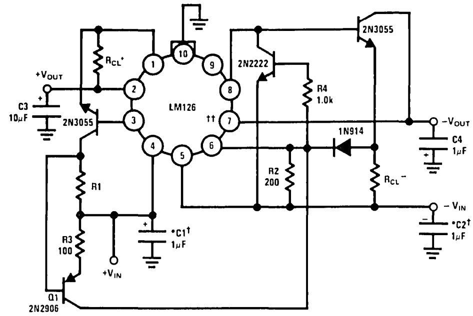
**Although no capacitor is needed for stability, it does help transient response. (If needed use 1μF electrolytic.)

***Although no capacitor is needed for stability, it does help transient response. (If needed use 10μF electrolytic.)

typical applications (con't)

(NOTE: Metal Can (H) packages shown. Short pins 6 and 7 on DIP (N) and 8 and 9 on Power DIP (S).)

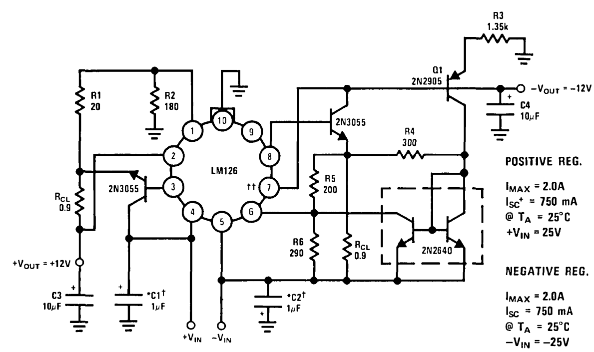
Positive Current Dependent Simultaneous Current Limiting



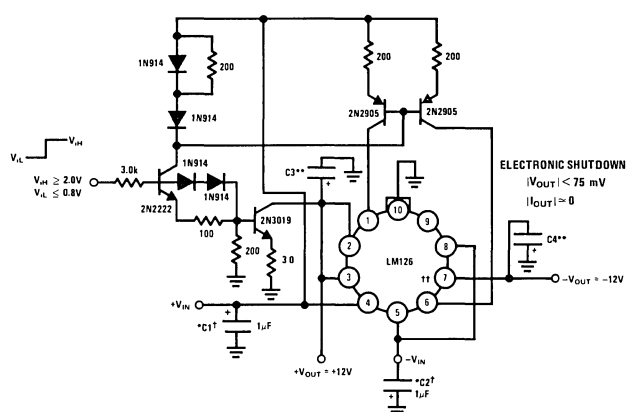
$$I_{CL}^{+} = \frac{\frac{V_{SENSE\ NEG}}{2} + V_{BEQ1}}{R1} \qquad R_{CL}^{+} = \frac{V_{SENSE}^{+}}{1.1\ I_{CL}^{+}}$$

$$I_{CL}^{-} = \frac{V_{SENSE\ NEG} + V_{DIODE}}{R_{CL}^{-}}$$

Boosted Regulator With Foldback Current Limit



Electronic Shutdown



†Solid tantalum.

††Short pins 6 and 7 on DIP or 8 and 9 on power DIP.

*Required if regulator is located an appreciable distance from power supply filter.

**Although no capacitor is needed for stability, it does help transient response. (If needed use 1µF electrolytic.)

Voltage Regulators

LM127/LM227/LM327 voltage regulators

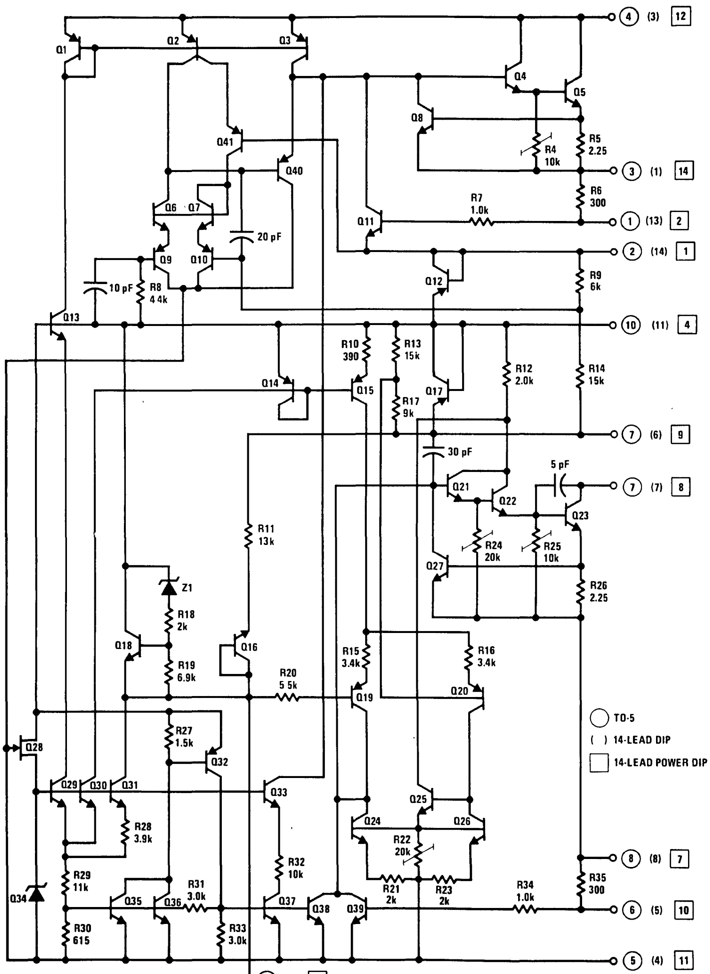
general description

The LM127/LM227 and LM327 are dual polarity tracking regulators designed to provide balanced positive and negative output voltages at currents up to 100 mA. Internally, the device is set for +5V, −12V outputs. Input voltages up to ±30V can be used and there is provision for adjustable current limiting. The device is available in three package types to accommodate various power requirements and temperature ranges.

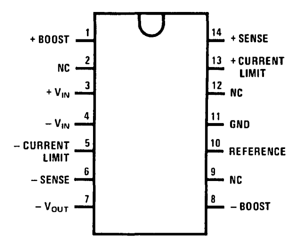
features

- +5V, −12V tracking outputs
- Output currents to 100 mA
- Specified to be compatible, worst case, with most MOS
- Internal thermal overload protection
- Standby current drain of 3 mA
- Externally adjustable current limit
- Internal current limit

schematic and connection diagrams

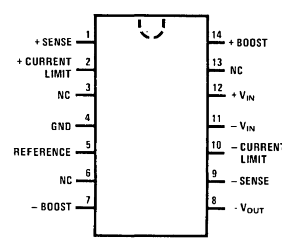


Dual-In-Line Package



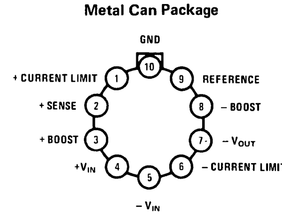
Order Number LM327N
See Package 22

Dual-In-Line Power Package



Order Number LM327S
See Package 39

Metal Can Package



Note: Pin 5 connected to case.

Order Number LM127H, LM227H or LM327H
See Package 13

absolute maximum ratings

Input Voltage	±30V
Forced V_O^+ (min) (Note 1)	−0.5V
Forced V_O^- (max) (Note 1)	+0.5V
Power Dissipation (Note 2)	Internally Limited
Output Short-Circuit Duration (Note 3)	Indefinite
Operating Temperature Range	
LM127	−55°C to +125°C
LM227	−25°C to +85°C
LM327	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C				
V_O^+		+4.8	+5.0	+5.2	V
V_O^-		−12.5	−12	−11.5	V
Input-Output Differential		2.0			V
Line Regulation	V^+_{IN} = +8.0V to +30V, V^-_{IN} = −15V to −30V, I_L = 20 mA, T_j = 25°C		2.0	15	mV
Line Regulation Over Temperature Range	V^+_{IN} = +8.0V to +30V, V^-_{IN} = −15V to −30V, I_L = 20 mA		2.0	30	mV
Load Regulation	I_L = 0 to 50 mA,				
V_O^+	V_{IN} = ±30V, T_j = 25°C		3.0	10	mV
V_O^-			5.0	10	mV
Load Regulation Over Temperature Range	I_L = 0 to 50 mA, V_{IN} = ±30V				
V_O^+			4.0	20	mV
V_O^-			7.0	20	mV
Output Voltage	$P < P_{MAX}$, $0 \leq I_O \leq 50$ mA,				
V_O^+	$+8.0V \leq V^+_{IN} \leq +30V$,	4.75		5.25	V
V_O^-	$-30V \leq V^-_{IN} \leq -15V$	−12.6		−11.4	V
Temperature Stability			±0.3		%
Short Circuit Current Limit	T_j = 25°C		260		mA
Output Noise Voltage	T_j = 25°C, BW = 100 − 10 kHz				
V_O^+			40		µVrms
V_O^-			100		µVrms
Positive Standby Current	T_j = 25°C, I_L = 0		1.75	3.0	mA
Negative Standby Current	T_j = 25°C, I_L = 0		3.1	5.0	mA
Long Term Stability			0.2		%/kHr
Thermal Resistance Junction to Case (Note 4)					
LM127H, LM227H, LM327H			45		°C/W
LM327S			12		°C/W
Junction to Ambient, LM327N			150		°C/W

Note 1: See Definition of Terms.

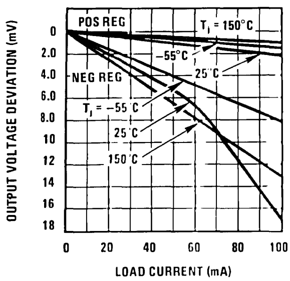
Note 2: Unless otherwise specified, these specifications apply for T_j = −55°C to +150°C on LM127, T_j = −25°C to +150°C on LM227, T_j = 0°C to +125°C on LM327, V_{IN} = ±20V, I_L = 0 mA. I_{MAX} = 100 mA, P_{MAX} = 2.0W for the TO-5H Package, I_{MAX} = 100 mA, P_{MAX} = 5.0W for the DIP S Package. I_{MAX} = 100 mA, P_{MAX} = 1.0W for the DIP N Package.

Note 3: If the junction temperature exceeds 150°C the output short circuit duration is 60 seconds.

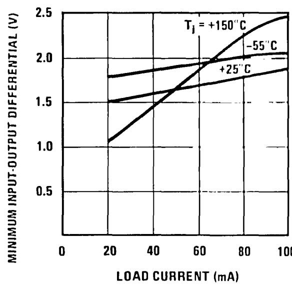
Note 4: Without a heat sink, the thermal resistance of the TO-5 Package is about 150°C/W, while that of the S Package is approximately 55°C/W. With a heat sink, the effective thermal resistance can only approach the values specified, depending on the efficiency of the sink.

typical performance characteristics (V_{IN} = ±20V, I_L = 0 mA, T_j = 25°C, unless otherwise noted.)

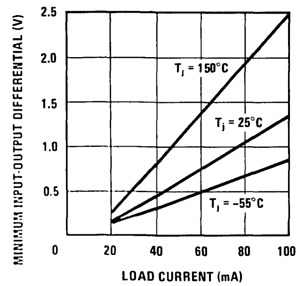
Load Regulation



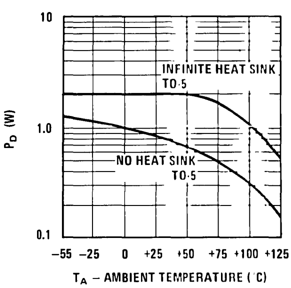
Regulator Dropout Voltage for Positive Regulator



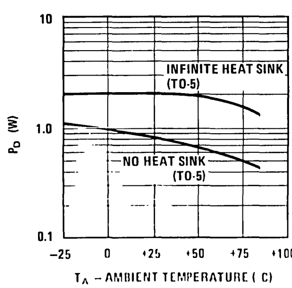
Regulator Dropout Voltage for Negative Regulator



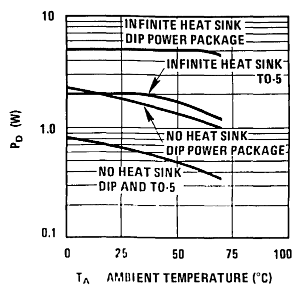
LM127 Maximum Average Power Dissipation vs Ambient Temperature



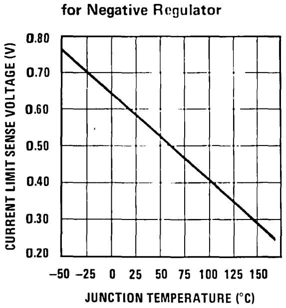
LM227 Maximum Average Power Dissipation vs Ambient Temperature



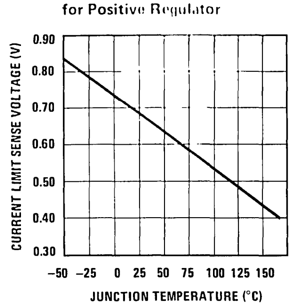
LM327 Maximum Average Power Dissipation vs Ambient Temperature



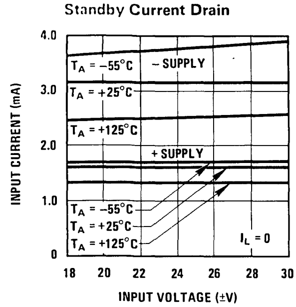
Current Limit Sense Voltage vs Temperature for Negative Regulator



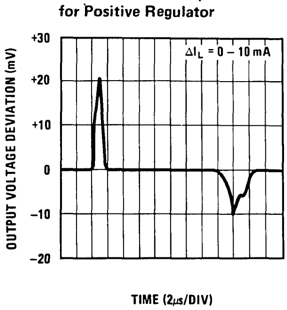
Current Limit Sense Voltage vs Temperature for Positive Regulator



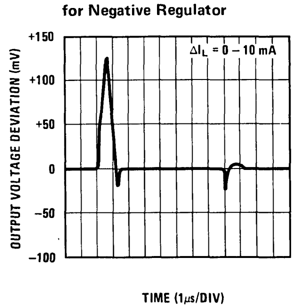
Standby Current Drain



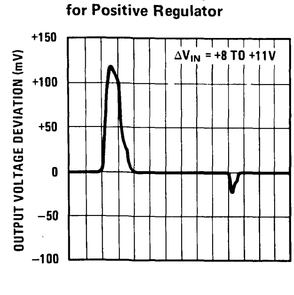
Load Transient Response for Positive Regulator



Load Transient Response for Negative Regulator

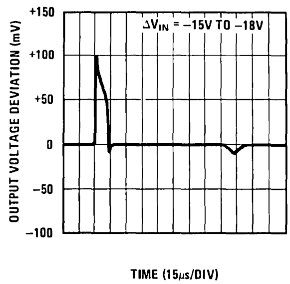


Line Transient Response for Positive Regulator

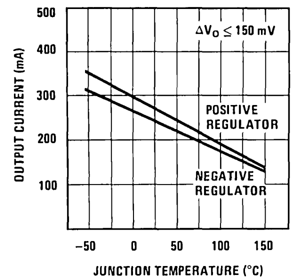


typical performance characteristics (con't)

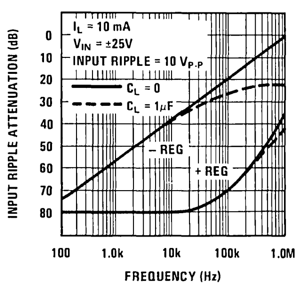
Line Transient Response for Negative Regulator



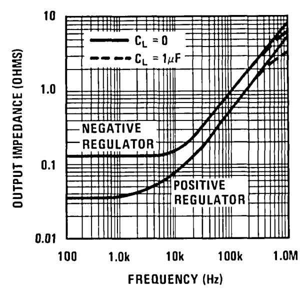
Peak Output Current vs Junction Temperature



Ripple Rejection



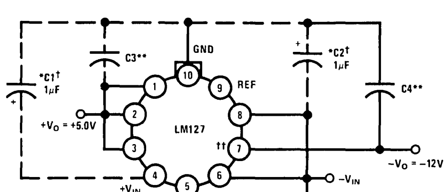
Output Impedance vs Frequency



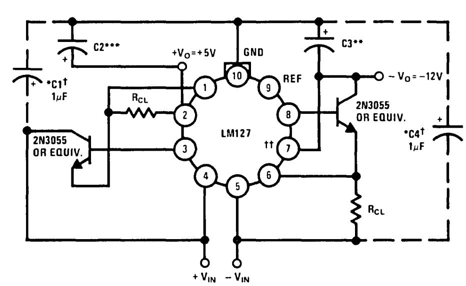
typical applications

(NOTE: Metal Can (H) packages shown. Short pins 6 and 7 on DIP (N) and 8 and 9 on Power DIP (S).)

Basic Regulator†††



2.0 Amp Boosted Regulator with Current Limit



$$I_{CL} = \frac{\text{Current limit sense voltage (see curve)}}{R_{CL}}$$

†Solid tantalum.

††Short pins 6 and 7 on DIP or 8 and 9 on power DIP.

†††R_{CL} can be added to the basic regulator between pins 6 and 5, 1 and 2 to reduce current limit.

*Required if regulator is located an appreciable distance from power supply filter.

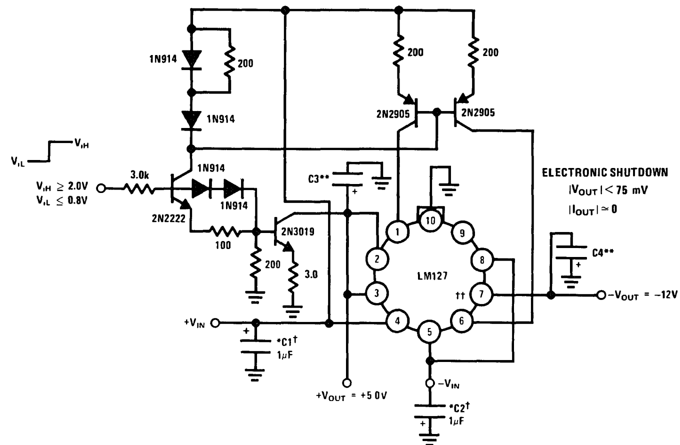
**Although no capacitor is needed for stability, it does help transient response. (If needed use 1μF electrolytic.)

***Although no capacitor is needed for stability, it does help transient response. (If needed use 10μF electrolytic.)

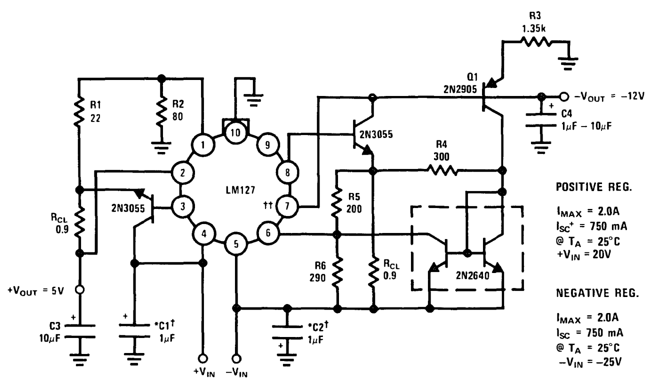
typical applications (con't)

(NOTE: Metal Can (H) packages shown. Short pins 6 and 7 on DIP (N) and 8 and 9 on Power DIP (S).)

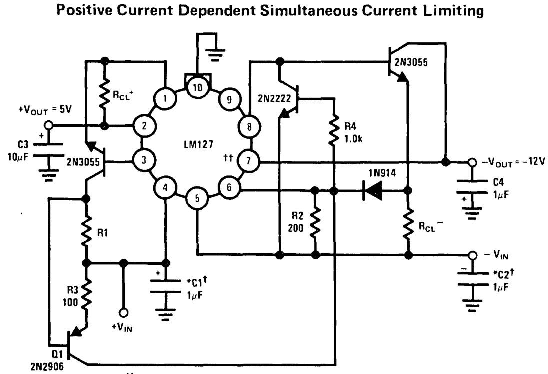
Electronic Shutdown



Boosted Regulator with Foldback Current Limit



Positive Current Dependent Simultaneous Current Limiting



$$I_{CL}^{+} = \frac{\frac{V_{SENSE\ NEG}}{2} + V_{BEQ1}}{R1}$$

$$I_{CL}^{-} = \frac{V_{SENSE\ NEG} + V_{DIODE}}{R_{CL}^{-}}$$

I_{CL}^{+} controls both sides of the regulator.

$$R_{CL}^{+} = \frac{V_{SENSE}^{+}}{1.1\ I_{CL}^{+}}$$

†Solid tantalum.

††Short pins 6 and 7 on DIP or 8 and 9 on power DIP.

*Required if regulator is located an appreciable distance from power supply filter.

**Although no capacitor is needed for stability, it does help transient response. (If needed use 1μF electrolytic.)

Voltage Regulators

LM145/LM245/LM345 negative three amp regulator

general description

The LM145 is a three-terminal negative regulator with a fixed output voltage of −5V or −5.2V, and up to 3A load current capability. This device needs only one external component—a compensation capacitor at the output, making it easy to apply. Worst case guarantees on output voltage deviation due to any combination of line, load or temperature variation assure satisfactory system operation.

Exceptional effort has been made to make the LM145 immune to overload conditions. The regulator has current limiting which is independent of temperature, combined with thermal overload protection. Internal current limiting protects against momentary faults while thermal shutdown prevents junction temperatures from exceeding safe limits during prolonged overloads.

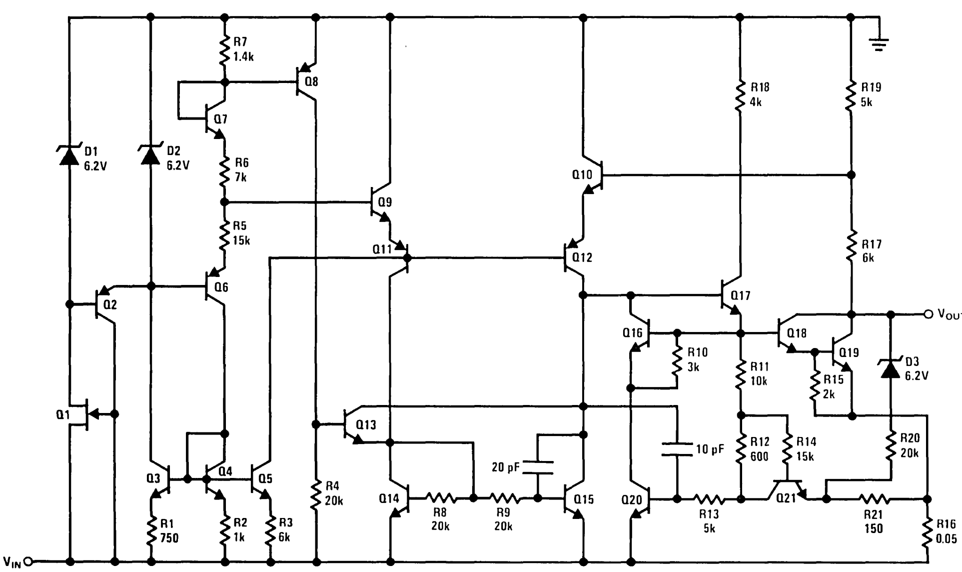
Although primarily intended for fixed output voltage applications, the LM145 may be programmed for higher output voltages with a simple resistive divider. The low quiescent drain current of the device allows this technique to be used with good regulation.

The LM145 comes in a hermetic TO-3 package rated at 25W. Two reduced temperature range parts, LM245 and LM345, are also available.

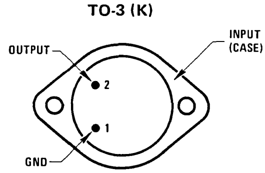
features

- Output voltage accurate to better than ±2%
- Current limit constant with temperature
- Internal thermal shutdown protection
- Operates with input-output voltage differential of 2.8V at full rated load over full temperature range
- Regulation guaranteed with 25W power dissipation
- 3A output current guaranteed
- Only one external component needed

schematic and connection diagrams



TO-3 (K)



BOTTOM VIEW

Order Number LM145K, LM245K or LM345K
See Package 18

absolute maximum ratings

Input Voltage	20V
Input-Output Differential	20V
Power Dissipation	Internally Limited
Operating Junction Temperature Range	
LM145	−55°C to +150°C
LM245	−25°C to +150°C
LM345	0°C to +125°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (−5V & −5.2V) (Note 1)

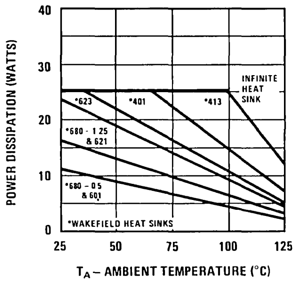
PARAMETER	CONDITIONS	LIMITS						UNITS
		LM145/LM245			LM345			
		MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	T_j = 25°C, I_{OUT} = 5 mA, V_{IN} = −7.5							
5.0V		−5.1	−5.0	−4.9	−5.2	−5.0	−4.8	V
5.2V		−5.3	−5.2	−5.1	−5.4	−5.2	−5.0	V
Line Regulation (Note 2)	T_j = 25°C, −20V ≤ V_{IN} ≤ −7.5V		5	15		5	25	mV
Load Regulation (Note 2)	T_j = 25°C, V_{IN} = −7.5V, 5 mA ≤ I_{OUT} ≤ 3A		30	75		30	100	mV
Output Voltage	−20V ≤ V_{IN} ≤ −7.8V, 5 mA ≤ I_{OUT} ≤ 3A, P ≤ 25W, $T_{MIN} \le T_j \le T_{MAX}$							
5.0V		−5.20		−4.80	−5.25		−4.75	V
5.2V		−5.40		−5.00	−5.45		−4.95	V
Quiescent Current	−20V ≤ V_{IN} ≤ −7.5V, 5 mA ≤ I_{OUT} ≤ 3A		1.0	3.0		1.0	3.0	mA
Short Circuit Current	V_{IN} = −7.5V		4			4	5.0	A
	V_{IN} = −20V		2			2	3.5	A
Output Noise Voltage	T_A = 25°C, C_L = 4.7μF, 10 Hz ≤ f ≤ 100 kHz		150			150		μV
Long Term Stability			5	50		5	50	mV
Thermal Resistance Junction to Case			2			2		°C/W

Note 1: Unless otherwise specified, these specifications apply: −55°C ≤ T_j ≤ +150°C for the LM145; −25°C ≤ T_j ≤ +150°C for the LM245 and 0°C ≤ T_j ≤ +125°C for the LM345. V_{IN} = −7.5V and I_{OUT} = 5 mA. Although power dissipation is internally limited, electrical specifications apply only for power levels up to 25W. For calculations of junction temperature rise due to power dissipation, use a thermal resistance of 35°C/W for the TO-3 with no heat sink. With a heat sink, use 2°C/W for junction to case thermal resistance.

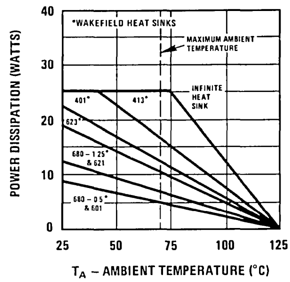
Note 2: Regulation is measured at constant junction temperature. Changes in output voltage due to heating effects must be taken into account separately. To ensure constant junction temperature, pulse testing with a low duty cycle is used.

typical performance characteristics

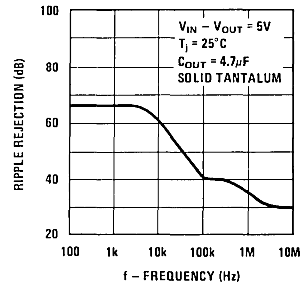
Maximum Average Power Dissipation for LM145, LM245



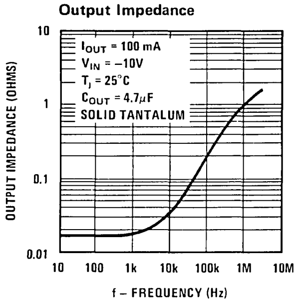
Maximum Average Power Dissipation for LM345



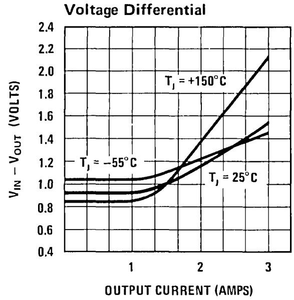
Ripple Rejection



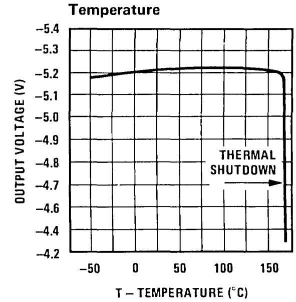
Output Impedance



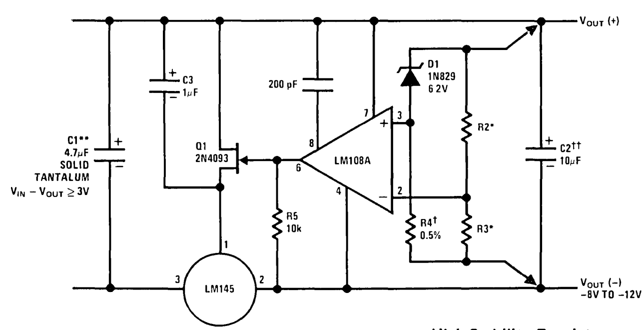
Minimum Input-Output Voltage Differential



Output Voltage vs Temperature



typical applications



*Select resistors to set output voltage. 1 ppm/°C tracking suggested.

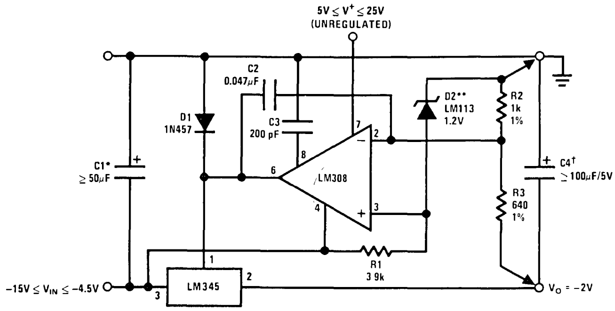
**C1 is not needed if power supply filter capacitor is within 3" of regulator.

†Determines zener current. May be adjusted to minimize temperature drift.

††*Solid tantalum.*

Load and line regulation < 0.01%
Temperature drift < 0.001%/°C

High Stability Regulator



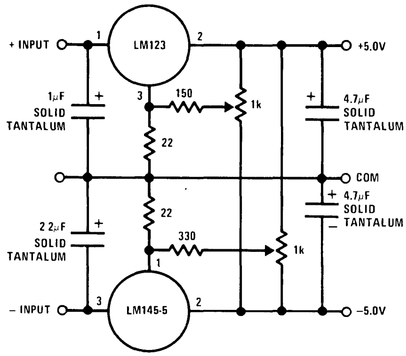
**C1 is not needed if power supply filter capacitor is within 3" of regulator.

†Keep C4 within 2" of LM345. There is no upper limit on C4 and unlimited capacitance can be added at extended distances from the regulator.

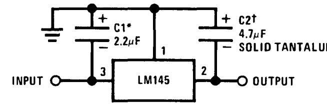
**D2 sets initial output voltage accuracy. The LM113 is available in ·5, ·2, and ·1% tolerance.

–2V ECL Termination Regulator

typical applications (con't)



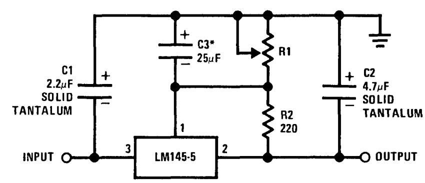
Dual 3 Amp Trimmed Supply



†Required for stability. For value given, capacitor must be solid tantalum. 50μF aluminum electrolytic may be substituted. Values given may be increased without limit.

*Required if regulator is separated from filter capacitor. For value given, capacitor must be solid tantalum. 50μF aluminum electrolytic may be substituted.

Fixed Regulator



*Optional. Improves transient response and ripple rejection.

$V_{OUT} = -5V \left(\frac{R1 + R2}{R2}\right)$

Variable Output (–5.0V to –15V)

Voltage Regulators

LM340 series 3-terminal positive regulators

general description

The LM340-XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. One of these is local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and currents.

The LM340-XX series is available in two power packages. Both the plastic TO-220 and metal TO-3 packages allow these regulators to deliver over 1.0A if adequate heat sinking is provided. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistor is provided to limit internal power dissipation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating.

Considerable effort was expended to make the LM340-XX series of regulators easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply.

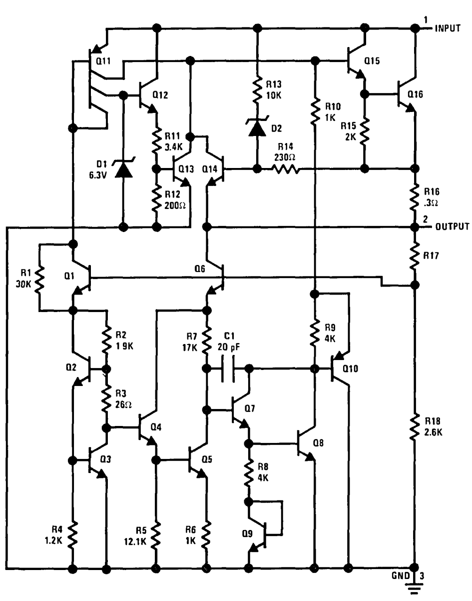
features

- Output current in excess of 1A
- Internal thermal overload protection
- No external components required
- Output transistor safe area protection
- Internal short circuit current limit
- Available in plastic TO-220 and metal TO-3 packages

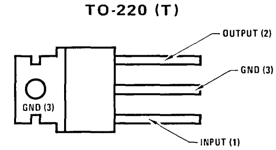
voltage range

LM340-05	5V	LM340-15	15V
LM340-06	6V	LM340-18	18V
LM340-08	8V	LM340-24	24V
LM340-12	12V		

schematic and connection diagrams



TO-220 (T)



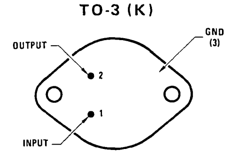
TOP VIEW

Order Numbers:

LM340T-5.0	**LM340T-15**
LM340T-6.0	**LM340T-18**
LM340T-8.0	**LM340T-24**
LM340T-12	

See Package 26

TO-3 (K)



BOTTOM VIEW

Order Numbers:

LM340K-5.0	**LM340K-15**
LM340K-6.0	**LM340K-18**
LM340K-8.0	**LM340K-24**
LM340K-12	

See Package 18

absolute maximum ratings

Input Voltage (V_O = 5V through 18V)	35V
(V_O = 24V)	40V
Internal Power Dissipation (Note 1)	Internally Limited
Operating Temperature Range	0°C to 70°C
Maximum Junction Temperature	
TO-3 Package	150°C
TO-220 Package	150°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature	
TO-3 Package (Soldering, 10 sec)	300°C
TO-220 Package (Soldering, 10 sec)	230°C

electrical characteristics

LM340-5 (V_{IN} = 10V, I_{OUT} = 500 mA, 0°C ≤ T_A ≤ 70°C, unless otherwise specified)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	4.8	5	5.2	V
Line Regulation	T_j = 25°C, 7V ≤ V_{IN} ≤ 25V				
	I_{OUT} = 100 mA			50	mV
	I_{OUT} = 500 mA			100	mV
Load Regulation	T_j = 25°C, 5 mA ≤ I_{OUT} ≤ 1.5A			100	mV
Output Voltage	7V ≤ V_{IN} ≤ 20V, 5 mA ≤ I_{OUT} ≤ 1.0A P_D ≤ 15W	4.75		5.25	V
Quiescent Current	T_j = 25°C		7	10	mA
Quiescent Current Change	7V ≤ V_{IN} ≤ 25V			1.3	mA
	5 mA ≤ I_{OUT} ≤ 1.5A			.5	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz		40		μV
Long Term Stability				20	mV/1000 hr
Ripple Rejection	f = 120 Hz		60		dB
Dropout Voltage	T_j = 25°C, I_{OUT} = 1.0A		2		V

LM340-6 (V_{IN} = 11V, I_{OUT} = 500 mA, 0°C ≤ T_A ≤ 70°C, unless otherwise specified)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	5.75	6	6.25	V
Line Regulation	T_j = 25°C, 8V ≤ V_{IN} ≤ 25V				
	I_{OUT} = 100 mA			60	mV
	I_{OUT} = 500 mA			120	mV
Load Regulation	T_j = 25°C, 5 mA ≤ I_{OUT} ≤ 1.5A			120	mV
Output Voltage	8V ≤ V_{IN} ≤ 21V, 5 mA ≤ I_{OUT} ≤ 1.0A P_D ≤ 15W	5.7		6.3	V
Quiescent Current	T_j = 25°C		7	10	mA
Quiescent Current Change	8V ≤ V_{IN} ≤ 25V			1.3	mA
	5 mA ≤ I_{OUT} ≤ 1.5A			.5	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz		45		μV
Long Term Stability				24	mV/1000 hr
Ripple Rejection	f = 120 Hz		57		dB
Dropout Voltage	T_j = 25°C, I_{OUT} = 1.0A		2		V

Note 1: Thermal resistance without a heat sink for junction to case temperature is 4°C/W for the TO-3 package and 4°C/W for the TO-220 package. Thermal resistance for case to ambient temperature is 35°C/W for the TO-3 package and 50°C/W for the TO-220 package.

electrical characteristics (con't)

LM340-8 (V_{IN} = 14V, I_{OUT} = 500 mA, $0°C \leq T_A \leq 70°C$, unless otherwise specified)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	7.7	8	8.3	V
Line Regulation	T_j = 25°C, $10.5V \leq V_{IN} \leq 25V$				
	I_{OUT} = 100 mA			80	mV
	I_{OUT} = 500 mA			160	mV
Load Regulation	T_j = 25°C, $5 mA \leq I_{OUT} \leq 1.5A$			160	mV
Output Voltage	$10.5V \leq V_{IN} \leq 23V$, $5 mA \leq I_{OUT} \leq 1.0A$ $P_D \leq 15W$	7.6		8.4	V
Quiescent Current	T_j = 25°C		7	10	mA
Quiescent Current Change	$10.5V \leq V_{IN} \leq 25V$			1	mA
	$5 mA \leq I_{OUT} \leq 1.5A$			.5	mA
Output Noise Voltage	T_A = 25°C, $10 Hz \leq f \leq 100 kHz$		52		µV
Long Term Stability				32	mV/1000 hr
Ripple Rejection	f = 120 Hz		55		dB
Dropout Voltage	T_j = 25°C, I_{OUT} = 1.0A		2		V

LM340-12 (V_{IN} = 19V, I_{OUT} = 500 mA, $0°C \leq T_A \leq 70°C$, unless otherwise specified)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	11.5	12	12.5	V
Line Regulation	T_j = 25°C, $14.5V \leq V_{IN} \leq 30V$				
	I_{OUT} = 100 mA			120	mV
	I_{OUT} = 500 mA			240	mV
Load Regulation	T_j = 25°C, $5 mA \leq I_{OUT} \leq 1.5A$			240	mV
Output Voltage	$14.5V \leq V_{IN} \leq 27V$, $5 mA \leq I_{OUT} \leq 1.0A$ $P_D \leq 15W$	11.4		12.6	V
Quiescent Current	T_j = 25°C		7	10	mA
Quiescent Current Change	$14.5V \leq V_{IN} \leq 30V$			1	mA
	$5 mA \leq I_{OUT} \leq 1.5A$			.5	mA
Output Noise Voltage	T_A = 25°C, $10 Hz \leq f \leq 100 kHz$		75		µV
Long Term Stability				48	mV/1000 hr
Ripple Rejection	f = 120 Hz		52		dB
Dropout Voltage	T_j = 25°C, I_{OUT} = 1.0A		2		V

LM340-15 (V_{IN} = 23V, I_{OUT} = 500 mA, $0°C \leq T_A \leq 70°C$, unless otherwise specified)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	14.4	15	15.6	V
Line Regulation	T_j = 25°C, $17.5V \leq V_{IN} \leq 30V$				
	I_{OUT} = 100 mA			150	mV
	I_{OUT} = 500 mA			300	mV
Load Regulation	T_j = 25°C, $5 mA \leq I_{OUT} \leq 1.5A$			300	mV
Output Voltage	$17.5V \leq V_{IN} \leq 30V$, $5 mA \leq I_{OUT} \leq 1.0A$ $P_D \leq 15W$	14.25		15.75	V
Quiescent Current	T_j = 25°C		7	10	mA
Quiescent Current Change	$17.5V \leq V_{IN} \leq 30V$			1	mA
	$5 mA \leq I_{OUT} \leq 1.5A$			.5	mA
Output Noise Voltage	T_A = 25°C, $10 Hz \leq f \leq 100 kHz$		90		µV
Long Term Stability				60	mV/1000 hr
Ripple Rejection	f = 120 Hz		50		dB
Dropout Voltage	T_j = 25°C, I_{OUT} = 1.0A		2		V

electrical characteristics (con't)

LM340-18 (V_{IN} = 27V, I_{OUT} = 500 mA, 0°C ≤ T_A ≤ 70°C, unless otherwise specified)

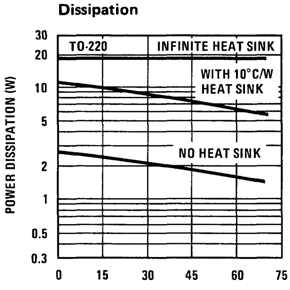
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	17.3	18	18.7	V
Line Regulation	T_j = 25°C, 21V ≤ V_{IN} ≤ 33V				
	I_{OUT} = 100 mA			180	mV
	I_{OUT} = 500 mA			360	mV
Load Regulation	T_j = 25°C, 5 mA ≤ I_{OUT} ≤ 1.0A			360	mV
Output Voltage	21V ≤ V_{IN} ≤ 33V, 5 mA ≤ I_{OUT} ≤ 1.0A P_D ≤ 15W	17.1		18.9	V
Quiescent Current	T_j = 25°C		7	10	mA
Quiescent Current Change	21V ≤ V_{IN} ≤ 33V			1	mA
	5 mA ≤ I_{OUT} ≤ 1.0A			.5	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz		110		μV
Long Term Stability				72	mV/1000 hr
Ripple Rejection	f = 120 Hz		48		dB
Dropout Voltage	T_j = 25°C, I_{OUT} = 1.0A		2		V

LM340-24 (V_{IN} = 33V, I_{OUT} = 500 mA, 0°C ≤ T_A ≤ 70°C, unless otherwise specified)

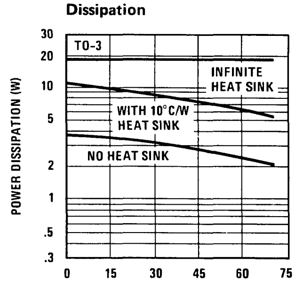
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	23	24	25	V
Line Regulation	T_j = 25°C, 27V ≤ V_{IN} ≤ 38V				
	I_{OUT} = 100 mA			240	mV
	I_{OUT} = 500 mA			480	mV
Load Regulation	T_j = 25°C, 5 mA ≤ I_{OUT} ≤ 1.0A			480	mV
Output Voltage	27V ≤ V_{IN} ≤ 38V, 5 mA ≤ I_{OUT} ≤ 1.0A P_D ≤ 15W	22.8		25.2	V
Quiescent Current	T_j = 25°C		7	10	mA
Quiescent Current Change	27V ≤ V_{IN} ≤ 38V			1	mA
	5 mA ≤ I_{OUT} ≤ 1.0A			.5	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz		170		μV
Long Term Stability				96	mV/1000 hr
Ripple Rejection	f = 120 Hz		44		dB
Dropout Voltage	T_j = 25°C, I_{OUT} = 1.0A		2		V

typical performance characteristics

Maximum Average Power Dissipation

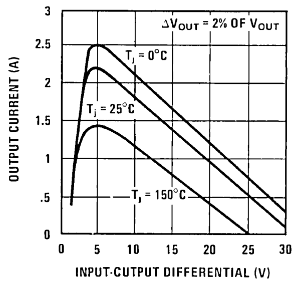


Maximum Average Power Dissipation

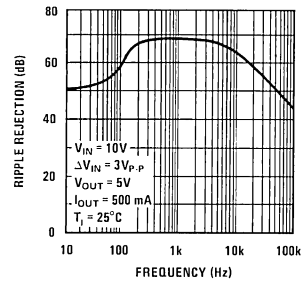


typical performance characteristics (con't)

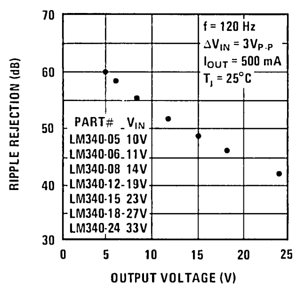
Peak Output Current



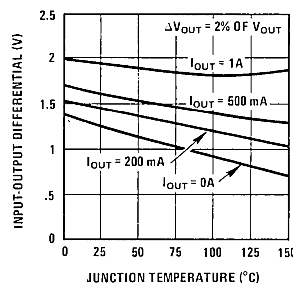
Ripple Rejection



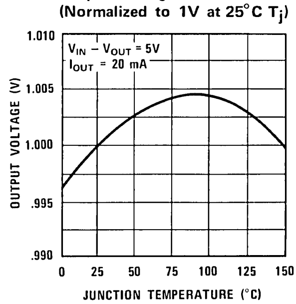
Ripple Rejection



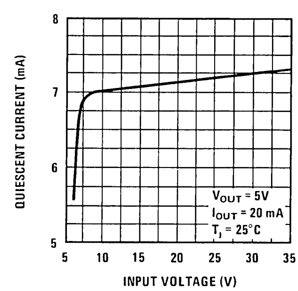
Dropout Voltage



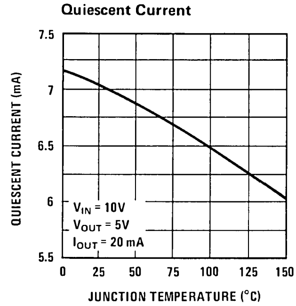
Output Voltage (Normalized to 1V at 25°C Tj)



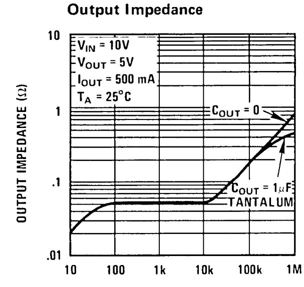
Quiescent Current



Quiescent Current

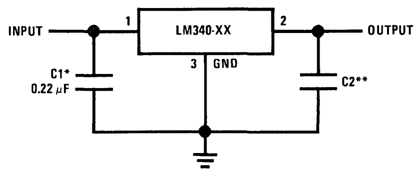


Output Impedance



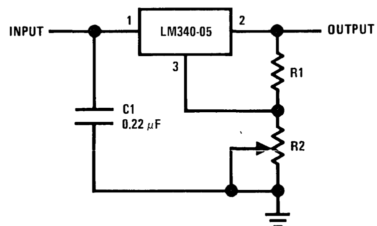
typical applications

Fixed Output Regulator



*REQUIRED IF THE REGULATOR IS LOCATED FAR FROM THE POWER SUPPLY FILTER.
**ALTHOUGH NO OUTPUT CAPACITOR IS NEEDED FOR STABILITY, IT DOES HELP TRANSIENT RESPONSE. (IF NEEDED USE 0.1μF, CERAMIC, DISC.)

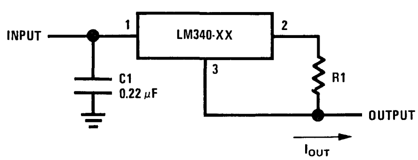
Adjustable Output Regulator



$V_{OUT} = 5V + (5V/R1 + I_Q)\ R2$

$5V/R1 > 3\ I_Q$, LOAD REGULATION $(L_r) \approx [(R1 + R2)/R1]\ (L_r$ OF LM340-05)

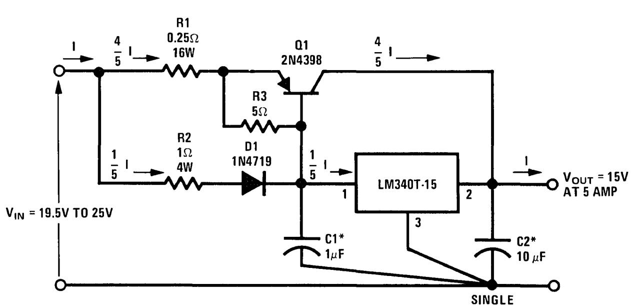
Current Regulator



$I_{OUT} = \frac{V_{2\text{-}3}}{R_1} + I_Q$

$\Delta I_Q = 1.5$ mA over line and load changes

15V 5 Amp Regulator With Short Circuit Current Limit



LOAD REGULATION: 1.1% FOR $0 \le I_{OUT} \le 5A$ PULSED WITH 50 ms t_{ON}.

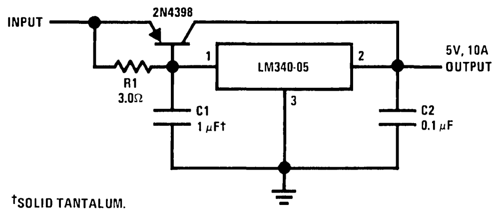
*SOLID TANTALUM.

NOTE 1: CURRENT SHARING BETWEEN THE LM340 and Q1 ALLOWS THE EXTENSION OF SHORT CIRCUIT CURRENT LIMIT, SAFE OPERATING AREA PROTECTION, AND (ASSUMING Q1'S Θ_{JA} IS ONE FORTH THE LM340'S Θ_{JA}) THERMAL SHUTDOWN PROTECTION.

NOTE 2: FOR OPTIMUM CURRENT SHARING OVER TEMPERATURE D1 SHOULD BE MOUNTED TO THE SAME HEAT SINK AS Q1 SO THAT ITS JUNCTION TEMPERATURE TRACKS THAT OF Q1.

typical applications (con't)

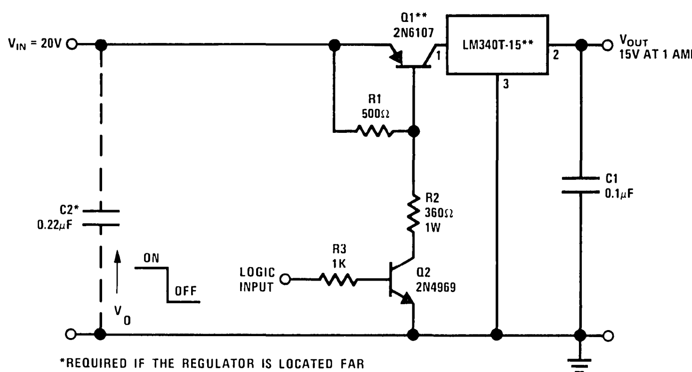
High Current Voltage Regulator



$T_A = 25°C$
@ V_{IN} 10V, 0A ≤ I_L ≤ 10A
Load Regulation = 2 mV
@ I_L = 10A, 9V ≤ V_{IN} ≤ 12V
Line Regulation = 20 mV

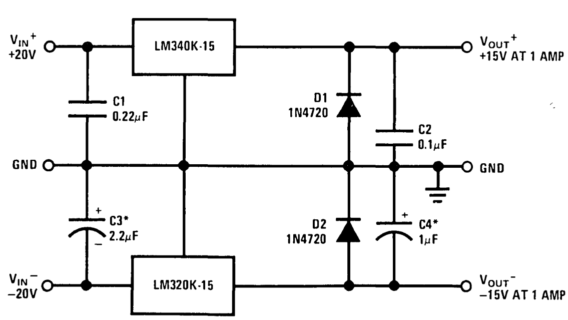
†SOLID TANTALUM.
NOTE: PASS TRANSISTOR NOT SHORT CIRCUIT PROTECTED.

Electronic Shutdown Circuit



*REQUIRED IF THE REGULATOR IS LOCATED FAR FROM THE POWER SUPPLY FILTER
**HEAT SINK Q1 AND THE LM340

Dual Power Supply



*SOLID TANTALUM.
NOTE 1: IF THE START UP COMMON LOAD IS MORE THAN 600 mA, REPLACE D1 WITH AN EQUIVALENT GERMANIUM DIODE.

Voltage Regulators

LM341 series three terminal positive regulators

general description

The LM341-XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. One of these is local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and currents.

The LM341-XX series is available in the plastic TO-202 package. This package allows these regulators to deliver over 0.5A if adequate heat sinking is provided. Even with over 0.5A of output current available the regulators are essentially blow-out proof. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistor is provided to limit internal power dissipation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating.

Considerable effort was expended to make the LM341-XX series of regulators easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply.

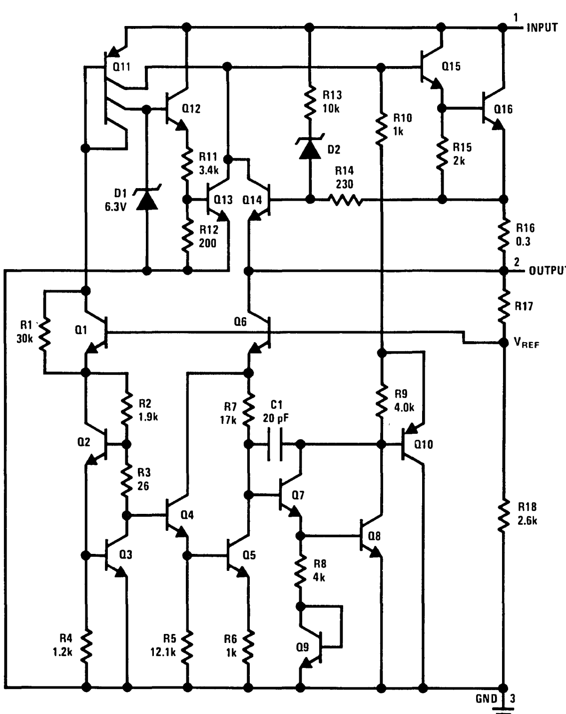
features

- Output current in excess of 0.5A
- Internal thermal overload protection
- No external components required
- Output transistor safe area protection
- Internal short circuit current limit
- Available in plastic TO-202 package

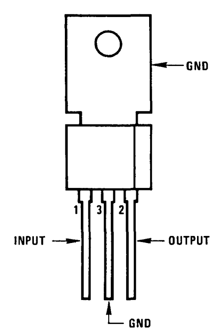
voltage range

LM341-5.0	5V	LM341-15	15V
LM341-6.0	6V	LM341-18	18V
LM341-8.0	8V	LM341-24	24V
LM341-12	12V		

schematic and connection diagrams



TO-202 (P)



FRONT VIEW

Order Numbers

LM341P-5.0	LM341P-15
LM341P-6.0	LM341P-18
LM341P-8.0	LM341P-24
LM341P-12	

See Package 37

absolute maximum ratings

Input Voltage	
(V_O = 5V through 18V)	35V
(V_O = 24V)	40V
Internal Power Dissipation (Note 1)	Internally Limited
Operating Temperature Range	0°C to +70°C
Maximum Junction Temperature	+150°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	+230°C

electrical characteristics

LM341-5.0 (V_{IN} = 10V, I_{OUT} = 500 mA, 0°C $\leq T_A \leq$ +70°C, unless otherwise specified)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	4.8	5	5.2	V
Line Regulation	T_j = 25°C, 7.2V $\leq V_{IN} \leq$ 25V				
	I_{OUT} = 500 mA			100	mV
	I_{OUT} = 100 mA			50	mV
Load Regulation	T_j = 25°C, 5 mA $\leq I_{OUT} \leq$ 0.5A			100	mV
Output Voltage	7.5V $\leq V_{IN} \leq$ 20V, 5 mA $\leq I_{OUT} \leq$ 0.5A, $P_D \leq$ 7.5W	4.75		5.25	V
Quiescent Current	T_j = 25°C		7	10	mA
Quiescent Current Change	T_j = 25°C, 7.5V $\leq V_{IN} \leq$ 25V			1	mA
	T_j = 25°C, 5 mA $\leq I_{OUT} \leq$ 0.5A			0.5	mA
Output Noise Voltage	T_A = 25°C, 10 Hz $\leq f \leq$ 100 kHz		40		µV
Long Term Stability				20	mV/1000 hr
Ripple Rejection	f = 120 Hz		60		dB
Dropout Voltage	T_j = 25°C, I_{OUT} = 0.5A		2		V

LM341-6.0 (V_{IN} = 11V, I_{OUT} = 500 mA, 0°C $\leq T_A \leq$ +70°C, unless otherwise specified)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	5.75	6	6.25	V
Line Regulation	T_j = 25°C, 8.3V $\leq V_{IN} \leq$ 25V				
	I_{OUT} = 500 mA			120	mV
	I_{OUT} = 100 mA			60	mV
Load Regulation	T_j = 25°C, 5 mA $\leq I_{OUT} \leq$ 0.5A			120	mV
Output Voltage	8.6V $\leq V_{IN} \leq$ 21V, 5 mA $\leq I_{OUT}$ 0.5A, $P_D \leq$ 7.5W	5.7		6.3	V
Quiescent Current	T_j = 25°C		7	10	mA
Quiescent Current Change	T_j = 25°C, 8.6V $\leq V_{IN} \leq$ 25V			1	mA
	T_j = 25°C, 5 mA $\leq I_{OUT} \leq$ 0.5A			0.5	mA
Output Noise Voltage	T_A = 25°C, 10 Hz $\leq f \leq$ 100 kHz		45		µV
Long Term Stability				24	mV/1000 hr
Ripple Rejection	f = 120 Hz		57		dB
Dropout Voltage	T_j = 25°C, I_{OUT} = 0.5A		2		V

Note 1: Thermal resistance without a heat sink for junction to case temperature is 12°C/W for the TO-202 package. Thermal resistance for case to ambient temperature is 70°C/W for the TO-202 package.

electrical characteristics (con't)

LM341-8.0 (V_{IN} = 14V, I_{OUT} = 500 mA, $0°C \leq T_A \leq +70°C$, unless otherwise specified)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	7.7	8	8.3	V
Line Regulation	T_j = 25°C, 10.3V ≤ V_{IN} ≤ 25V				
	I_{OUT} = 500 mA			160	mV
	I_{OUT} = 100 mA			80	mV
Load Regulation	T_j = 25°C, 5 mA ≤ I_{OUT} ≤ 0.5A			160	mV
Output Voltage	10.6V ≤ V_{IN} ≤ 23V, 5 mA ≤ I_{OUT} ≤ 0.5A, P_D ≤ 7.5W	7.6		8.4	V
Quiescent Current	T_j = 25°C		7	10	mA
Quiescent Current Change	T_j = 25°C, 10.6V ≤ V_{IN} ≤ 25V			1	mA
	T_j = 25°C, 5 mA ≤ I_{OUT} ≤ 0.5A			0.5	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz		52		μV
Long Term Stability				32	mV/1000 hr
Ripple Rejection	f = 120 Hz		55		dB
Dropout Voltage	T_j = 25°C, I_{OUT} = 0.5A		2		V

LM341-12 (V_{IN} = 19V, I_{OUT} = 500 mA, $0°C \leq T_A \leq +70°C$, unless otherwise specified)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	11.5	12	12.5	V
Line Regulation	T_j = 25°C, 14.5V ≤ V_{IN} ≤ 30V				
	I_{OUT} = 500 mA			240	mV
	I_{OUT} = 100 mA			120	mV
Load Regulation	T_j = 25°C, 5 mA ≤ I_{OUT} ≤ 0.5A			240	mV
Output Voltage	14.8V ≤ V_{IN} ≤ 27V, 5 mA ≤ I_{OUT} ≤ 0.5A, P_D ≤ 7.5W	11.4		12.6	V
Quiescent Current	T_j = 25°C		7	10	mA
Quiescent Current Change	T_j = 25°C, 14.8V ≤ V_{IN} ≤ 30V			1	mA
	T_j = 25°C, 5 mA ≤ I_{OUT} ≤ 0.5A			0.5	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz		75		μV
Long Term Stability				48	mV/1000 hr
Ripple Rejection	f = 120 Hz		52		dB
Dropout Voltage	T_j = 25°C, I_{OUT} = 0.5A		2		V

LM341-15 (V_{IN} = 23V, I_{OUT} = 500 mA, $0°C \leq T_A \leq +70°C$, unless otherwise specified)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	14.4	15	15.6	V
Line Regulation	T_j = 25°C, 17.6V ≤ V_{IN} ≤ 30V				
	I_{OUT} = 500 mA			300	mV
	I_{OUT} = 100 mA			150	mV
Load Regulation	T_j = 25°C, 5 mA ≤ I_{OUT} ≤ 0.5A			300	mV
Output Voltage	18V ≤ V_{IN} ≤ 30V, 5 mA ≤ I_{OUT} ≤ 0.5A, P_D ≤ 7.5W	14.25		15.75	V
Quiescent Current	T_j = 25°C		7	10	mA
Quiescent Current Change	T_j = 25°C, 18V ≤ V_{IN} ≤ 30V			1	mA
	T_j = 25°C, 5 mA ≤ I_{OUT} ≤ 0.5A			0.5	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz		90		μV
Long Term Stability				60	mV/1000 hr
Ripple Rejection	f = 120 Hz		50		dB
Dropout Voltage	T_j = 25°C, I_{OUT} = 0.5A		2		V

electrical characteristics (con't)

LM341-18 (V_{IN} = 27V, I_{OUT} = 500 mA, $0°C \le T_A \le +70°C$, unless otherwise specified)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	17.3	18	18.7	V
Line Regulation	T_j = 25°C, 20.7V ≤ V_{IN} ≤ 33V				
	I_{OUT} = 500 mA			360	mV
	I_{OUT} = 100 mA			180	mV
Load Regulation	T_j = 25°C, 5 mA ≤ I_{OUT} ≤ 0.5A			360	mV
Output Voltage	21V ≤ V_{IN} ≤ 33V, 5 mA ≤ I_{OUT} ≤ 0.5A, P_D ≤ 7.5W	17.1		18.9	V
Quiescent Current	T_j = 25°C		7	10	mA
Quiescent Current Change	T_j = 25°C, 21V ≤ V_{IN} ≤ 33V			1	mA
	T_j = 25°C, 5 mA ≤ I_{OUT} ≤ 0.5A			0.5	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz		110		μV
Long Term Stability				72	mV/1000 hr
Ripple Rejection	f = 120 Hz		48		dB
Dropout Voltage	T_j = 25°C, I_{OUT} = 0.5A		2		V

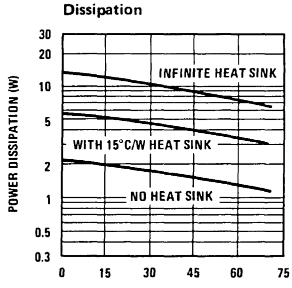
LM341-24 (V_{IN} = 33V, I_{OUT} = 500 mA, $0°C \le T_A \le +70°C$, unless otherwise specified)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	23	24	25	V
Line Regulation	T_j = 25°C, 27V ≤ V_{IN} ≤ 38V				
	I_{OUT} = 500 mA			480	mV
	I_{OUT} = 100 mA			240	mV
Load Regulation	T_j = 25°C, 5 mA ≤ I_{OUT} ≤ 0.5A			480	mV
Output Voltage	27.3 ≤ V_{IN} ≤ 38V, 5 mA ≤ I_{OUT} ≤ 0.5A, P_D ≤ 7.5W	22.8		25.2	V
Quiescent Current	T_j = 25°C		7	10	mA
Quiescent Current Change	T_j = 25°C, 27.3 ≤ V_{IN} ≤ 38V			1	mA
	T_j = 25°C, 5 mA ≤ I_{OUT} ≤ 0.5A			0.5	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz		170		μV
Long Term Stability				96	mV/1000 hr
Ripple Rejection	f = 120 Hz		44		dB
Dropout Voltage	T_j = 25°C, I_{OUT} = 0.5A		2		V

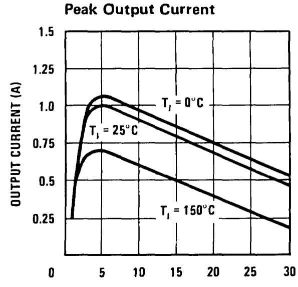
1

typical performance characteristics

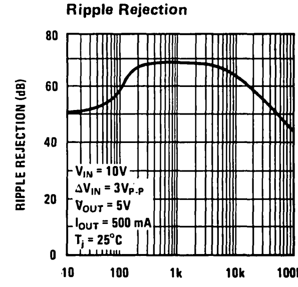
Maximum Average Power Dissipation



Peak Output Current

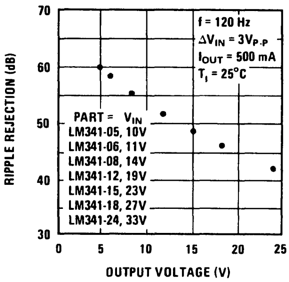


Ripple Rejection

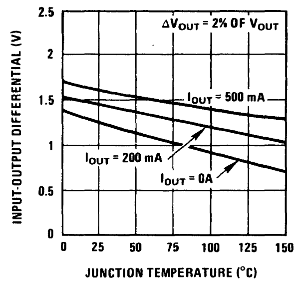


typical performance characteristics (con't)

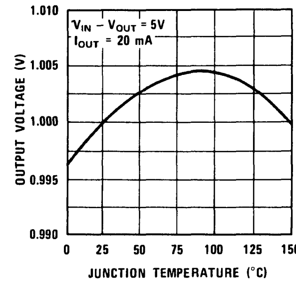
Ripple Rejection



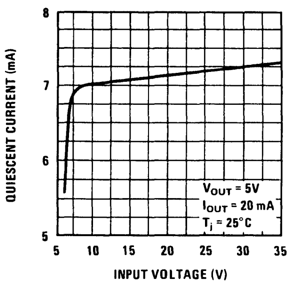
Dropout Voltage



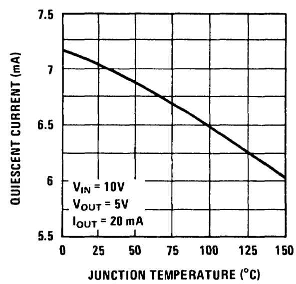
Output Voltage (Normalized to 1V at 25°C T_j)



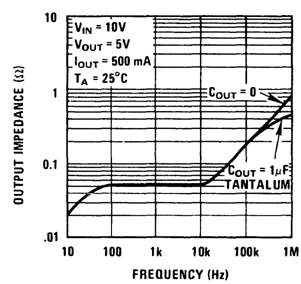
Quiescent Current



Quiescent Current

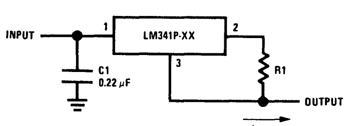


Output Impedance



typical applications

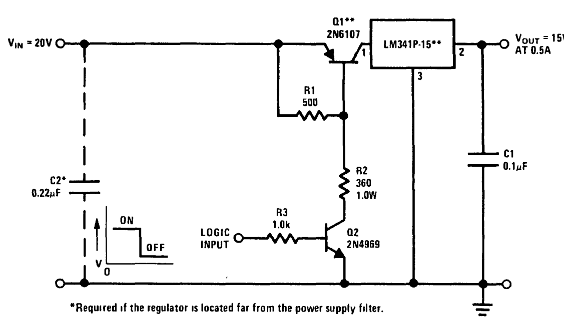
Current Regulator



$I_{OUT} = \frac{V_{23}}{R_1} + I_Q$

ΔI_Q = 1.5 mA over line and load changes

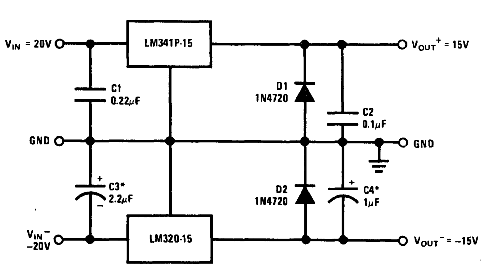
Electronic Shutdown Circuit



*Required if the regulator is located far from the power supply filter.

**Heat sink Q1 and the LM341.

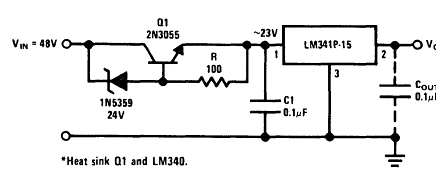
Dual Power Supply



*Solid tantalum.

Note 1: Diodes D1 and D2 assure regulator startup into a common load regardless of the input voltage startup sequence.

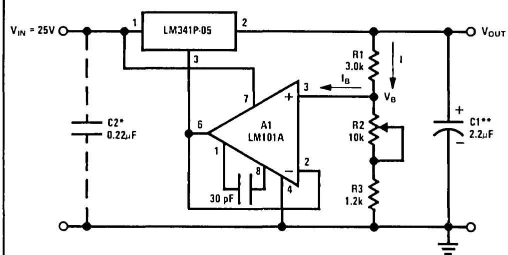
High Input Voltage Regulator



*Heat sink Q1 and LM340.

typical applications (con't)

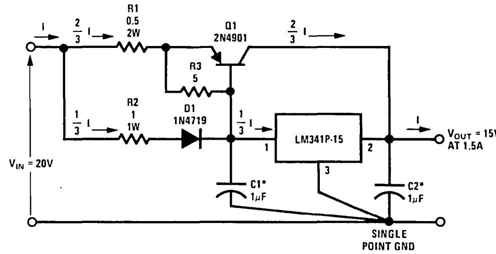
Variable Output Regulator



*Required if the regulator is located far from the power supply filter.

**Solid tantalum.

15V 1.5A Regulator with Short Circuit Current Limit



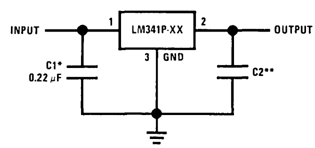
Load Regulation: 0.8% for $0 \leq I_{OUT} \leq 1.5A$ pulsed with 50 ms t_{ON}.

*Solid tantalum.

Note 1: Current sharing between the LM341 and Q1 allows the extension of short circuit current limit, safe operating area protection, and (assuming Q1's Θ_{JA} is one half the LM341's Θ_{JA}) thermal shutdown protection.

Note 2: For optimum current sharing over temperature D1 should be mounted to the same heat sink as Q1 so that its junction temperature tracks that of Q1.

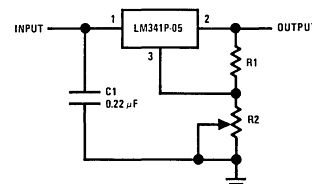
Fixed Output Regulator



*Required if the regulator is located far from the power supply filter.

**Although no output capacitor is needed for stability, it does help transient response. (If needed use 0.1μF, ceramic disc.)

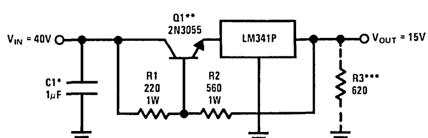
Adjustable Output Regulator



$V_{OUT} = 5V + (5V/R1 + I_Q)\ R2$

$5V/R1 > 3\ I_Q$, Load Regulation $(L_r) \approx [(R1 + R2)/R1]\ (L_r$ of LM341P-05)

High Voltage Short Circuit Protected Regulator



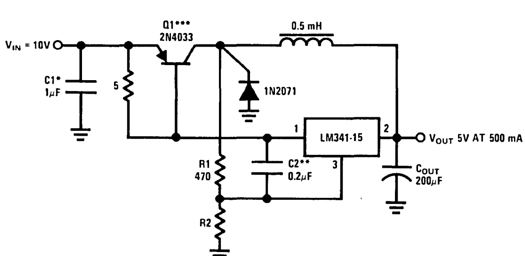
*Solid tantalum.

**Heat sink Q1.

***Since the LM341 will not sink current the regulator should have a minimum load to sink the standby current through R1 R2.

****An output short circuit will cause Q1 to drop the input voltage of the regulator and limit the regulator's power dissipation. The regulator will start again under load after removal of the short circuit.

Switching Regulator



*Solid tantalum.

**Needed for stability.

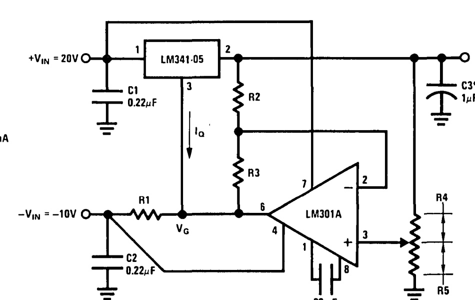
***Heat sink Q1.

$R2 = 0.5\Omega$, $f \simeq 45$ kHz, RIPPLE $\cong$ 17 mW

$R2 = 1\Omega$, $f \simeq 25$ kHz, RIPPLE $\simeq$ 35 mW

LOAD = 500 mA

Variable Output Regulator 0.5V – 18V



*Solid tantalum.

$V_{OUT} = V_G + 5V$, $R1 = (-V_{IN}/I_{Q\,LM341})$

$V_{OUT} = 5V\ (R2/R4)$ for $(R2 + R3) = (R4 + R5)$

A 0.5V output will correspond to $(R2/R4) = 0.1$, $(R3/R4) = 0.9$

Voltage Regulators

LM342 series three terminal positive regulators

general description

The LM342-XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. One of these is local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and currents.

The LM342-XX series is available in the plastic TO-202 package. This package allows these regulators to deliver over 0.2A if adequate heat sinking is provided. Even with over 0.2A of output current available the regulators are essentially blow-out proof. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistor is provided to limit internal power dissipation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating.

Considerable effort was expended to make the LM342-XX series of regulators easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply.

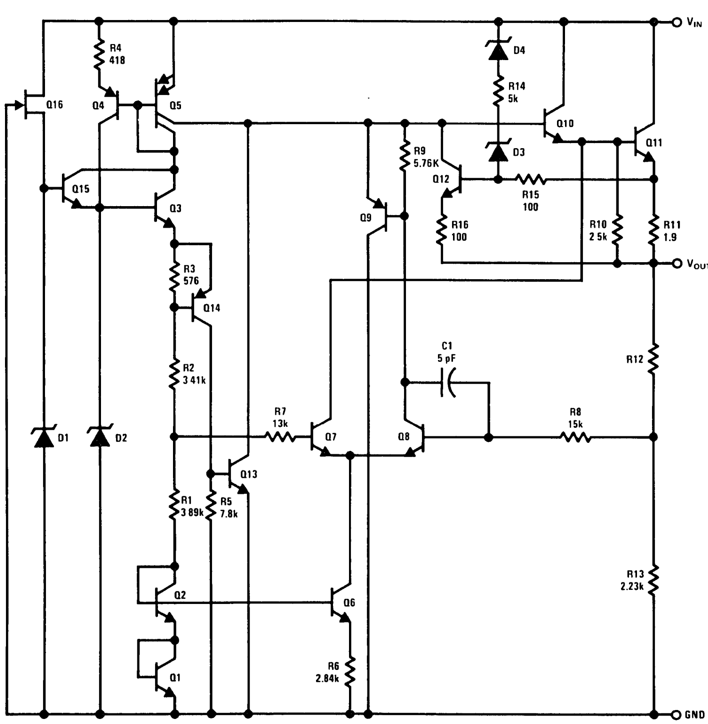
features

- Output current in excess of 0.2A
- Internal thermal overload protection
- No external components required
- Output transistor safe area protection
- Internal short circuit current limit
- Available in plastic TO-202 package

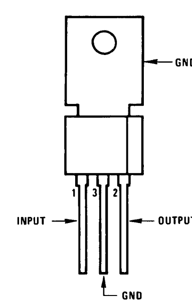
voltage range

LM342-5.0	5V	LM342-12	12V
LM342-6.0	6V	LM342-15	15V
LM342-8.0	8V	LM342-18	18V
LM342-10	10V	LM342-24	24V

schematic and connection diagrams



TO-202 (P)



FRONT VIEW

Order Numbers:

LM342P-5.0	LM342P-12
LM342P-6.0	LM343P-15
LM342P-8.0	LM342P-18
LM342P-10	LM342P-24

See Package 37

absolute maximum ratings

Input Voltage	
V_O = 5V to 8V	30V
V_O = 10V to 18V	35V
V_O = 24V	40V
Internal Power Dissipation (Note 1)	Internally Limited
Operating Temperature Range	0°C to +70°C
Maximum Junction Temperature	150°C
Storage Temperature Range	
Metal Can Package (H)	−65°C to +150°C
Molded TO-202 Package (P)	−55°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

LM342-5 V_{IN} = 10V, I_{OUT} = 200 mA, 0°C ≤ T_A ≤ 70°C, unless otherwise specified. (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	4.8	5.0	5.2	V
Line Regulation	T_j = 25°C, 7.5 ≤ V_{IN} ≤ 25V			100	mV
Load Regulation	T_j = 25°C, 1 mA ≤ I_{OUT} ≤ 200 mA			100	mV
Output Voltage	8V ≤ V_{IN} ≤ 20V, 1 mA ≤ I_{OUT} ≤ 200 mA	4.75		5.25	V
Quiescent Current	T_j = 25°C			6	mA
Quiescent Current Change	T_j = 25°C, 7.5V ≤ V_{IN} ≤ 25V T_j = 25°C, 1 mA ≤ I_{OUT} ≤ 200 mA			1.5 0.5	mA mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz		40		μV
Long Term Stability			20		mV/1000 hr
Ripple Rejection	f = 120 Hz	45	60		dB
Dropout Voltage	T_j = 25°C		2		V

LM342-6 V_{IN} = 11V, I_{OUT} = 200 mA, 0°C ≤ T_A ≤ 70°C, unless otherwise specified. (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	5.75	6	6.25	V
Line Regulation	T_j = 25°C, 8.5V ≤ V_{IN} ≤ 25V			120	mV
Load Regulation	T_j = 25°C, 1 mA ≤ I_{OUT} ≤ 200 mA			120	mV
Output Voltage	9V ≤ V_{IN} ≤ 21V, 1 mA ≤ I_{OUT} ≤ 200 mA	5.7		6.3	V
Quiescent Current	T_j = 25°C			6	mA
Quiescent Current Change	T_j = 25°C, 8.5V ≤ V_{IN} ≤ 25V T_j = 25°C, 1 mA ≤ I_{OUT} ≤ 200 mA			1.5 0.5	mA mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz		48		μV
Long Term Stability			24		mV/1000 hr
Ripple Rejection	f = 120 Hz	43	59		dB
Dropout Voltage	T_j = 25°C		2		V

Note 1: Thermal resistance of the Metal Can Package (H) without a heat sink is 40°C/W junction to case and 140°C/W junction to ambient. Thermal resistance of the TO-202 Package (P) without a heat sink is 12°C/W junction to case and 80°C/W junction to ambient.

Note 2: The maximum steady state usable output current and input voltage are very dependent on the heat sinking. The electrical characteristics data represent pulse test conditions with junction temperatures as shown at the initiation of tests.

electrical characteristics (con't)

LM342-8 V_{IN} = 14V, I_{OUT} = 200 mA, $0°C \leq T_A \leq 70°C$, unless otherwise specified. (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	7.7	8	8.3	V
Line Regulation	T_j = 25°C, $11V \leq V_{IN} \leq 25V$			160	mV
Load Regulation	T_j = 25°C, $1 mA \leq I_{OUT} \leq 200 mA$			160	mV
Output Voltage	$11.5V \leq V_{IN} \leq 23V$, $1 mA \leq I_{OUT} \leq 200 mA$	7.6		8.4	V
Quiescent Current	T_j = 25°C			6	mA
Quiescent Current Change	T_j = 25°C, $11V \leq V_{IN} \leq 25V$ T_j = 25°C, $1 mA \leq I_{OUT} \leq 200 mA$			1.5 0.5	mA mA
Output Noise Voltage	T_A = 25°C, $10 Hz \leq f \leq 10 kHz$		64		μV
Long Term Stability			32		mV/1000 hr
Ripple Rejection	f = 120 Hz	39	57		dB
Dropout Voltage	T_j = 25°C		2		V

LM342-10 V_{IN} = 16V, I_{OUT} = 200 mA, $0°C \leq T_A \leq 70°C$, unless otherwise specified. (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	9.6	10	10.4	V
Line Regulation	T_j = 25°C, $13V \leq V_{IN} \leq 25V$			200	mV
Load Regulation	T_j = 25°C, $1 mA \leq I_{OUT} \leq 200 mA$			200	mV
Output Voltage	$13.5V \leq V_{IN} \leq 25V$, $1 mA \leq I_{OUT} \leq 20 mA$	9.5		10.5	V
Quiescent Current	T_j = 25°C			6	mA
Quiescent Current Change	T_j = 25°C, $13V \leq V_{IN} \leq 25V$ T_j = 25°C, $1 mA \leq I_{OUT} \leq 200 mA$			1.5 0.5	mA mA
Output Noise Voltage	T_A = 25°C, $10 Hz \leq f \leq 10 kHz$		80		μV
Long Term Stability			40		mV/1000 hr
Ripple Rejection	f = 120 Hz	36	55		dB
Dropout Voltage	T_j = 25°C		2		V

LM342-12 V_{IN} = 19V, I_{OUT} = 200 mA, $0°C \leq T_A \leq 70°C$, unless otherwise specified. (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	11.5	12	12.5	V
Line Regulation	T_j = 25°C, $15V \leq V_{IN} \leq 30V$			240	mV
Load Regulation	T_j = 25°C, $1 mA \leq I_{OUT} \leq 200 mA$			240	mV
Output Voltage	$15.5V \leq V_{IN} \leq 27V$, $1 mA \leq I_{OUT} \leq 200 mA$	11.4		12.6	V
Quiescent Current	T_j = 25°C			6	mA
Quiescent Current Change	T_j = 25°C, $15V \leq V_{IN} \leq 30V$ T_j = 25°C, $1 mA \leq I_{OUT} \leq 200 mA$			1.5 0.5	mA mA
Output Noise Voltage	T_A = 25°C, $10 Hz \leq f \leq 10 kHz$		96		μV
Long Term Stability			48		mV/1000 hr
Ripple Rejection	f = 120 Hz	36	54		dB
Dropout Voltage	T_j = 25°C		2		V

electrical characteristics (con't)

LM342-15 V_{IN} = 23V, I_{OUT} = 200 mA, 0°C ≤ T_A ≤ 70°C, unless otherwise specified. (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	14.4	15	15.6	V
Line Regulation	T_j = 25°C, 18V ≤ V_{IN} ≤ 30V			300	mV
Load Regulation	T_j = 25°C, 1 mA ≤ I_{OUT} ≤ 200 mA			300	mV
Output Voltage	18.5V ≤ V_{IN} ≤ 30V, 1 mA ≤ I_{OUT} ≤ 200 mA	14.25		15.75	V
Quiescent Current	T_j = 25°C			6	mA
Quiescent Current Change	T_j = 25°C, 18V ≤ V_{IN} ≤ 30V T_j = 25°C, 1 mA ≤ I_{OUT} ≤ 200 mA			1.5 0.5	mA mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz		120		μV
Long Term Stability			60		mV/1000 hr
Ripple Rejection	f = 120 Hz	32	51		dB
Dropout Voltage	T_j = 25°C		2		V

LM342-18 V_{IN} = 27V, I_{OUT} = 200 mA, 0°C ≤ T_A ≤ 70°C, unless otherwise specified. (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	17.3	18	18.7	V
Line Regulation	T_j = 25°C, 21V ≤ V_{IN} ≤ 33V			360	mV
Load Regulation	T_j = 25°C, 1 mA ≤ I_{OUT} ≤ 200 mA			360	mV
Output Voltage	22V ≤ V_{IN} ≤ 33V, 1 mA ≤ I_{OUT} ≤ 200 mA	17.1		18.9	V
Quiescent Current	T_j = 25°C			6	mA
Quiescent Current Change	T_j = 25°C, 21 ≤ V_{IN} ≤ 33V T_j = 25°C, 1 mA ≤ I_{OUT} ≤ 200 mA			1.5 0.5	mA mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz		150		μV
Long Term Stability			72		mV/1000 hr
Ripple Rejection	f = 120 Hz	31	48		dB
Dropout Voltage	T_j = 25°C		2		V

LM342-24 V_{IN} = 33, I_{OUT} = 200 mA, 0°C ≤ T_A ≤ 70°C, unless otherwise specified. (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_j = 25°C	23	24	25	V
Line Regulation	T_j = 25°C, 27.2V ≤ V_{IN} ≤ 38V			480	mV
Load Regulation	T_j = 25°C, 1 mA ≤ I_{OUT} ≤ 200 mA			480	mV
Output Voltage	28V ≤ V_{IN} ≤ 38V, 1 mA ≤ I_{OUT} ≤ 200 mA	22.8		25.2	V
Quiescent Current	T_j = 25°C			6	mA
Quiescent Current Change	T_j = 25°C, 27.2V ≤ V_{IN} ≤ 38V T_j = 25°C, 1 mA ≤ f ≤ 200 mA			1.5 0.5	mA mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz		190		μV
Long Term Stability			96		mV/1000 hr
Ripple Rejection	f = 120 Hz	27	45		dB
Dropout Voltage	T_j = 25°C		2		V

Voltage Regulators

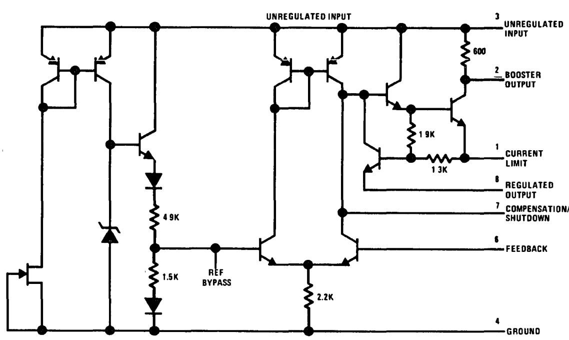
LM376 voltage regulator

general description

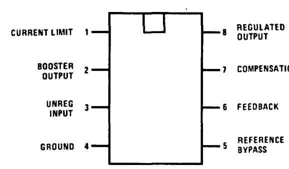
The LM376 is a positive voltage regulator designed primarily for commercial product applications. The device is especially useful because it is packaged in an 8-pin mini-DIP which has the advantage of reduced size and low cost. Used independently, the device will supply 25 mA; but with the addition of external pass elements any desired load current can be achieved. The circuit features extremely low standby current drain, and provision is made for either linear or foldback current limiting. Important characteristics of the LM376 are:

- Output voltage range +5V to 37V
- Output current 25 mA
- Load regulation 0.2%
- Line regulation 0.03%/V

simplified schematic and connection diagrams



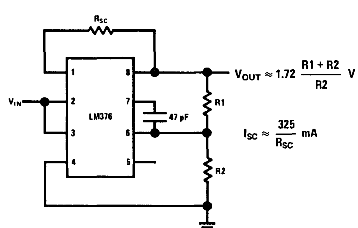
Dual-In-Line Package



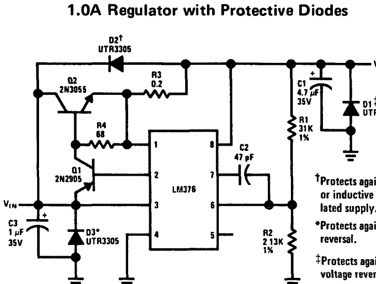
Order Number LM376N
See Package 20

typical applications

Basic Positive Regulator with Current Limiting



1.0A Regulator with Protective Diodes

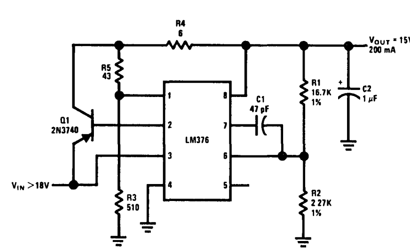


†Protects against shorted input or inductive loads on unregulated supply.

*Protects against input voltage reversal.

‡Protects against output voltage reversal.

Linear Regulator with Foldback Current Limiting



absolute maximum ratings

Input Voltage	40V
Input-Output Voltage Differential	40V
Power Dissipation (Note 1)	400 mW
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 2)

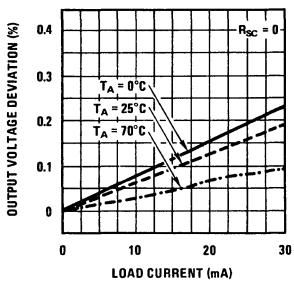
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range		9.0		40	V
Output Voltage Range		5.0		37	V
Output-Input Voltage Differential		3.0		30	V
Load Regulation	$0 \leq I_O \leq 25$ mA				
	$R_{SC} = 0\Omega$, $T_A = 25°C$			0.2	%
	$R_{SC} = 0\Omega$, $T_A = 70°C$			0.5	%
	$R_{SC} = 0\Omega$, $T_A = 0°C$			0.5	%
Line Regulation	$T_A = 25°C$			.03	%/V
				.1	%/V
Ripple Rejection	f = 120 Hz, $T_A = 25°C$			0.1	%/V
Standby Current Drain	$V_{IN} = 30V$, $T_A = 25°C$			2.5	mA
Reference Voltage		1.60	1.72	1.80	V
Current Limit Sense Voltage			.360		V

Note 1: For operating at elevated temperatures, the device must be derated based on a 100°C maximum junction temperature and a thermal resistance of 187°C/W junction to ambient.

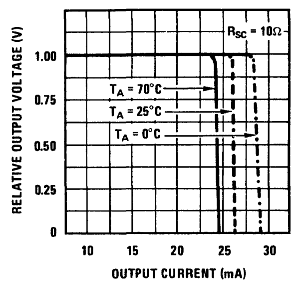
Note 2: These specifications apply for an operating temperature between 0°C and 70°.

typical performance characteristics

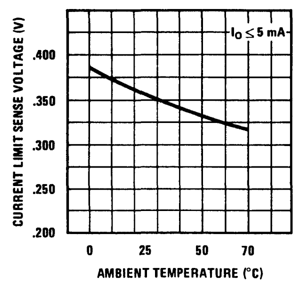
Load Regulation



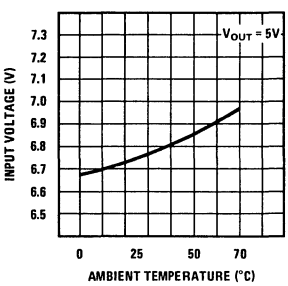
Current Limiting Characteristics



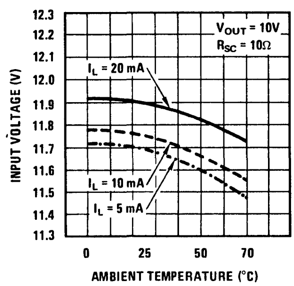
Current Limit Sense Voltage



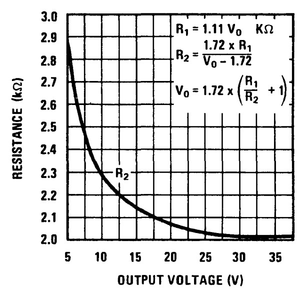
Minimum Input Voltage



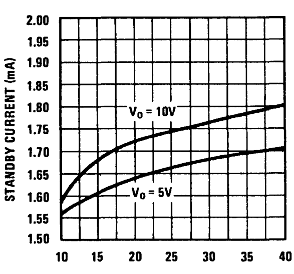
Regulator Dropout Voltage



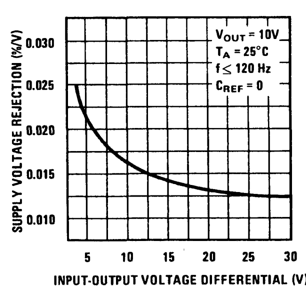
Optimum Divider Resistance



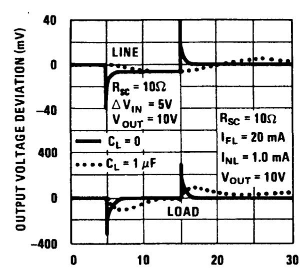
Standby Current Drain
$T_A = 25°C$



Supply Voltage Rejection



Transient Response



Voltage Regulators

LM723/LM723C voltage regulator

general description

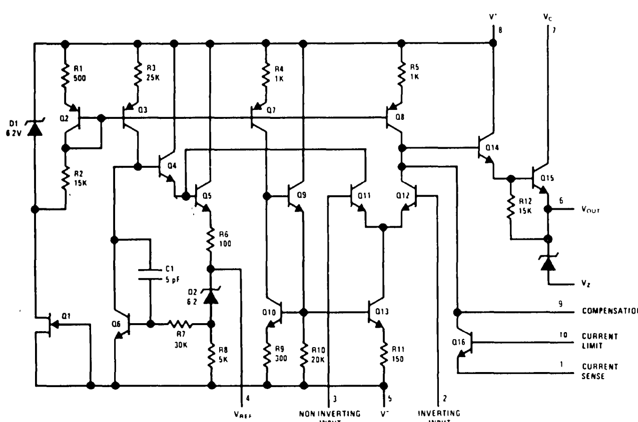
The LM723/LM723C is a voltage regulator designed primarily for series regulator applications. By itself, it will supply output currents up to 150 mA; but external transistors can be added to provide any desired load current. The circuit features extremely low standby current drain, and provision is made for either linear or foldback current limiting. Important characteristics are:

- 150 mA output current without external pass transistor
- Output currents in excess of 10A possible by adding external transistors
- Input voltage 40V max
- Output voltage adjustable from 2V to 37V
- Can be used as either a linear or a switching regulator.

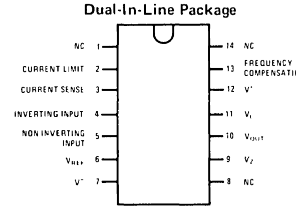
The LM723/LM723C is also useful in a wide range of other applications such as a shunt regulator, a current regulator or a temperature controller.

The LM723C is identical to the LM723 except that the LM723C has its performance guaranteed over a 0°C to 70°C temperature range, instead of −55°C to +125°C.

schematic and connection diagrams*



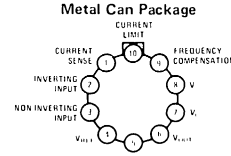
Dual-In-Line Package



Order Number LM 723D or LM723CD
See Package 1

Order Number LM723N or LM723CN
See Package 22

Metal Can Package

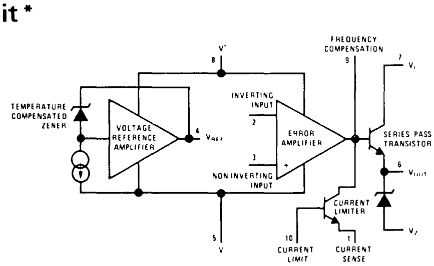


Note: Pin 5 connected to case.

TOP VIEW

Order Number LM723H or LM723CH
See Package 13

equivalent circuit*



*Pin numbers to metal can package only Note 7.

absolute maximum ratings

Pulse Voltage from V^+ to V^- (50 ms)	50V
Continuous Voltage from V^+ to V^-	40V
Input-Output Voltage Differential	40V
Maximum Amplifier Input Voltage (Either Input)	7.5V
Maximum Amplifier Input Voltage (Differential)	5V
Current from V_Z	25 mA
Current from V_{REF}	15 mA
Internal Power Dissipation Metal Can (Note 1)	800 mW
Cavity DIP (Note 1)	900 mW
Molded DIP (Note 1)	660 mW
Operating Temperature Range LM723	-55°C to +125°C
LM723C	0°C to +70°C
Storage Temperature Range Metal Can	-65°C to +150°C
DIP	-55°C to +125°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	LM723			LM723C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Line Regulation	V_{IN} = 12V to V_{IN} = 15V		.01	0.1		.01	0.1	% V_{OUT}
	-55°C ≤ T_A ≤ +125°C			0.3				% V_{OUT}
	0°C ≤ T_A ≤ +70°C						0.3	% V_{OUT}
	V_{IN} = 12V to V_{IN} = 40V		.02	0.2		0.1	0.5	% V_{OUT}
Load Regulation	I_L = 1 mA to I_L = 50 mA		.03	0.15		.03	0.2	% V_{OUT}
	-55°C ≤ T_A ≤ +125°C			0.6				%V $_{OUT}$
	0°C ≤ T_A ≤ = +70°C						0.6	%V $_{OUT}$
Ripple Rejection	f = 50 Hz to 10 kHz, C_{REF} = 0		74			74		dB
	f = 50 Hz to 10 kHz, C_{REF} = 5 μF		86			86		dB
Average Temperature Coefficient of Output Voltage	-55°C ≤ T_A ≤ +125°C		.002	.015				%/°C
	0°C ≤ T_A ≤ +70°C					.003	.015	%/°C
Short Circuit Current Limit	R_{SC} = 10Ω, V_{OUT} = 0		65			65		mA
Reference Voltage		6.95	7.15	7.35	6.80	7.15	7.50	V
Output Noise Voltage	BW = 100 Hz to 10 kHz, C_{REF} = 0		20			20		μVrms
	BW = 100 Hz to 10 kHz, C_{REF} = 5 μF		2.5			2.5		μVrms
Long Term Stability			0.1			0.1		%/1000 hrs
Standby Current Drain	I_L = 0, V_{IN} = 30V		1.3	3.5		1.3	4.0	mA
Input Voltage Range		9.5		40	9.5		40	V
Output Voltage Range		2.0		37	2.0		37	V
Input-Output Voltage Differential		3.0		38	3.0		38	V

Note 1: See derating curves for maximum power rating above 25°C.

Note 2: Unless otherwise specified, T_A = 25°C, V_{IN} = V^+ = V_C = 12V, V^- = 0, V_{OUT} = 5V, I_L = 1 mA, R_{SC} = 0, C_1 = 100 pF, C_{REF} = 0 and divider impedance as seen by error amplifier ≤ 10 kΩ connected as shown in Figure 1. Line and load regulation specifications are given for the condition of constant chip temperature. Temperature drifts must be taken into account separately for high dissipation conditions.

Note 3: L_1 is 40 turns of No. 20 enameled copper wire wound on Ferroxcube P36/22-3B7 pot core or equivalent with 0.009 in. air gap.

Note 4: Figures in parentheses may be used if R1/R2 divider is placed on opposite input of error amp.

Note 5: Replace R1/R2 in figures with divider shown in Figure 13.

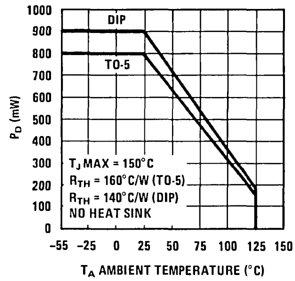
Note 6: V^+ must be connected to a +3V or greater supply.

Note 7: For metal can applications where V_Z is required, an external 6.2 volt zener diode should be connected in series with V_{OUT}.

maximum power ratings

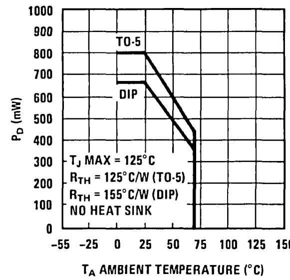
LM723

Power Dissipation vs Ambient Temperature



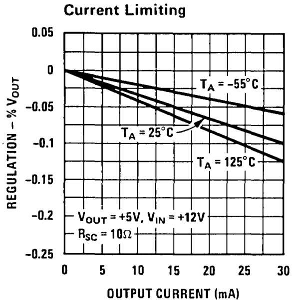
LM723C

Power Dissipation vs Ambient Temperature

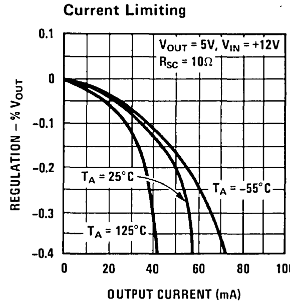


typical performance characteristics

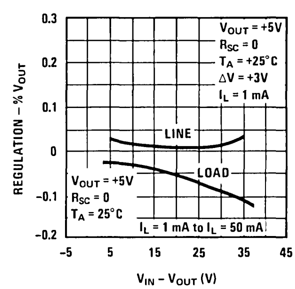
Load Regulation Characteristics with Current Limiting



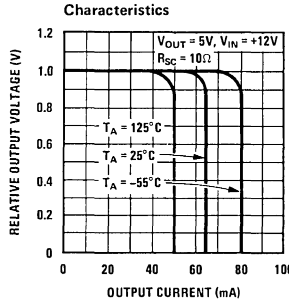
Load Regulation Characteristics with Current Limiting



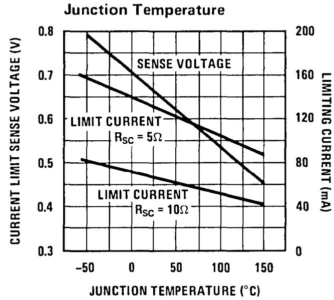
Load & Line Regulation vs Input-Output Voltage Differential



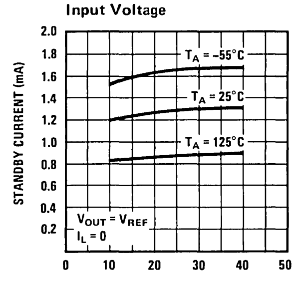
Current Limiting Characteristics



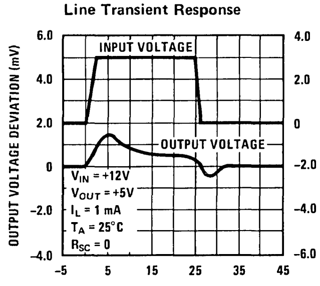
Current Limiting Characteristics vs Junction Temperature



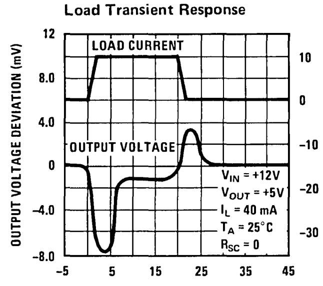
Standby Current Drain vs Input Voltage



Line Transient Response



Load Transient Response



Output Impedance vs Frequency

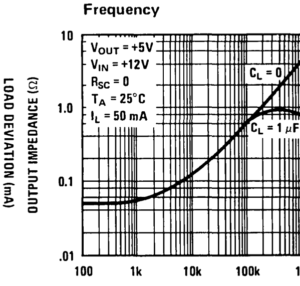


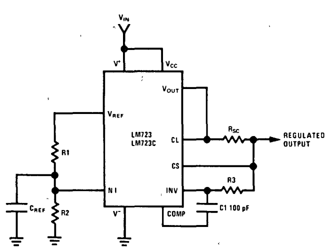
TABLE I RESISTOR VALUES (kΩ) FOR STANDARD OUTPUT VOLTAGE

POSITIVE OUTPUT VOLTAGE	APPLICABLE FIGURES	FIXED OUTPUT ±5%		OUTPUT ADJUSTABLE ±10% (Note 5)			NEGATIVE OUTPUT VOLTAGE	APPLICABLE FIGURES	FIXED OUTPUT ±5%		5% OUTPUT ADJUSTABLE ±10%		
	(Note 4)	R1	R2	R1	P1	R2			R1	R2	R1	P1	R2
+3.0	1, 5, 6, 9, 12 (4)	4.12	3.01	1.8	0.5	1.2	+100	7	3.57	102	2.2	10	91
+3.6	1, 5, 6, 9, 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, 12 (4)	2.15	4.99	.75	0.5	2.2	−6 (Note 6)	3, (10)	3.57	2.43	1.2	0.5	.75
+6.0	1, 5, 6, 9, 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, 12, 9)	1.87	7.15	.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	3.65	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	97.6	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 FORMULAE FOR INTERMEDIATE OUTPUT VOLTAGES

Outputs from +2 to +7 volts [Figures 1, 5, 6, 9, 12, (4)]	Outputs from +4 to +250 volts [Figure 7]	Current Limiting
$V_{OUT} = [V_{REF} \times \frac{R2}{R1 + R2}]$	$V_{OUT} = [\frac{V_{REF}}{2} \times \frac{R2 - R1}{R1}]$; R3 = R4	$I_{LIMIT} = \frac{V_{SENSE}}{R_{SC}}$
Outputs from +7 to +37 volts [Figures 2, 4, (5, 6, 9, 12)]	**Outputs from −6 to −250 volts** [Figures 3, 8, 10]	**Foldback Current Limiting**
$V_{OUT} = [V_{REF} \times \frac{R1 + R2}{R2}]$	$V_{OUT} = [\frac{V_{REF}}{2} \times \frac{R1 + R2}{R1}]$; R3 = R4	$I_{KNEE} = [\frac{V_{OUT} R3}{R_{SC} R4} + \frac{V_{SENSE}(R3 + R4)}{R_{SC} R4}]$ $I_{SHORT\,CKT} = [\frac{V_{SENSE}}{R_{SC}} \times \frac{R3 + R4}{R4}]$

typical applications

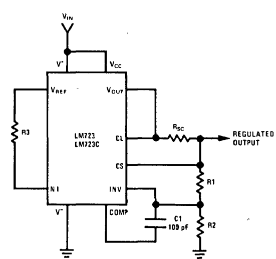


Note: $R3 = \frac{R1\,R2}{R1 + R2}$ for minimum temperature drift.

TYPICAL PERFORMANCE

Regulated Output Voltage	5V
Line Regulation (ΔV_{IN} = 3V)	0.5 mV
Load Regulation (ΔI_L = 50 mA)	1.5 mV

FIGURE 1. Basic Low Voltage Regulator (V_{OUT} = 2 to 7 Volts)

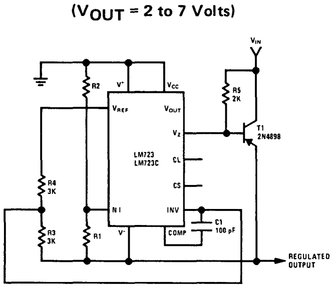


Note: $R3 = \frac{R1\,R2}{R1 + R2}$ for minimum temperature drift.
R3 may be eliminated for minimum component count.

TYPICAL PERFORMANCE

Regulated Output Voltage	15V
Line Regulation (ΔV_{IN} = 3V)	1.5 mV
Load Regulation (ΔI_L = 50 mA)	4.5 mV

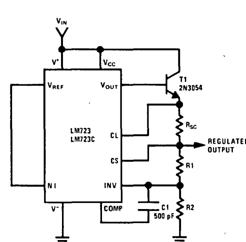
FIGURE 2. Basic High Voltage Regulator (V_{OUT} = 7 to 37 Volts)



TYPICAL PERFORMANCE

Regulated Output Voltage	−15V
Line Regulation (ΔV_{IN} = 3V)	1 mV
Load Regulation (ΔI_L = 100 mA)	2 mV

FIGURE 3. Negative Voltage Regulator

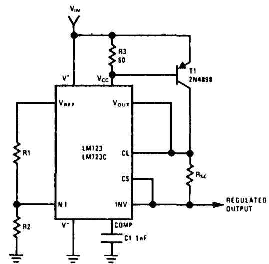


TYPICAL PERFORMANCE

Regulated Output Voltage	+15V
Line Regulation (ΔV_{IN} = 3V)	1.5 mV
Load Regulation (ΔI_L = 1A)	15 mV

FIGURE 4. Positive Voltage Regulator (External NPN Pass Transistor)

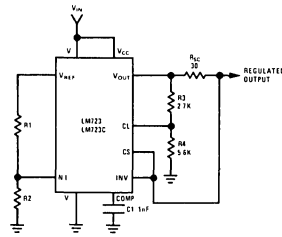
typical applications(con't.)



TYPICAL PERFORMANCE

Regulated Output Voltage	+5V
Line Regulation (ΔV_{IN} = 3V)	0.5 mV
Load Regulation (ΔI_L = 1A)	5 mV

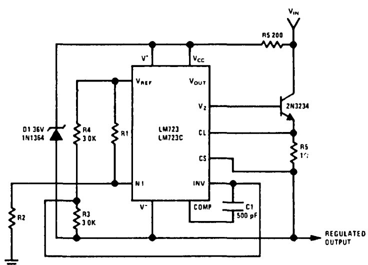
FIGURE 5. Positive Voltage Regulator (External PNP Pass Transistor)



TYPICAL PERFORMANCE

Regulated Output Voltage	+5V
Line Regulation (ΔV_{IN} = 3V)	0.5 mV
Load Regulation (ΔI_L = 10 mA)	1 mV
Short Circuit Current	20 mA

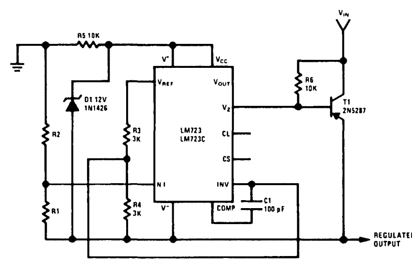
FIGURE 6. Foldback Current Limiting



TYPICAL PERFORMANCE

Regulated Output Voltage	+50V
Line Regulation (ΔV_{IN} = 20V)	15 mV
Load Regulation (ΔI_L = 50 mA)	20 mV

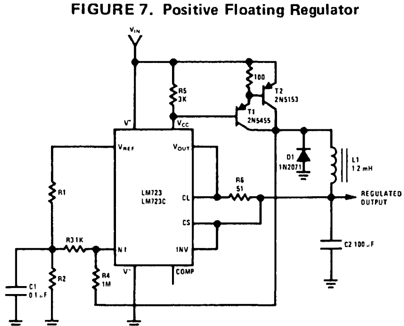
FIGURE 7. Positive Floating Regulator



TYPICAL PERFORMANCE

Regulated Output Voltage	-100V
Line Regulation (ΔV_{IN} = 20V)	30 mV
Load Regulation (ΔI_L = 100 mA)	20 mV

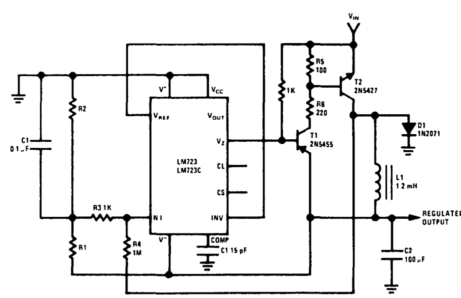
FIGURE 8. Negative Floating Regulator



TYPICAL PERFORMANCE

Regulated Output Voltage	+5V
Line Regulation (ΔV_{IN} = 30V)	10 mV
Load Regulation (ΔI_L = 2A)	80 mV

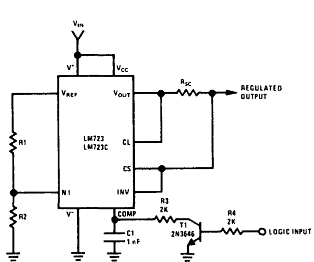
FIGURE 9. Positive Switching Regulator



TYPICAL PERFORMANCE

Regulated Output Voltage	-15V
Line Regulation (ΔV_{IN} = 20V)	8 mV
Load Regulation (ΔI_L = 2A)	6 mV

FIGURE 10. Negative Switching Regulator

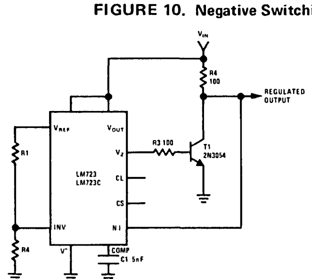


Note: Current limit transistor may be used for shutdown if current limiting is not required.

TYPICAL PERFORMANCE

Regulated Output Voltage	+5V
Line Regulation (ΔV_{IN} = 3V)	0.5 mV
Load Regulation (ΔI_L = 50 mA)	1.5 mV

FIGURE 11. Remote Shutdown Regulator with Current Limiting



TYPICAL PERFORMANCE

Regulated Output Voltage	+5V
Line Regulation (ΔV_{IN} = 10V)	0.5 mV
Load Regulation (ΔI_L = 100 mA)	1.5 mV

FIGURE 12. Shunt Regulator

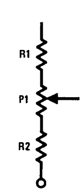


FIGURE 13. Output Voltage Adjust (See Note 5)

1

Voltage Regulators

LM78LXX series three terminal positive regulators

general description

The LM78LXX series of three terminal positive regulators is available with several fixed output voltages making them useful in a wide range of applications. When used as a zener diode/resistor combination replacement, the LM78LXX usually results in an effective output impedance improvement of two orders of magnitude, and lower quiescent current. These regulators can provide local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow the LM78LXX to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and currents.

The LM78LXX is available in the metal three lead TO-5 (H) and the plastic TO-92 (Z). With adequate heat sinking the regulator can deliver 100 mA output current. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistor is provided to limit internal power dissipation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating.

features

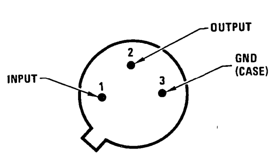
- Output voltage tolerances of ±5% (LM78LXXAC) and ±10% (LM78LXXC) over the temperature range
- Output current of 100 mA
- Internal thermal overload protection
- No external components required
- Output transistor safe area protection
- Internal short circuit current limit
- Available in plastic TO-92 and metal TO-39 low profile packages

voltage range

LM78L05	5V	LM78L15	15V
LM78L08	8V	LM78L18	18V
LM78L12	12V	LM78L24	24V

connection diagrams

TO-5 (H)



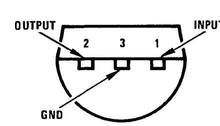
BOTTOM VIEW

Order Numbers:

LM78L05ACH	LM78L05CH
LM78L08ACH	LM78L08CH
LM78L12ACH	LM78L12CH
LM78L15ACH	LM78L15CH
LM78L18ACH	LM78L18CH
LM78L24ACH	LM78L24CH

See Package 9

TO-92 (Z)



BOTTOM VIEW

Order Numbers:

LM78L05ACZ	LM78L05CZ
LM78L08ACZ	LM78L08CZ
LM78L12ACZ	LM78L12CZ
LM78L15ACZ	LM78L15CZ
LM78L18ACZ	LM78L18CZ
LM78L24ACZ	LM78L24CZ

See Package 38

absolute maximum ratings

Input Voltage	V_O = 5V to 8V	30V
	V_O = 12V to 18V	35V
	V_O = 24V	40V
Internal Power Dissipation (Note 1)		Internally Limited
Operating Temperature Range		0°C to +70°C

Maximum Junction Temperature	+150°C
Storage Temperature Range	
Metal Can (H Package)	−65°C to +150°C
Molded TO-92	−55°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 2)

LM78L05AC V_{IN} = 10V, I_{OUT} = 40 mA, $0°C \le T_J \le 125°C$, C_{IN} = 0.33μF, C_{OUT} = 0.1μF, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_J = 25°C	4.8	5.0	5.2	V
Line Regulation	T_J = 25°C, $7V \le V_{IN} \le 20V$		18	150	mV
	T_J = 25°C, $8V \le V_{IN} \le 20V$		10	100	mV
Load Regulation	T_J = 25°C, $1\ mA \le I_{OUT} \le 100\ mA$		11	60	mV
	T_J = 25°C, $1\ mA \le I_{OUT} \le 40\ mA$		5.0	30	mV
Output Voltage	$7V \le V_{IN} \le 20V$, $1\ mA \le I_{OUT} \le 40\ mA$	4.75		5.25	V
	$1\ mA \le I_{OUT} \le 70\ mA$	4.75		5.25	V
Quiescent Current	T_J = 25°C		3.0	6.0	mA
	T_J = 125°C			5.5	mA
Quiescent Current Change					
With Line	$8V \le V_{IN} \le 20V$			1.5	mA
With Load	$1\ mA \le I_{OUT} \le 40\ mA$			0.1	mA
Output Noise Voltage	T_A = 25°C, $10\ Hz \le f \le 10\ kHz$ (Note 3)		40		μV
Long Term Stability			12		mV
Ripple Rejection	f = 120 Hz, $8V \le V_{IN} \le 18V$, T_J = 25°C	41	62		dB
Dropout Voltage	T_A = 25°C		1.7		V

LM78L05C V_{IN} = 10V, I_{OUT} = 40 mA, $0°C \le T_J \le 125°C$, C_{IN} = 0.33μF, C_{OUT} = 0.1μF, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_J = 25°C	4.6	5.0	5.4	V
Line Regulation	T_J = 25°C, $7V \le V_{IN} \le 20V$		18	200	mV
	T_J = 25°C, $8V \le V_{IN} \le 20V$		10	150	mV
Load Regulation	T_J = 25°C, $1\ mA \le I_{OUT} \le 100\ mA$		11	60	mV
	T_J = 25°C, $1\ mA \le I_{OUT} \le 40\ mA$		5.0	30	mV
Output Voltage	$7V \le V_{IN} \le 20V$, $1\ mA \le I_{OUT} \le 40\ mA$	4.5		5.5	V
	$1\ mA \le I_{OUT} \le 70\ mA$	4.5		5.5	V
Quiescent Current	T_J = 25°C		3.0	6.0	mA
	T_J = 125°C			5.5	mA
Quiescent Current Change					
With Line	$8V \le V_{IN} \le 20V$			1.5	mA
With Load	$1\ mA \le I_{OUT} \le 40\ mA$			0.2	mA
Output Noise Voltage	T_A = 25°C, $10\ Hz \le f \le 10\ kHz$ (Note 3)		40		μV
Long Term Stability			12		mV
Ripple Rejection	f = 120 Hz, $8V \le V_{IN} \le 18V$, T_J = 25°C	40	60		dB
Dropout Voltage	T_A = 25°C		1.7		V

Note 1: Thermal resistance of the Metal Can Package (H) without a heat sink is 40°C/W junction to case and 140°C/W junction to ambient. Thermal resistance of the TO-92 package is 180°C/W junction to ambient with 0.4 inch leads from a PC board and 160°C/W junction to ambient with 0.125 inch lead length to a PC board.

Note 2: The maximum steady state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The data above represent pulse test conditions with junction temperatures as indicated at the initiation of tests.

Note 3: It is recommended that a minimum load capacitor of 0.01μF be used to limit the high frequency noise bandwidth.

1

electrical characteristics (con't) (Note 2)

LM78L08AC V_{IN} = 14V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33μF, C_{OUT} = 0.1μF, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_J = 25°C	7.7	8	8.3	V
Line Regulation	T_J = 25°C, 10.5V ≤ V_{IN} ≤ 23V		20	175	mV
	T_J = 25°C, 11V ≤ V_{IN} ≤ 23V		12	125	mV
Load Regulation	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 100 mA		15	80	mV
	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 40 mA		8.0	40	mV
Output Voltage	10.5V ≤ V_{IN} ≤ 23V, 1 mA ≤ I_{OUT} ≤ 40 mA	7.6		8.4	V
	1 mA ≤ I_{OUT} ≤ 70 mA	7.6		8.4	V
Quiescent Current	T_J = 25°C		3.0	6.0	mA
	T_J = 125°C			5.5	mA
Quiescent Current Change					
With Line	11V ≤ V_{IN} ≤ 23V			1.5	mA
With Load	1 mA ≤ I_{OUT} ≤ 40 mA			0.1	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz (Note 3)		60		μV
Long Term Stability			20		mV
Ripple Rejection	f = 120 Hz, 12V ≤ V_{IN} ≤ 23V, T_J = 25°C	37	57		dB
Dropout Voltage	T_A = 25°C		1.7		V

LM78L08C V_{IN} = 14V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33μF, C_{OUT} = 0.1μF, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_J = 25°C	7.36	8	8.64	V
Line Regulation	T_J = 25°C, 10.5V ≤ V_{IN} ≤ 23V		20	200	mV
	T_J = 25°C, 11V ≤ V_{IN} ≤ 23V		12	150	mV
Load Regulation	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 100 mA		15	80	mV
	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 40 mA		6.0	40	mV
Output Voltage	10.5V ≤ V_{IN} ≤ 23V, 1 mA ≤ I_{OUT} ≤ 40 mA	7.2		8.8	V
	1 mA ≤ I_{OUT} ≤ 70 mA	7.2		8.8	V
Quiescent Current	T_J = 25°C		3.0	6.0	mA
	T_J = 125°C			5.5	mA
Quiescent Current Change					
With Line	11V ≤ V_{IN} ≤ 23V			1.5	mA
With Load	1 mA ≤ I_{OUT} ≤ 40 mA			0.2	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz (Note 3)		60		μV
Long Term Stability			20		mV
Ripple Rejection	f = 120 Hz, 12V ≤ V_{IN} ≤ 23V, T_J = 25°C	36	55		dB
Dropout Voltage	T_A = 25°C		1.7		V

electrical characteristics (con't) (Note 2)

LM78L12AC V_{IN} = 19V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33μF, C_{OUT} = 0.1μF, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_J = 25°C	11.5	12	12.5	V
Line Regulation	T_J = 25°C, 14.5V ≤ V_{IN} ≤ 27V		30	250	mV
	T_J = 25°C, 16V ≤ V_{IN} ≤ 27V		20	200	mV
Load Regulation	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 100 mA		20	100	mV
	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 40 mA		10	50	mV
Output Voltage	14.5V ≤ V_{IN} ≤ 27V, 1 mA ≤ I_{OUT} ≤ 40 mA	11.4		12.6	V
	1 mA ≤ I_{OUT} ≤ 70 mA	11.4		12.6	V
Quiescent Current	T_J = 25°C		3.0	6.5	mA
	T_J = 125°C			6.0	mA
Quiescent Current Change					
With Line	16V ≤ V_{IN} ≤ 27V			1.5	mA
With Load	1 mA ≤ I_{OUT} ≤ 40 mA			0.1	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz (Note 3)		80		μV
Long Term Stability			24		mV
Ripple Rejection	f = 120 Hz, 15V ≤ V_{IN} ≤ 25V, T_J = 25°C	37	54		dB
Dropout Voltage	T_A = 25°C		1.7		V

LM78L12C V_{IN} = 19V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33μF, C_{OUT} = 0.1μF, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_J = 25°C	11.1	12	12.9	V
Line Regulation	T_J = 25°C, 14.5V ≤ V_{IN} ≤ 27V		30	250	mV
	T_J = 25°C, 16V ≤ V_{IN} ≤ 27V		20	200	mV
Load Regulation	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 100 mA		20	100	mV
	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 40 mA		10	50	mV
Output Voltage	14.5V ≤ V_{IN} ≤ 27V, 1 mA ≤ I_{OUT} ≤ 40 mA	10.8		13.2	V
	1 mA ≤ I_{OUT} ≤ 70 mA	10.8		13.2	V
Quiescent Current	T_J = 25°C		3.0	6.5	mA
	T_J = 125°C			6.0	mA
Quiescent Current Change					
With Line	16V ≤ V_{IN} ≤ 27V			1.5	mA
With Load	1 mA ≤ I_{OUT} ≤ 40 mA			0.2	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz (Note 3)		80		μV
Long Term Stability			24		mV
Ripple Rejection	f = 120 Hz, 15V ≤ V_{IN} ≤ 25V, T_J = 25°C	36	52		dB
Dropout Voltage	T_A = 25°C		1.7		V

electrical characteristics (con't) (Note 2)

LM78L15AC V_{IN} = 23V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33μF, C_{OUT} = 0.1μF, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_J = 25°C	14.4	15	15.6	V
Line Regulation	T_J = 25°C, 17.5V ≤ V_{IN} ≤ 30V		37	300	mV
	T_J = 25°C, 20V ≤ V_{IN} ≤ 30V		25	250	mV
Load Regulation	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 100 mA		25	150	mV
	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 40 mA		12	75	mV
Output Voltage	17.5V ≤ V_{IN} ≤ 30V, 1 mA ≤ I_{OUT} ≤ 40 mA	14.25		15.75	V
	1 mA ≤ I_{OUT} ≤ 70 mA	14.25		15.75	V
Quiescent Current	T_J = 25°C		3.1	6.5	mA
	T_J = 125°C			6.0	mA
Quiescent Current Change					
With Line	20V ≤ V_{IN} ≤ 30V			1.5	mA
With Load	1 mA ≤ I_{OUT} ≤ 40 mA			0.1	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz (Note 3)		90		μV
Long Term Stability			30		mV
Ripple Rejection	f = 120 Hz, 18.5V ≤ V_{IN} ≤ 28.5V, T_J = 25°C	34	51		dB
Dropout Voltage	T_A = 25°C		1.7		V

LM78L15C V_{IN} = 23V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33μF, C_{OUT} = 0.1μF, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_J = 25°C	13.8	15	16.2	V
Line Regulation	T_J = 25°C, 17.5V ≤ V_{IN} ≤ 30V		30	300	mV
	T_J = 25°C, 20V ≤ V_{IN} ≤ 30V		25	250	mV
Load Regulation	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 100 mA		25	150	mV
	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 40 mA		12	75	mV
Output Voltage	17.5V ≤ V_{IN} ≤ 30V, 1 mA ≤ I_{OUT} ≤ 40 mA	13.5		16.5	V
	1 mA ≤ I_{OUT} ≤ 70 mA	13.5		16.5	V
Quiescent Current	T_J = 25°C		3.1	6.5	mA
	T_J = 125°C			6.0	mA
Quiescent Current Change					
With Line	20V ≤ V_{IN} ≤ 30V			1.5	mA
With Load	1 mA ≤ I_{OUT} ≤ 40 mA			0.2	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz (Note 3)		90		μV
Long Term Stability			30		mV
Ripple Rejection	f = 120 Hz, 18.5V ≤ V_{IN} ≤ 28.5V, T_J = 25°C	33	49		dB
Dropout Voltage	T_A = 25°C		1.7		V

electrical characteristics (con't) (Note 2)

LM78L18AC V_{IN} = 27V, I_{OUT} = 40 mA, $0°C \leq T_J \leq 125°C$, C_{IN} = 0.33μF, C_{OUT} = 0.1μF, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_J = 25°C	17.3	18	18.7	V
Line Regulation	T_J = 25°C, $20.7V \leq V_{IN} \leq 33V$		45	325	mV
	T_J = 25°C, $21V \leq V_{IN} \leq 33V$		35	275	mV
Load Regulation	T_J = 25°C, $1 mA \leq I_{OUT} \leq 100 mA$		30	170	mV
	T_J = 25°C, $1 mA \leq I_{OUT} \leq 40 mA$		15	85	mV
Output Voltage	$20.7V \leq V_{IN} \leq 33V$, $1 mA \leq I_{OUT} \leq 40 mA$	17.1		18.9	V
	$1 mA \leq I_{OUT} \leq 70 mA$	17.1		18.9	V
Quiescent Current	T_J = 25°C		3.1	6.5	mA
	T_J = 125°C			6.0	mA
Quiescent Current Change					
With Line	$21V \leq V_{IN} \leq 33V$			1.5	mA
With Load	$1 mA \leq I_{OUT} \leq 40 mA$			0.1	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz (Note 3)		150		μV
Long Term Stability			45		mV
Ripple Rejection	f = 120 Hz, $23V \leq V_{IN} \leq 33V$, T_J = 25°C	33	48		dB
Dropout Voltage	T_A = 25°C		1.7		V

LM78L18C V_{IN} = 27V, I_{OUT} = 40 mA, $0°C \leq T_J \leq 125°C$, C_{IN} = 0.33μF, C_{OUT} = 0.1μF, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_J = 25°C	16.6	18	19.4	V
Line Regulation	T_J = 25°C, $21.4V \leq V_{IN} \leq 33V$		32	327	mV
	T_J = 25°C, $22V \leq V_{IN} \leq 33V$		27	275	mV
Load Regulation	T_J = 25°C, $1 mA \leq I_{OUT} \leq 100 mA$		30	170	mV
	T_J = 25°C, $1 mA \leq I_{OUT} \leq 40 mA$		15	85	mV
Output Voltage	$21.4V \leq V_{IN} \leq 33V$, $1 mA \leq I_{OUT} \leq 40 mA$	16.2		19.8	V
	$1 mA \leq I_{OUT} \leq 70 mA$	16.2		19.8	V
Quiescent Current	T_J = 25°C		3.1	6.5	mA
	T_J = 125°C			6.0	mA
Quiescent Current Change					
With Line	$22V \leq V_{IN} \leq 33V$			1.5	mA
With Load	$1 mA \leq I_{OUT} \leq 40 mA$			0.2	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz (Note 3)		150		μV
Long Term Stability			45		mV
Ripple Rejection	f = 120 Hz, $23V \leq V_{IN} \leq 33V$, T_J = 25°C	32	46		dB
Dropout Voltage	T_A = 25°C		1.7		V

electrical characteristics (con't) (Note 2)

LM78L24AC V_{IN} = 33V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33µF, C_{OUT} = 0.1µF, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_J = 25°C	23	24	25	V
Line Regulation	T_J = 25°C, 27V ≤ V_{IN} ≤ 38V		60	350	mV
	T_J = 25°C, 28V ≤ V_{IN} ≤ 38V		50	300	mV
Load Regulation	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 100 mA		40	200	mV
	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 40 mA		20	100	mV
Output Voltage	27V ≤ V_{IN} ≤ 38V, 1 mA ≤ I_{OUT} ≤ 40 mA	22.8		25.2	V
	1 mA ≤ I_{OUT} ≤ 70 mA	22.8		25.2	V
Quiescent Current	T_J = 25°C		3.1	6.5	mA
	T_J = 125°C			6.0	mA
Quiescent Current Change					
With Line	28V ≤ V_{IN} ≤ 38V			1.5	mA
With Load	1 mA ≤ I_{OUT} ≤ 40 mA			0.1	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz (Note 3)		200		µV
Long Term Stability			56		mV
Ripple Rejection	f = 120 Hz, 29V ≤ V_{IN} ≤ 35V, T_J = 25°C	31	45		dB
Dropout Voltage	T_A = 25°C		1.7		V

LM78L24C V_{IN} = 33V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33µF, C_{OUT} = 0.1µF, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_J = 25°C	22.1	24	25.9	V
Line Regulation	T_J = 25°C, 27.5V ≤ V_{IN} ≤ 38V		35	350	mV
	T_J = 25°C, 28V ≤ V_{IN} ≤ 38V		30	300	mV
Load Regulation	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 100 mA		40	200	mV
	T_J = 25°C, 1 mA ≤ I_{OUT} ≤ 40 mA		20	100	mV
Output Voltage	28V ≤ V_{IN} ≤ 38V, 1 mA ≤ I_{OUT} ≤ 40 mA	21.4		26.4	V
	1 mA ≤ I_{OUT} ≤ 70 mA	21.4		26.4	V
Quiescent Current	T_J = 25°C		3.1	6.5	mA
	T_J = 125°C			6.0	mA
Quiescent Current Change					
With Line	28V ≤ V_{IN} ≤ 38V			1.5	mA
With Load	1 mA ≤ I_{OUT} ≤ 40 mA			0.2	mA
Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz (Note 3)		200		µV
Long Term Stability			56		mV
Ripple Rejection	f = 120 Hz, 29V ≤ V_{IN} ≤ 35V, T_J = 25°C	30	43		dB
Dropout Voltage	T_A = 25°C		1.7		V

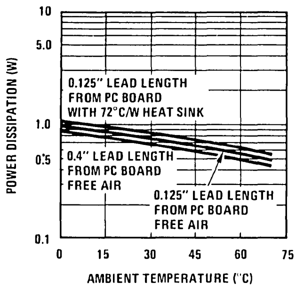
Note 1: Thermal resistance of the Metal Can Package (H) without a heat sink is 40°C/W junction to case and 140°C/W junction to ambient. Thermal resistance of the TO-92 package is 180°C/W junction to ambient with 0.4 inch leads from a PC board and 160°C/W junction to ambient with 0.125 inch lead length to a PC board.

Note 2: The maximum steady state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The data above represent pulse test conditions with junction temperatures as indicated at the initiation of tests.

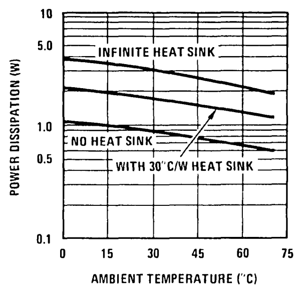
Note 3: It is recommended that a minimum load capacitor of 0.01µF be used to limit the high frequency noise bandwidth.

typical performance characteristics

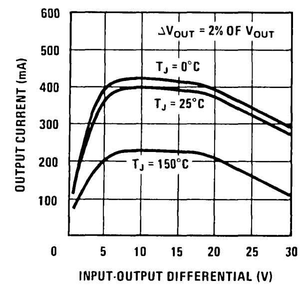
Maximum Average Power Dissipation (Plastic Package)



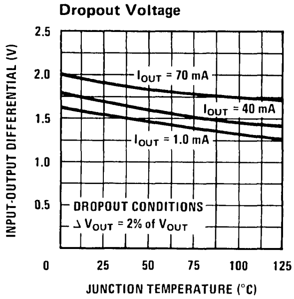
Maximum Average Power Dissipation (Metal Can Package)



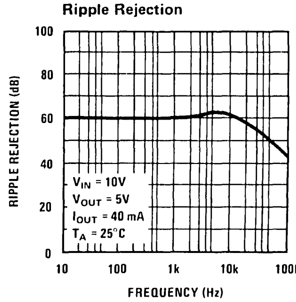
Peak Output Current



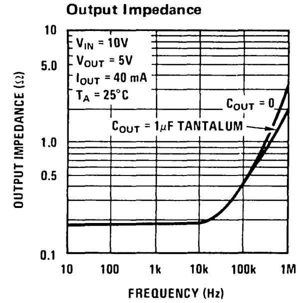
Dropout Voltage



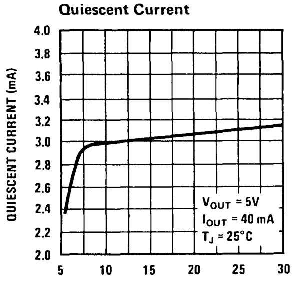
Ripple Rejection



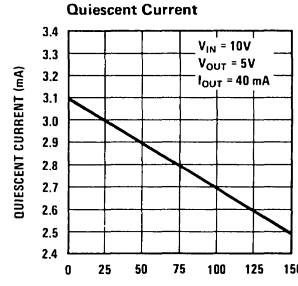
Output Impedance



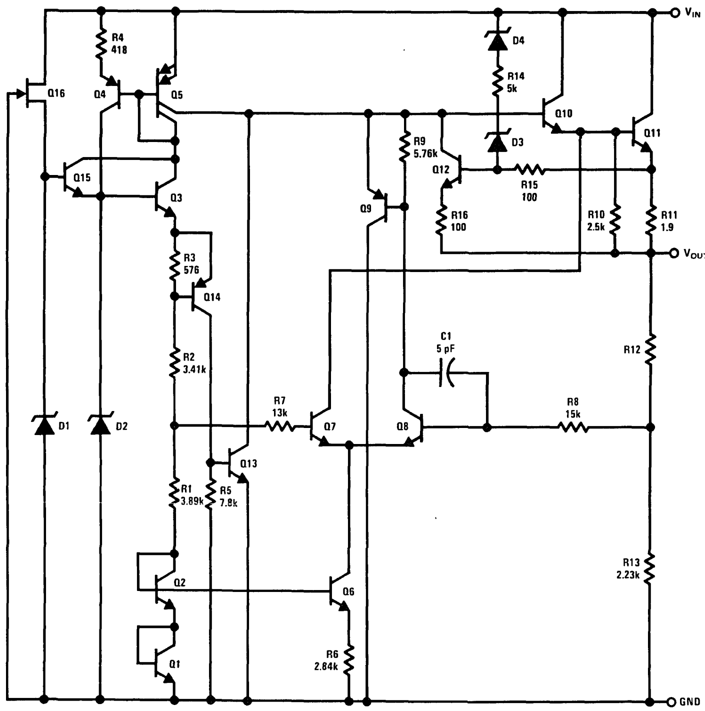
Quiescent Current



Quiescent Current

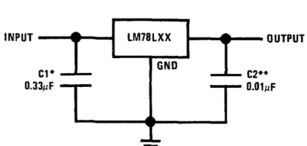


equivalent circuit



LM78LXX

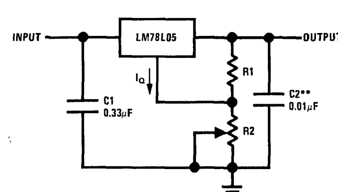
typical applications



*Required if the regulator is located far from the power supply filter.

**See Note 3 in the electrical characteristics table.

Fixed Output Regulator

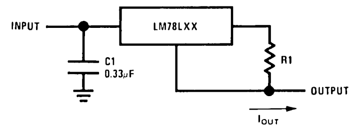


$V_{OUT} = 5V + (5V/R1 + I_Q)\ R2$

$5V/R1 > 3\ I_Q$, load regulation $(L_r) \approx [(R1 + R2)/R1]$ (L_r of LM78L05)

Adjustable Output Regulator

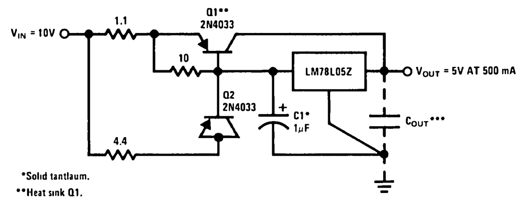
typical applications (con't)



$I_{OUT} = (V_{23}/R1) + I_Q$

ΔI_Q = 1.5 mA over line and load changes

Current Regulator



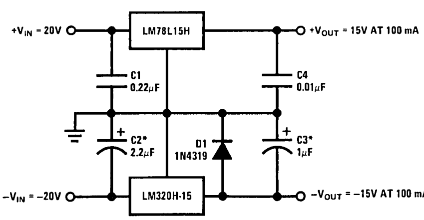
*Solid tantlaum.

**Heat sink Q1.

***Optional: Improves ripple rejection and transient response.

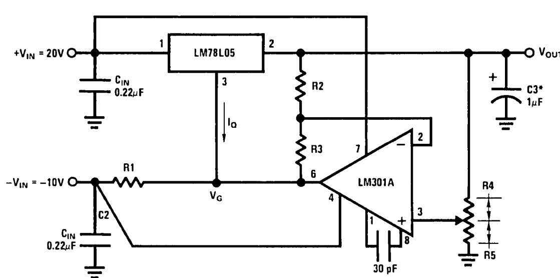
Load Regulation: 0.6% $0 \le I_L \le 250$ mA pulsed with t_{ON} = 50 ms.

5V, 500 mA Regulator with Short Circuit Protection



*Solid tantalum.

±15V, 100 mA Dual Power Supply



*Solid tantalum.

$V_{OUT} = V_G + 5V$, $R1 = (-V_{IN}/I_{Q\,LM78L05})$

$V_{OUT} = 5V\,(R2/R4)$ for $(R2 + R3) = (R4 + R5)$

A 0.5V output will correspond to $(R2/R4) = 0.1$, $(R3/R4) = 0.9$

Variable Output Regulator 0.5V — 18V

Operational Amplifiers

LH0001*/LH0001C low power operational amplifier

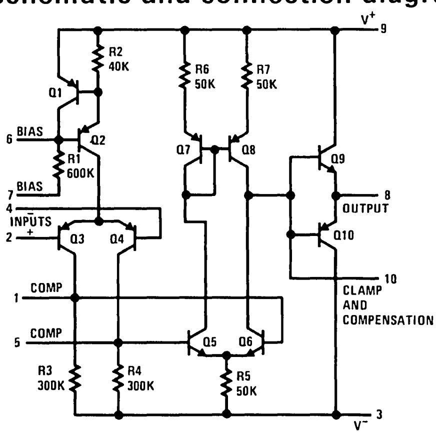
general description

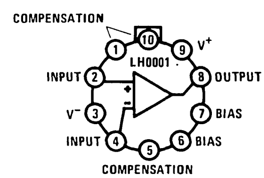
The LH0001/LH0001C is a general purpose operational amplifier designed for extremely low quiescent power. Typical NO-load dissipation at 25°C is 2 milliwatts at V_S = ±15 volts, and 0.5 milliwatts at V_S = ±5 volts. Even with this low power dissipation, the LH0001/LH0001C will deliver ±10 volts into a 2K load with ±15 volt supplies, and typical short circuit currents of 20 to 30 milliamps. Additional features are:

- Operation from ±5V to ±20V
- Very low offset voltage: typically 200 μV at 25°C, 600 μV at −55°C to 125°C
- Very low input offset current: typically 3 nA at 25°C, 6 nA at −55°C
- Low noise: typically 3 μV rms
- Frequency compensation with 2 small capacitors
- Output may be clamped at any desired level
- Output is continuously short circuit proof

The LH0001/LH0001C is ideally suited for space borne applications or where battery operated equipment requires extremely low power dissipation.

schematic and connection diagrams





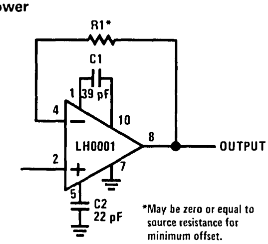
TOP VIEW

Note: Pin 7 must be grounded or connected to a voltage at least 5 volts more negative than the positive supply (Pin 9). Pin 7 may be connected to the negative supply, however the standby current will be increased. A resistor may be inserted in series with Pin 7 up to a maximum of 100 kΩ per volt between Pin 3 and Pin 9.

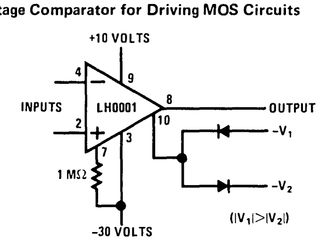
Order Number LH0001H
See Package 14

typical applications

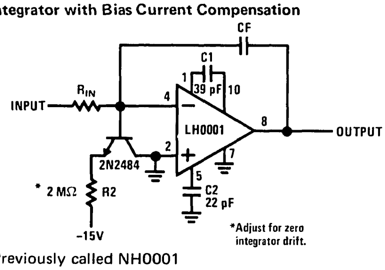
Voltage Follower



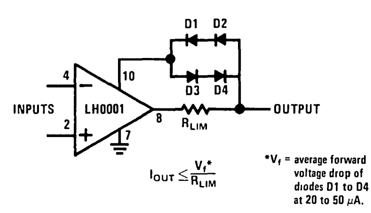
Voltage Comparator for Driving MOS Circuits



Integrator with Bias Current Compensation



External Current Limiting Method



$I_{OUT} \leq \frac{V_f^*}{R_{LIM}}$

*V_f = average forward voltage drop of diodes D1 to D4 at 20 to 50 μA.

*Previously called NH0001

absolute maximum ratings

Supply Voltage	±20V
Power Dissipation (see Curve)	400 mW
Differential Input Voltage	±7V
Input Voltage	Equal to supply
Short Circuit Duration (Note 1)	Continuous
Operating Temperature Range	−55°C to +125°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering 10 sec.)	300°C

electrical characteristics (Note 2)

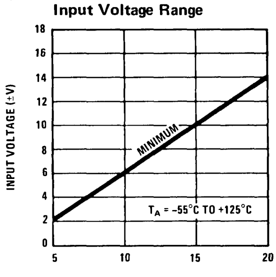
PARAMETER	TEMP (°C)	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	25 −55 to 125	$R_S \leq 5K$ $R_S \leq 5K$		0.2 0.6	1.0 2.0	mV mV
Input Offset Current	25 to 125 −55				20 100	nA nA
Input Bias Current	25 to 125 −55				100 300	nA nA
Supply Current (+)	25 125 −55	$V_S = \pm 20V$ $V_S = \pm 20V$ $V_S = \pm 20V$		90 70 100	125 100 150	µA µA µA
Supply Current (−)	25 125 −55	$V_S = \pm 20V$ $V_S = \pm 20V$ $V_S = \pm 20V$		60 45 75	90 75 125	µA µA µA
Voltage Gain	−55 to 25 125	$R_L = 100\ K\Omega$, $V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L = 100\ K\Omega$, $V_S = \pm 15V$, $V_{OUT} = \pm 10V$	25 10	60 30		V/mV V/mV
V_{OUT}	25 −55 125	$V_S = \pm 15V$, $R_L = 2K$ $V_S = \pm 15V$, $R_L = 2K$ $V_S = \pm 15V$, $R_L = 2K$	10 9 11	11.5 10.5 12.5		V V V
Common Mode Rejection Ratio	−55 to 125	$V_S = \pm 15V$, $V_{IN} = \pm 10V$, $R_S \leq 5K$	70	90		dB
Power Supply Rejection Ratio	−55 to 125	$V_S = \pm 15V$, $\Delta V = 5V$ to $20V$, $R_S = \leq 5K$	70	90		dB
Input Resistance	25		0.5	1.5		MΩ
Average Temperature Coefficient of Offset Voltage	−55 to 125	$R_S \leq 5K$		4		µA/°C
Average Temperature Coefficient of Bias Current	−55 to 125			0.4		nA/°C
Equivalent Input Noise Voltage	25	$R_S = 1K$, f = 5 Hz to 1000 Hz, $V_S = \pm 15V$		3.0		µV rms

Note 1: Based on maximum short circuit current of 50 mA, device may be operated at any combination of supply voltages, and temperature to be within rated power dissipation (see Curve).

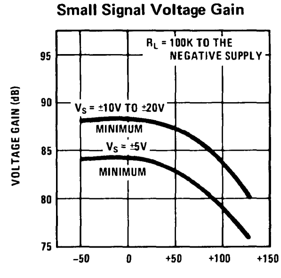
Note 2: These specifications apply for Pin 7 grounded, for $\pm 5V \leq V_S \leq \pm 20V$, with Capacitor C1 = 39 pF from Pin 1 to Pin 10, and C2 = 22 pF from Pin 5 to ground, unless otherwise specified.

guaranteed performance

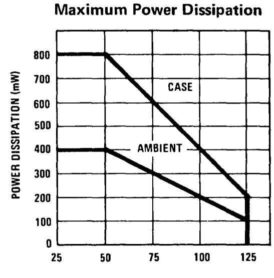
Input Voltage Range



Small Signal Voltage Gain

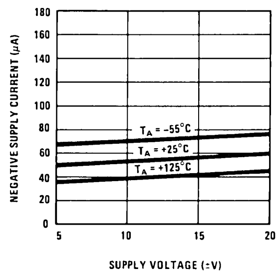


Maximum Power Dissipation

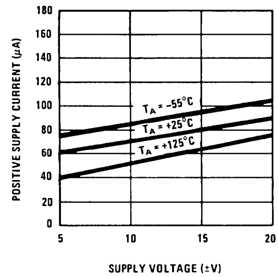


typical performance characteristics

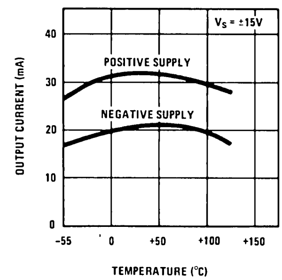
Negative Supply Current



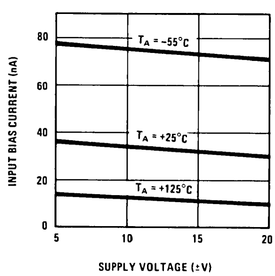
Positive Supply Currents



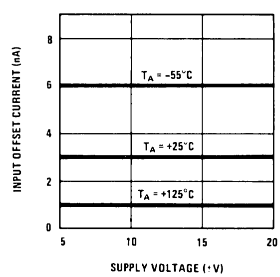
Short Circuit Output Current



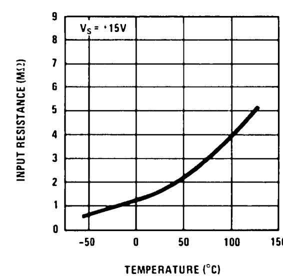
Input Bias Current



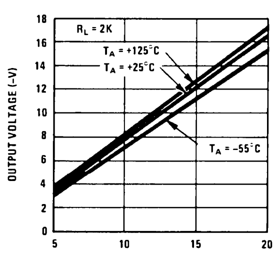
Input Offset Current



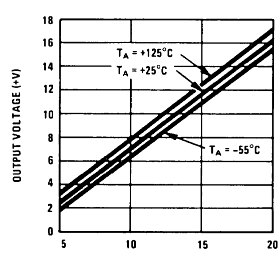
Input Resistance



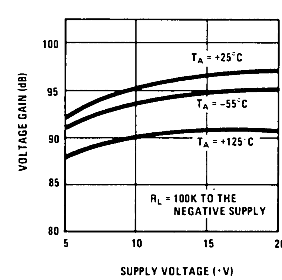
Negative Output Voltage Swing



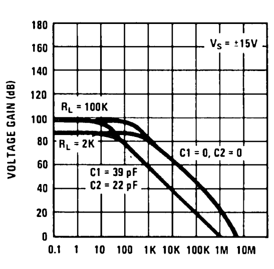
Positive Output Voltage Swing



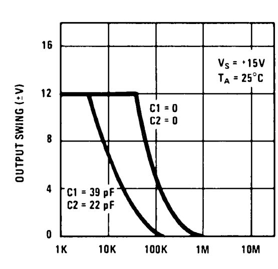
Voltage Gain



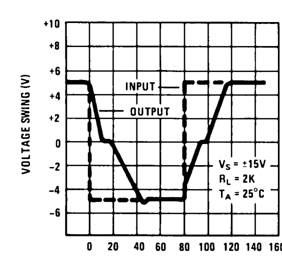
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



2

Operational Amplifiers

LH0001A/LH0001AC micropower operational amplifier

general description

The LH0001A/LH0001AC is a micropower, high performance integrated circuit operational amplifier designed to have a no load power dissipation of less than 0.5 mW at $V_S = \pm5V$ and less than 2 mW at $V_S = \pm20V$. Open loop gain is greater than 50k and input bias current is typically 20 nA.

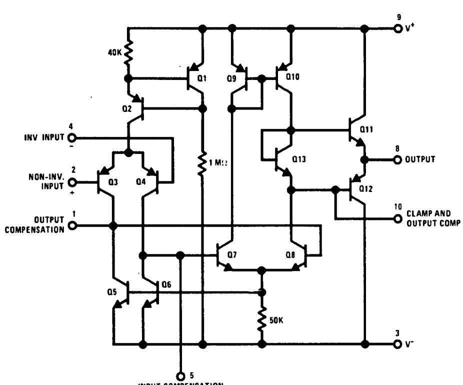
features

- 1.0 mV Typical low offset voltage
- 5 nA Typical low offset current
- 3 μVrms Typical low noise
- Simple frequency compensation
- Moderate bandwidth and slewrate
- Output short circuit proof

The LH0001A/LH0001AC may be substituted directly for the LH0001/LH0001C. Low power consumption, high open loop gain, and excellent input characteristics make the LH0001A an ideal amplifier for many low power applications such as battery powered instrument or transducer amplifiers.

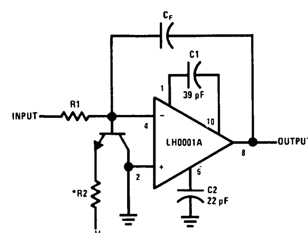
The LH0001A is specified for operation over the −55°C to +125°C military temperature range. The LH0001AC is specified for operation over the 0°C to +85°C temperature range.

schematic diagram*



*Pin shown for TO-5 package

typical application*

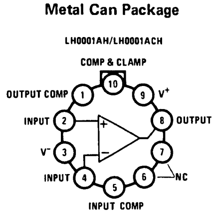


*Adjust for zero integrator drift.

Integrator with Bias Compensation

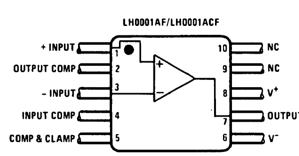
connection diagrams

Metal Can Package



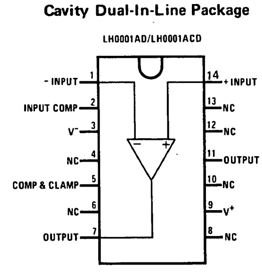
Order Number
LH0001AH or LH0001ACH
See Package 14

Flat Package



Order Number
LH0001AF or LH0001ACF
See Package 3

Cavity Dual-In-Line Package



Order Number
LH0001AD or LH0001ACD
See Package 1

absolute maximum ratings

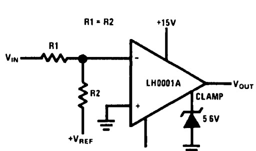
Supply Voltage		±20V
Power Dissipation (See curve)		400 mW
Differential Input Voltage		±7V
Input Voltage		$\pm V_S$
Short Circuit Duration		Continuous
Operating Temperature Range	LH0001A	−55°C to 125°C
	LH0001AC	−25°C to 85°C
Storage Temperature Range		−65°C to 150°C
Lead Temperature (Soldering, 10 sec)		300°C

electrical characteristics (Note 1)

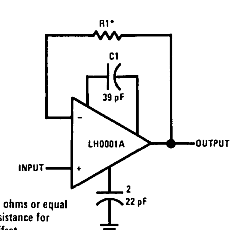
PARAMETERS	CONDITIONS	LH0001A			LH0001AC			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$R_S \leq 1k$, $T_A = 25°C$		1.0	2.5		2.0	5.0	mV
				4.0			7.0	mV
Input Bias Current	$T_A = 25°C$		20	100		20	200	nA
				300			300	nA
Input Offset Current	$T_A = 25°C$		5	20		20	60	nA
				100			100	nA
Supply Current	$V_S = \pm 20V$, $T_A = 25°C$		80	125		80	125	µA
	$V_S = \pm 20V$			150			150	nA
Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = 10V$, $R_L = 100k$,	25	60		25	60		V/mV
	$T_A = 25°C$	25	60		25	60		
	$V_S = \pm 15V$, $V_{OUT} = 10V$, $R_L = 100k$	10	30		10			V/mV
Output Voltage	$V_S = \pm 15V$, $R_L = 2k$, $T_A = 25°C$	10	11.5		10	11.5		V
	$V_S = \pm 15V$, $R_L = 2k$	9			9			V
Common Mode Rejection Ratio	$V_S = \pm 15V$, $V_{IN} = 10V$, $R_S = 1k$	70	90		70	90		db
Power Supply Rejection Ratio	$V_S = \pm 15V$, $R_S = 1k$, $V_S = \pm 5V$ to $\pm 20V$	70	90		70	90		db
Equivalent Input Noise Voltage	$V_S = \pm 15V$, $R_S = 1k$, $T_A = 25°C$ f = 500 Hz to 5 kHz		3.0			3.0		µVrms
Average Temperature Coefficient of Offset Voltage	$R_S \leq 1k$		3.0			3.0		µV/°C
Average Temperature Coefficient of Bias Current			0.3			0.3		nA/°C

Note 1: The specifications apply for $\pm 5V \leq V_S \leq 20V$, with output compensation capacitor, C_1 = 39 pF, input compensation capacitor, C_2 = 22 pF, −55°C to 125°C for the LH0001A and −25°C to +85°C for the LH0001AC unless otherwise specified.

typical applications

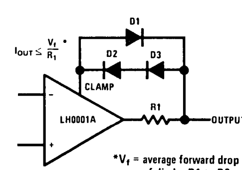


TTL/DTL Compatible Comparator



*May be zero ohms or equal to source resistance for minimum offset.

Voltage Follower

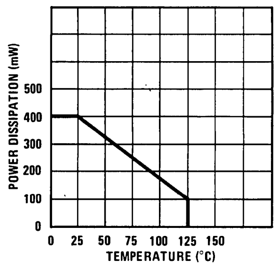


*V_f = average forward drop of diodes D1 to D3 at 20 to 50 µA.

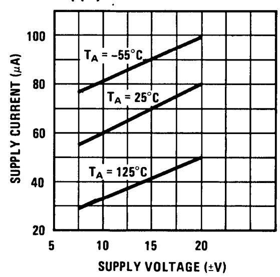
External Output Current Limiting

typical performance characteristics

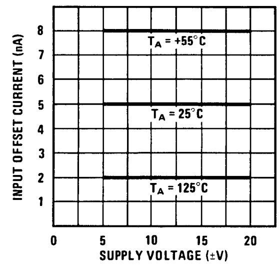
Maximum Power Dissipation



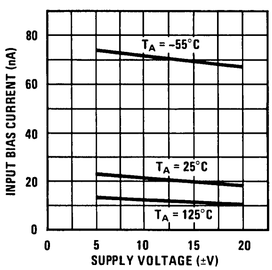
Supply Current



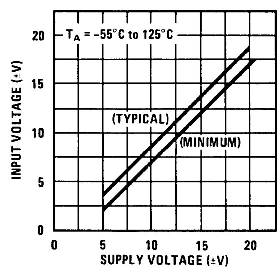
Input Offset Current



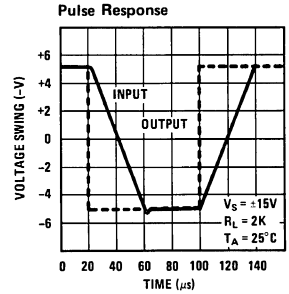
Input Bias Current



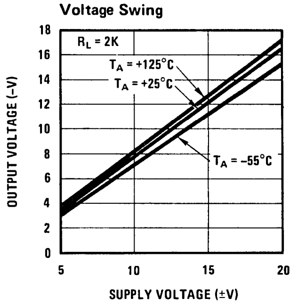
Input Voltage Range



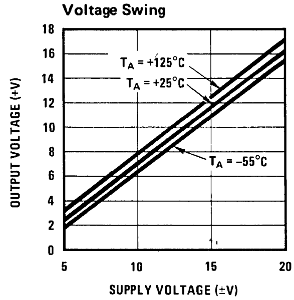
Voltage Follower
Pulse Response



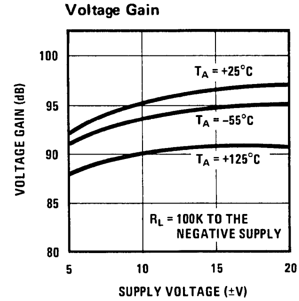
Negative Output
Voltage Swing



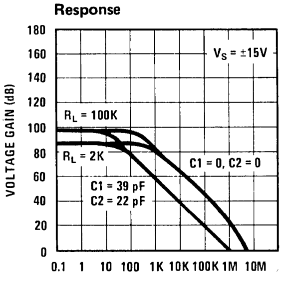
Positive Output
Voltage Swing



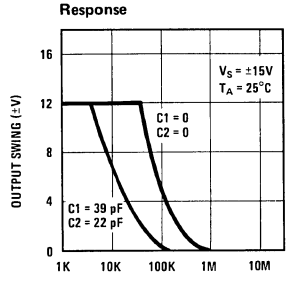
Voltage Gain



Open Loop Frequency
Response



Large Signal Frequency
Response



Operational Amplifiers

LH0002/LH0002C* current amplifier

general description

The LH0002/LH0002C is a general purpose thick film hybrid current amplifier that is built on a single substrate. The circuit features:

- High Input Impedance 400 kΩ
- Low Output Impedance 6Ω
- High Power Efficiency
- Low Harmonic Distortion
- DC to 30 MHz Bandwidth
- Output Voltage Swing that Approaches Supply Voltage
- 400 mA Pulsed Output Current
- Slew rate is typically 200V/μs
- Operation from ±5V to ±20V

These features make it ideal to integrate with an operational amplifier inside a closed loop configuration to increase current output. The symmetrical output portion of the circuit also provides a low output impedance for both the positive and negative slopes of output pulses.

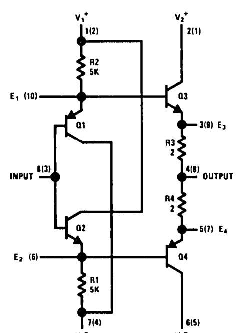
The LH0002 is available in an 8-lead low-profile TO-5 header; the LH0002C is also available in an 8-lead TO-5, and a 10-pin molded dual-in-line package.

The LH0002 is specified for operation over the −55°C to +125°C military temperature range. The LH0002C is specified for operation over the 0°C to +85°C temperature range.

applications

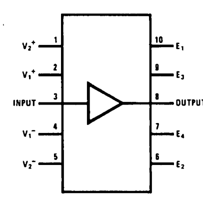
- Line driver
- 30 MHz buffer
- High speed D/A conversion
- Instrumentation buffer
- Precision current source

schematic and connection diagrams



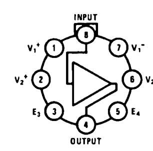
Pin numbers in parentheses denote pin connections for dual-in-line package.

Dual-In-Line Package



Order Number LH0002CN
See Package 21

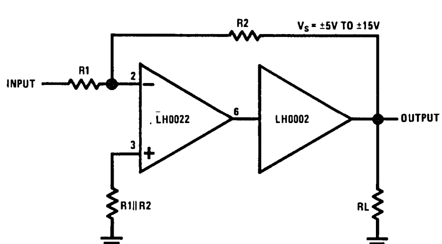
Metal Can Package



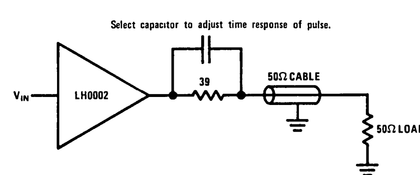
Order Number LH0002H
or LH0002CH
See Package 11

typical applications

High Current Operational Amplifier



Line Driver



*Previously called NH0002/NH0002C

absolute maximum ratings

Supply Voltage		±22V
Power Dissipation Ambient		600 mW
Input Voltage (Equal to Power Supply Voltage)		
Storage Temperature Range		−65°C to +150°C
Operating Temperature Range	LH0002	−55°C to +125°C
	LH0002C	0°C to +85°C
Steady State Output Current		±100 mA
Pulsed Output Current (50 ms On/1 sec Off)		±400 mA

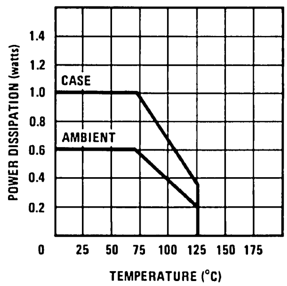
electrical characteristics (Note 1)

PARAMETERS	CONDITIONS	MIN	TYP	MAX	UNITS
Voltage Gain	R_S = 10 kΩ, R_L = 1.0 kΩ V_{IN} = 3.0 V_{PP}, f = 1.0 kHz T_A = −55°C to 125°C	.95	.97		
AC Current Gain	V_{IN} = 1.0 V_{rms} f = 1.0 kHz		40		A/mA
Input Impedance	R_S = 200 kΩ, V_{IN} = 1.0 V_{rms}, f = 1.0 kHz, R_L = 1.0 kΩ	180	400	–	kΩ
Output Impedance	V_{IN} = 1.0 V_{rms}, f = 1.0 kHz R_L = 50Ω, R_S = 10 kΩ	–	6	10	Ω
Output Voltage Swing	R_L = 1.0 kΩ, f = 1.0 kHz	±10	±11	–	V
Output Voltage Swing	V_S = ±15V, V_{IN} = ±10V, R_L = 100Ω , T_A = 25°C	±9.5V			
DC Output Offset Voltage	R_S = 300Ω, R_L = 1.0 kΩ T_A = −55°C to 125°C	–	±10	±30	mV
DC Input Offset Current	R_S = 10 kΩ, R_L = 1.0 kΩ T_A = −55°C to 125°C	–	±6.0	±10	μA
Harmonic Distortion	V_{IN} = 5.0 V_{rms}, f = 1.0 kHz	–	0.1	–	%
Bandwidth	V_{IN} = 1.0 V_{rms}, R_L = 50Ω, f = 1 MHz	30	50	–	MHz
Positive Supply Current	R_S = 10 kΩ, R_L = 1 kΩ	–	+6.0	+10.0	mA
Negative Supply Current	R_S = 10 kΩ, R_L = 1 kΩ	–	−6.0	−10.0	mA

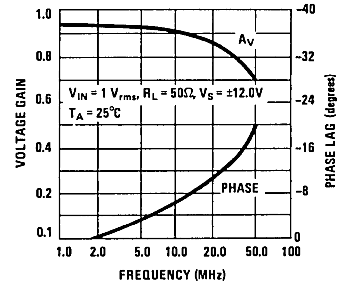
Note 1: Specification applies for T_A = 25°C with +12V on Pins 1 and 2; −12V on Pins 6 and 7 for the metal can package and +12V on Pins 1 and 2; −12V on Pins 4 and 5 for the dual-in-line package unless otherwise specified. The parameter guarantees for LH0002C apply over the temperature range of 0°C to +85°C, while parameters for the LH0002 are guaranteed over the temperature range −55°C to 125°C.

typical performance

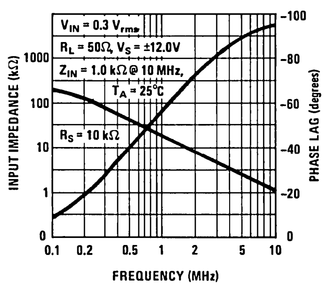
Maximum Power Dissipation



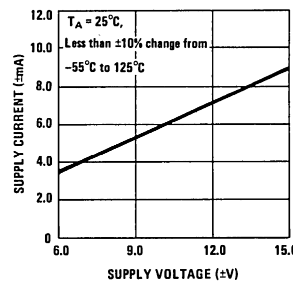
Frequency Response



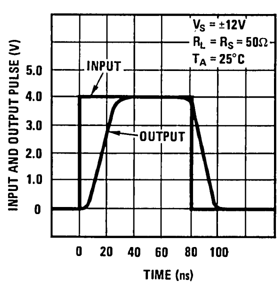
Input Impedance (Magnitude & Phase)



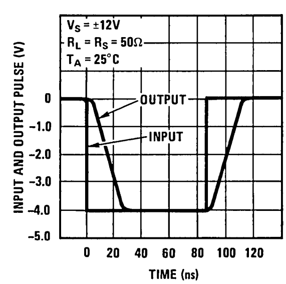
Supply Current



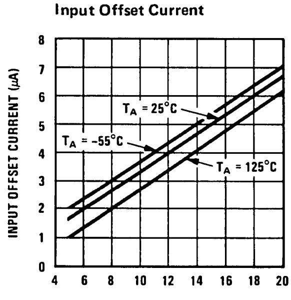
Positive Pulse



Negative Pulse



Input Offset Current



2

Operational Amplifiers

LH0003/LH0003C* wide bandwidth operational amplifier

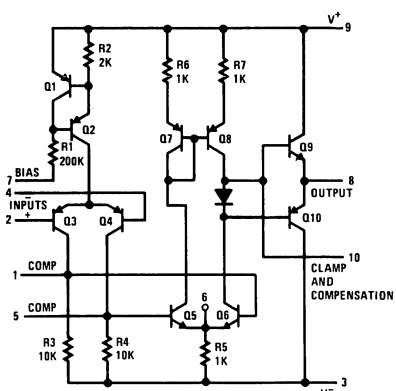
general description

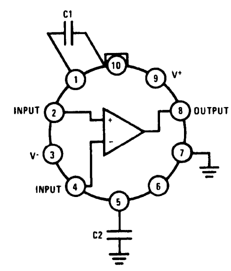
The LH0003/LH0003C is a general purpose operational amplifier which features: slewing rate up to 70 volts/µsec, a gain bandwidth of up to 30 MHz, and high output currents. Other features are:

- Very low offset voltage — Typically 0.4 mV
- Large output swing — > ±10V into 100Ω load
- High CMRR — Typically > 90 dB
- Good large signal frequency response — 50 kHz to 400 kHz depending on compensation

The LH0003 is specified for operation over the −55°C to +125°C military temperature range. The LH0003C is specified for operation over the 0°C to +85°C temperature range.

schematic and connection diagrams





TOP VIEW

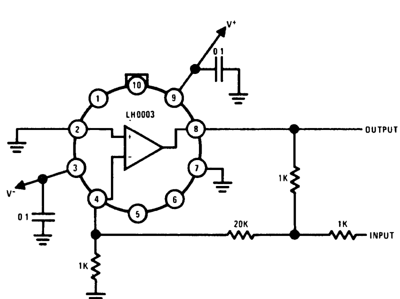
Order Number LH0003H or LH0003CH
See Package 14

Circuit Gain	C_1 pF	C_2 pF	Slew Rate R_L > 200Ω, V/µsec	Full Output Frequency R_L 200Ω V_{OUT} ±10 V
≥ 40	0	0	70	400 kHz
≥ 10	5	30	30	350 kHz
≥ 5	15	30	15	250 kHz
≥ 2	50	50	5	100 kHz
≥ 1	90	90	2	50 kHz

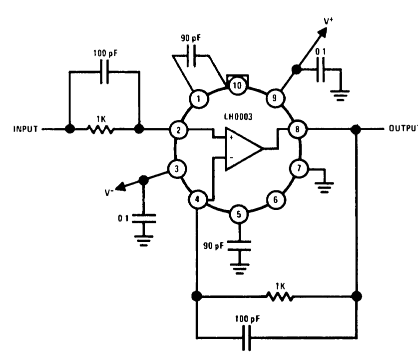
Typical Compensation

typical applications

High Slew Rate Unity Gain Inverting Amplifier



Unity Gain Follower



*Previously called NH0003/NH0003C

absolute maximum ratings

Supply Voltage		±20V
Power Dissipation		See curve
Differential Input Voltage		±7V
Input Voltage		Equal to supply
Load Current		120 mA
Operating Temperature Range	LH0003	−55°C to +125°C
	LH0003C	0°C to +85°C
Storage Temperature Range		−65°C to +150°C
Lead Temperature (Soldering, 10 sec)		300°C

electrical characteristics (Notes 1 & 2)

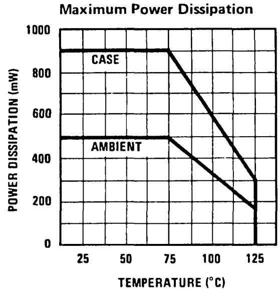
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$R_S < 1k$		0.4	3.0	mV
Input Offset Current			0.02	0.2	µA
Input Bias Current			0.4	2.0	µA
Supply Current	$V_S = \pm 20V$		1.2	3	mA
Voltage Gain	$R_L = 100k$, $V_S = \pm 15V$, $V_{OUT} = \pm 10V$	20	70		V/mV
Voltage Gain	$R_L = 2k$, $V_S = \pm 15V$, $V_{OUT} = \pm 10V$	15	40		V/mV
Output Voltage Swing	$V_S = \pm 15$, $R_L = 100\Omega$	±10	±12		V
Input Resistance			100		kΩ
Average Temperature Coefficient of Offset Voltage	$R_S < 5k$		4		µV/°C
Average Temperature Coefficient of Bias Current			8		nA/°C
CMRR	$R_S < 1k$, $V_S = \pm V$, $V_{IN} = \pm 10V$	70	90		dB
PSRR	$R_S < 1k$, $V_S = \pm 15V$, $\Delta V = 5V$ to $20V$	70	90		dB
Equivalent Input Noise Voltage	$R_S = 1K$, f = 10 kHz to 100 kHz $V_S = \pm 15V$ dc		1.8		µVrms

Note 1. These specifications apply for Pin 7 grounded, for $\pm 5V < V_S < \pm 20V$, with capacitor $C_1 = 90$ pF from Pin 1 to Pin 10 and $C_2 = 90$ pF from Pin 5 to ground, over the specified operating temperature range, unless otherwise specified.

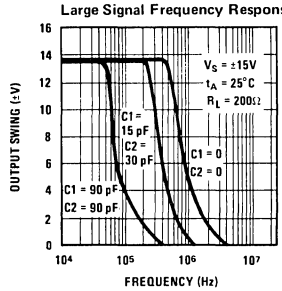
Note 2. Typical values are for $t_{AMBIENT} = 25°C$ unless otherwise specified.

typical performance

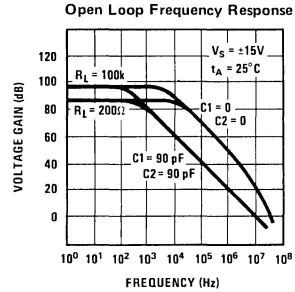
Maximum Power Dissipation



Large Signal Frequency Response



Open Loop Frequency Response



Operational Amplifiers

LH0004/LH0004C* high voltage operational amplifier

general description

The LH0004/LH0004C is a general purpose operational amplifier designed to operate from supply voltages up to ±40V. The device dissipates extremely low quiescent power, typically 8 mW at 25°C and V_S = ±40V. Additional features include:

- Capable of operation over the range of ±5V to ±40V
- Large output voltage typically ±35V for the LH0004 and ±33V for the LH0004C into a 2 KΩ load with ±40V supplies
- Low input offset current typically 20 nA for the LH0004 and 45 nA for the LH0004C
- Low input offset voltage typically 0.3 mV
- Frequency compensation with 2 small capacitors
- Low power consumption 8 mW at ±40V

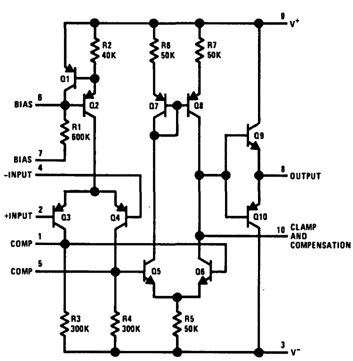
The LH0004's high gain and wide range of operating voltages make it ideal for applications requiring large output swing and low power dissipation.

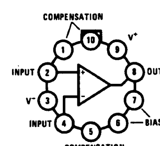
The LH0004 is specified for operation over the −55°C to +125°C military temperature range. The LH0004C is specified for operation over the 0°C to +85°C temperature range.

applications

- Precision high voltage power supply
- Resolver excitation
- Wideband high voltage amplifier
- Transducer power supply

schematic and connection diagrams



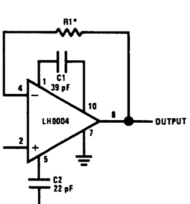


Note: Pin 7 must be grounded or connected to a voltage at least 5V more negative than the positive supply (Pin 9). Pin 7 may be connected to the negative supply; however, the standby current will be increased. A resistor may be inserted in series with Pin 7 to Pin 9. The value of the resistor should be a maximum of 100 KΩ per volt of potential between Pin 3 and Pin 9.

Order Number LH0004H or LH0004CH
See Package 14

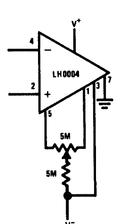
typical applications

Voltage Follower

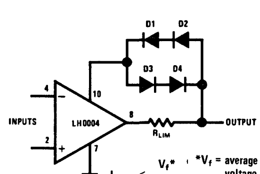


*May be zero or equal to source resistance for minimum offset.

Input Offset Voltage Adjust



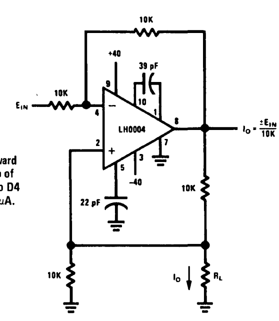
External Current Limiting Method



$I_{OUT} \le \frac{V_f^*}{R_{LIM}}$

*V_f = average forward voltage drop of diodes D1 to D4 at 20 to 50 μA.

High Compliance Current Source



$I_O = \frac{\pm E_{IN}}{10K}$

*Previously called NH0004/NH0004C

absolute maximum ratings

Supply Voltage, Continuous	±45V
Supply Voltage, Transient ($\leq$0.1 sec, no load)	±60V
Power Dissipation (See curve)	400 mW
Differential Input Voltage	±7V
Input Voltage	Equal to supply
Short Circuit Duration	3 sec
Operating Temperature Range LH0004	−55°C to +125°C
LH0004C	0°C to 85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

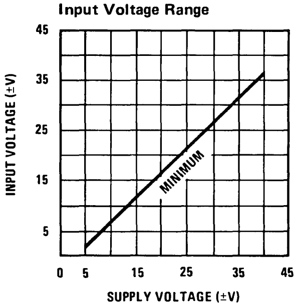
electrical characteristics (Note 1)

PARAMETER	CONDITIONS	LH0004			LH0004C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$R_S \leq 5k$, $T_A = 25°C$		0.3	1.0		0.3	1.5	mV
	$R_S \leq 5k$			2.0			3.0	mV
Input Bias Current	$T_A = 25°C$		20	100		30	120	nA
	$= -55°C$			300			300	nA
Input Offset Current	$T_A = 25°C$		3	20		10	45	nA
	$= -55°C$			100			150	nA
Positive Supply Current	$V_S = \pm40V$, $T_A = 25°C$		110	150		110	150	μA
	$V_S = \pm40V$			175			175	μA
Negative Supply Current	$V_S = \pm40V$, $T_A = 25°C$		80	100		80	100	μA
	$V_S = \pm40V$			135			135	μA
Voltage Gain	$V_S = \pm40V$, $R_L = 100k$, $T_A = 25°C$ $V_{OUT} = \pm30V$	30	60		30	60		V/mV
	$V_S = \pm40V$, $R_L = 100k$ $V_{OUT} = \pm30V$	10			10			V/mV
Output Voltage	$V_S = \pm40V$, $R_L = 2k$	±30	±35		±30	±33		V
	$V_S = \pm40V$, $R_L = 4k$	±34	±36		±33	±35		V
CMRR	$V_S = \pm40V$, $R_S \leq 5k$ $V_{IN} = \pm33V$	70	90		70	90		dB
PSRR	$V_S = \pm40V$, $R_S \leq 5k$ $\Delta V = 20V$ to $40V$	70	90		70	90		dB
Average Temperature Coefficient Offset Voltage	$R_S \leq 5k$		4.0			4.0		μV/°C
Average Temperature Coefficient of Offset Current			0.4			0.4		nA/°C
Equivalent Input Noise Voltage	$R_S = 1k$, $V_S = \pm40V$ f = 500 Hz to 5 kHz, $T_A = 25°C$		3.0			3.0		μVrms

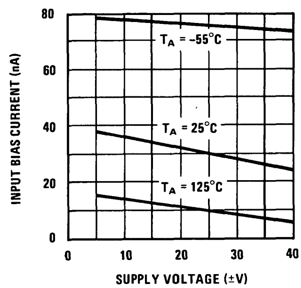
Note 1: These specifications apply for $\pm5V \leq V_S \leq \pm40V$, Pin 7 grounded, with capacitors C1 = 39 pF between Pin 1 and Pin 10, C2 = 22 pF between Pin 5 and ground, −55°C to +125°C for the LH0004, and 0°C to +85°C for the LH0004C unless otherwise specified.

typical performance

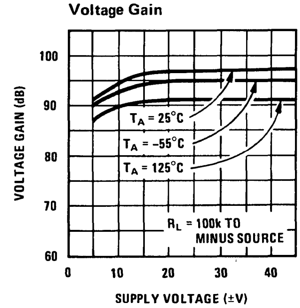
Input Voltage Range



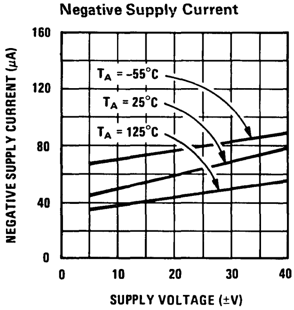
Input Bias Current



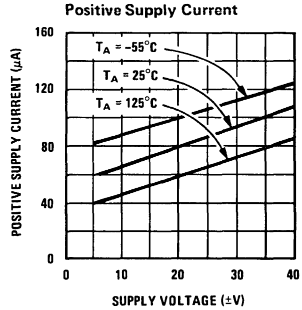
Voltage Gain



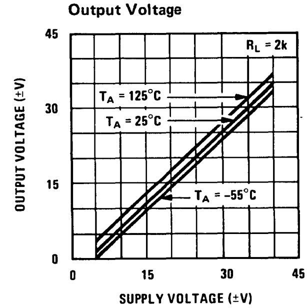
Negative Supply Current



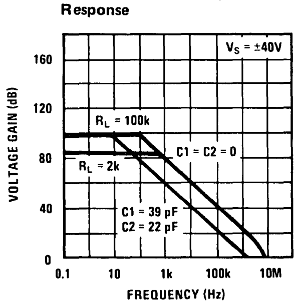
Positive Supply Current



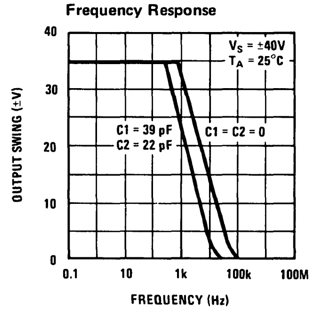
Output Voltage



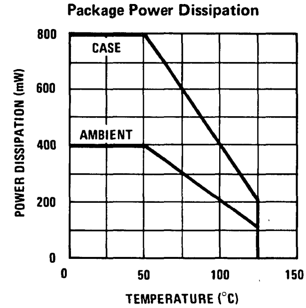
Open Loop Frequency Response



Large Signal Frequency Response



Package Power Dissipation



Operational Amplifiers

LH0005/LH0005A* operational amplifier

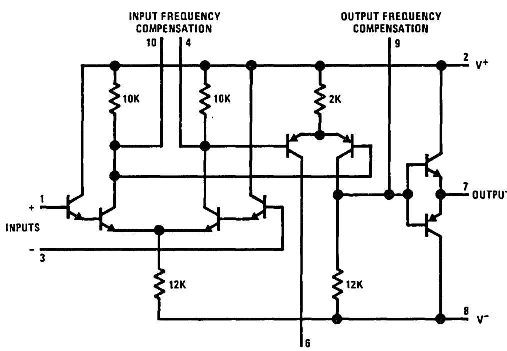
general description

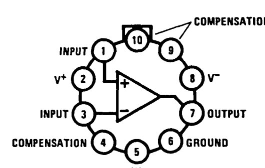
The LH0005/LH0005A is a hybrid integrated circuit operational amplifier employing thick film resistors and discrete silicon semiconductors in its design. The select matching of the input pairs of transistors results in low input bias currents and a very low input offset current, both of which exhibit excellent temperature tracking. In addition, the device features:

- Very high output current capability: ±50 mA into a 100 ohm load
- Low standby power dissipation: typically 60 mW at ±12V
- High input resistance: typically 2M at 25°C
- Full operating range: −55°C to +125°C
- Good high frequency response: unity gain at 30 MHz

With no external roll-off network, the amplifier is stable with a feedback ratio of 10 or greater. By adding a 200 pF capacitor between pins 9 and 10, and a 200 ohm resistor in series with a 75 pF capacitor from pin 4 to ground, the amplifier is stable to unity gain. The unity gain loop phase margin with the above compensation is typically 70 degrees. With a gain of 10 and no compensation the loop phase margin is typically 50 degrees.

schematic and connection diagrams



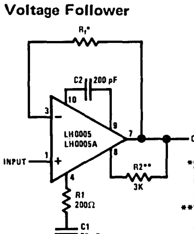


TOP VIEW

Order Number LH0005H or LH0005AH
See Package 14

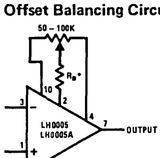
typical applications

Voltage Follower



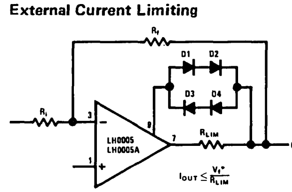
*May be zero or equal to the input resistance for minimum offset.
**To minimize crossover distortion at higher frequencies. May be omitted for low frequency application or selected to suit design requirements

Offset Balancing Circuit



*Typical value, $R_B \approx 100K$.
R_B may be increased for greater sensitivity with reduction in range.

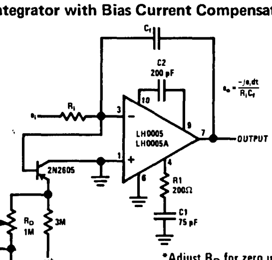
External Current Limiting



$I_{OUT} \le \frac{V_f}{R_{LIM}}$

*V_f = Average forward voltage drop of diodes D_1 to D_4 at approx. 1 mA.
For continuous short circuit protection ($V_S = \pm 12V$, $-55°C \le T_A \le +100°C$) $R_{LIM} \ge 50\Omega$

Integrator with Bias Current Compensation



$e_o = \frac{-\int e_i dt}{R_i C_f}$

*Adjust R_D for zero integration drift.

*Previously called NH0005/NH0005A

absolute maximum ratings

Supply Voltage	±20V
Power Dissipation (see Curve)	400 mW
Differential Input Voltage	±15V
Input Voltage	Equal to supply voltages
Peak Load Current	±100 mA
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	−55°C to +125°C
Lead Temperature (Soldering, 10 seconds)	300°C

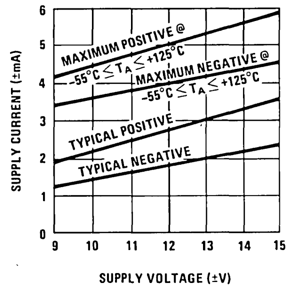
electrical characteristics (Note 1)

PARAMETER	CONDITIONS	LH0005			LH0005A			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage								
25°C	$R_S \leq 20\ k\Omega$		5	10		1	3	mV
−55°C, 125°C	$R_S \leq 20\ k\Omega$			10			4	mV
Input Offset Current								
25°C to 125°C			10	20		2	5	nA
−55°C			25	75		10	25	nA
Input Bias Current								
25°C to 125°C			15	50		8	25	nA
−55°C			100	250		60	125	nA
Large Signal Voltage Gain								
−55°C to 25°C	R_L = 10K, R2 = 3K, V_{OUT} = ±5V	2	4		4	5.5		V/mV
125°C		1.5	3		3	5		V/mV
Output Voltage Swing								
−55°C to 125°C	$R_L = 10\ k\Omega$	−10		+6	−10		+6	V
25°C to 125°C	$R_L = 100\Omega$	−5		+5	−5		+5	V
−55°C	$R_L = 100\Omega$	−4		+4	−4		+4	V
Input Resistance								
25°C		1	2		1	2		MΩ
Common Mode Rejection Ratio								
25°C	V_{IN} = ±4V, $RS \leq 20\ k\Omega$	55	60		60	66		dB
Power Supply Rejection Ratio								
25°C		55	60		60	66		dB
Supply Current (+)								
−55°C to 125°C			3	5		3	5	mA
Supply Current (−)								
−55°C to 125°C			2	4		2	4	mA
Average Temperature Coefficient of Input Offset Voltage								
−55°C to 125°C	$R_S \leq 20\ k\Omega$		20			10		uV/°C
Output Resistance								
25°C			70			70		Ω

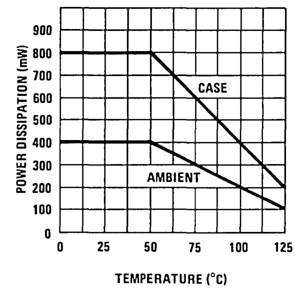
Note 1: These specifications apply for pin 6 grounded, V_S = ±12V, with Resistor R_1 = 200Ω in series with Capacitor C_1 = 75 pF from pin 4 to ground, and C_2 = 200 pF between pins 9 and 10 unless otherwise specified.

guaranteed performance characteristics

Supply Current

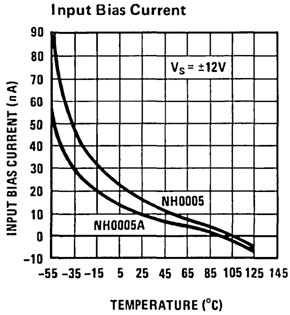


Maximum Power Dissipation

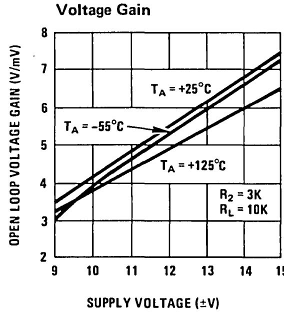


typical performance characteristics

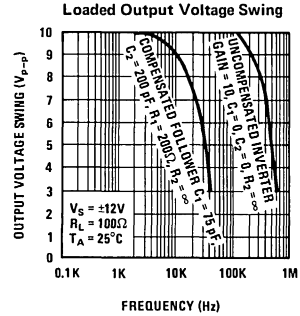
Input Bias Current



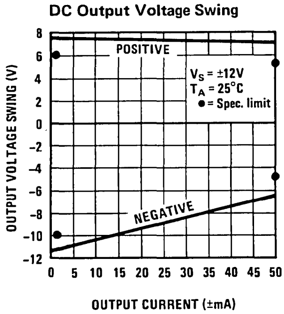
Voltage Gain



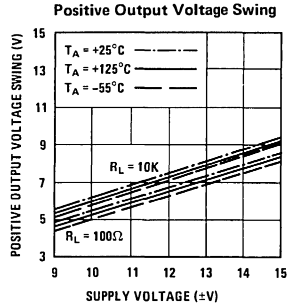
Loaded Output Voltage Swing



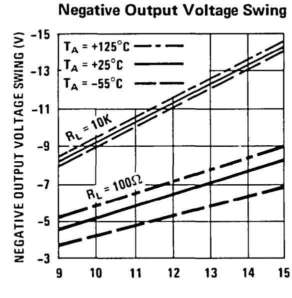
DC Output Voltage Swing



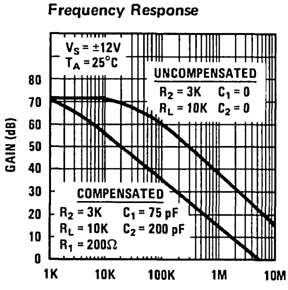
Positive Output Voltage Swing



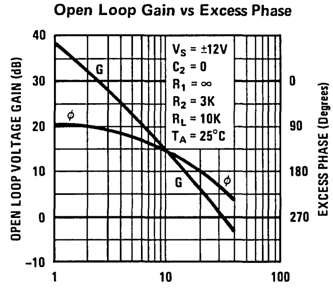
Negative Output Voltage Swing



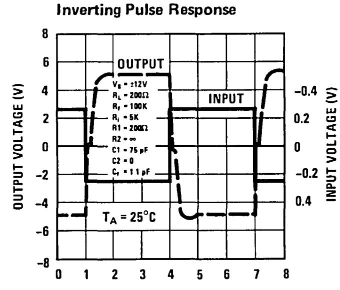
Frequency Response



Open Loop Gain vs Excess Phase



Inverting Pulse Response



2

Operational Amplifiers

LH0005C* operational amplifier

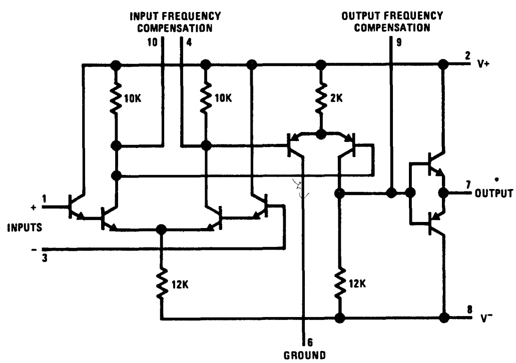
general description

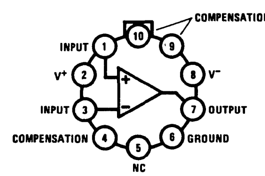
The LH0005C is a hybrid integrated circuit operational amplifier employing thick film resistors and discrete silicon semiconductors in its design. The select matching of the input pairs of transistors results in low input bias currents and a very low input offset current both of which exhibit excellent temperature tracking. In addition, the device features:

- Very high output current capability: ±40 mA into a 100 ohm load
- Low standby power dissipation: typically 60 mW at ±12V
- High input resistance: typically 2M at 25°C
- Operating range: 0° to 70°C
- Good high frequency response: unity gain at 30 MHz

With no external roll-off network, the amplifier is stable with a feedback ratio of 10 or greater. By adding a 200 pF capacitor between pins 9 and 10, and a 200 ohm resistor in series with a 75 pF capacitor from pin 4 to ground, the amplifier is stable to unity gain. The unity gain loop phase margin with the above compensation is typically 70 degrees. With a gain of 10 and no compensation the loop phase margin is typically 50 degrees.

schematic and connection diagrams



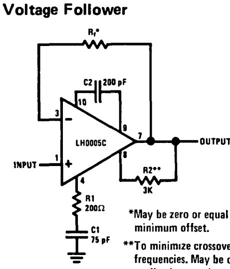


TOP VIEW

Order Number LH0005CH
See Package 14

typical applications

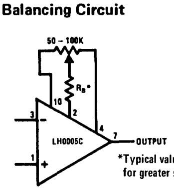
Voltage Follower



*May be zero or equal to the input resistance for minimum offset.

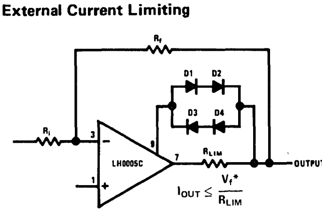
**To minimize crossover distortion at higher frequencies. May be omitted for low frequency application or selected to suit design requirements.

Offset Balancing Circuit



*Typical value, R_B = 100K, R_B may be increased for greater sensitivity with reduction in range.

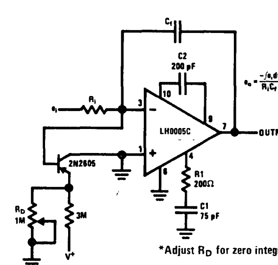
External Current Limiting



For continuous short circuit protection (V_S = ±12V, 0°C ≤ T_A ≤ 70°C, R_{LIM} ≥ 50Ω)

*V_f = average forward voltage drop of diodes D1 to D4 at approximately 1 mA.

Integrator With Bias Current Compensation



$$e_o = \frac{-\int e_i dt}{R_i C_f}$$

*Adjust R_D for zero integration drift.

*Previously called NH0005C

absolute maximum ratings

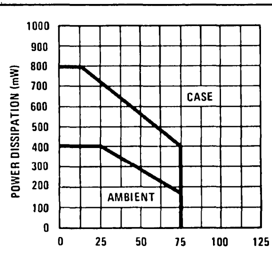
Supply Voltage	±20V
Power Dissipation (see Curve)	400 mW
Differential Input Voltage	±15V
Input Voltage	Equal to supply voltages
Peak Load Current	±100 mA
Storage Temperature Range	−55°C to +125°C
Operating Temperature Range	0°C to 85°C
Lead Temperature (soldering, 10 sec)	300°C

electrical characteristics

PARAMETER	CONDITIONS	LH0005C MIN	LH0005C TYP (Note 2)	LH0005C MAX	UNITS
Input Offset Voltage	$R_S \leq 20\ k\Omega$		3	10	mV
Input Offset Current			5	25	nA
Input Bias Current			20	100	nA
Large Signal Voltage Gain	$R_L = 10K$, $R2 = 3K$, $V_{OUT} = \pm 5V$	2	5		V/mV
Output Voltage Swing	$R_L = 10\ k\Omega$ $R_L = 100\Omega$	−10 −4	 ±6	+6 +4	V V
Input Resistance	$T_A = 25°C$	0.5	2		MΩ
Common Mode Rejection Ratio	$V_{IN} = \pm 4V$, $R_S \leq 20\ k\Omega$, $T_A = 25°C$	50	60		dB
Power Supply Rejection Ratio	$T_A = 25°C$	50	60		dB
Supply Current (+)			3	5	mA
Supply Current (−)			2	4	mA

Note 1: These specifications apply for pin 6 grounded, $V_S = \pm 12V$, with Resistor R1 = 200Ω in series with Capacitor C1 = 75 pF from pin 4 to ground, and C2 = 200 pF between pins 9 and 10, over the temperature range of 0°C to +85°C unless otherwise specified.

Note 2: Typical values are for 25°C only.



Maximum Power Dissipation

2

Operational Amplifiers

LH0020/LH0020C* high gain instrumentation operational amplifier

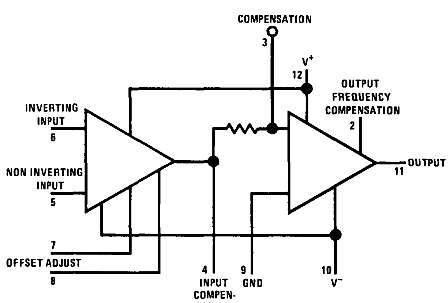
general description

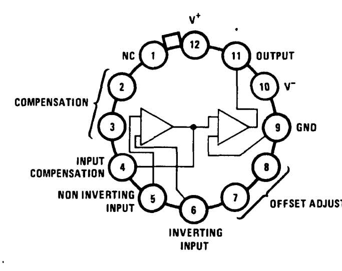
The LH0020/LH0020C is a general purpose operational amplifier designed to source and sink 50 mA output currents. In addition to its high output capability, the LH0020/LH0020C exhibits excellent open loop gain, typically in excess of 100 dB. The parameters of the LH0020 are guaranteed over the temperature range of −55°C to +125°C and ±15V ≤ V_S ≤ ±22V, while those of the LH0020C are guaranteed over the temperature range of 0°C to 85°C and ≤ ±5V ≤ V_S ≤ ±18V. Additional features include:

- Low offset voltage typically 1.0 mV at 25°C over the entire common mode voltage range.
- Low offset current typically 10 nA at 25°C for the LH0020 and 30 nA for the LH0020C.
- Offset voltage is adjustable to zero with a single potentiometer.
- ±14V, 50 mA output capability.

Output current capability, excellent input characteristics, and large open loop gain make the LH0020/LH0020C suitable for application in a wide variety of applications from precision dc power supplies to precision medium power comparator.

schematic and connection diagrams

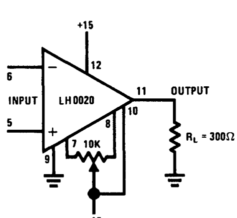




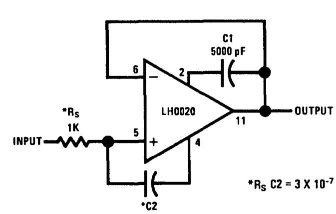
Order Number LH0020G or LH0020CG
See Package 6

typical applications

Offset Adjustment



Unity Gain Frequency Compensation



*Previously called NH0020/NH0020C

absolute maximum ratings

Supply Voltage		±22V
Power Dissipation		1.5W
Differential Input Voltage		±30V
Input Voltage (Note 1)		±15V
Output Short Circuit Duration		Continuous
Operating Temperature Range	LH0020	−55°C to +125°C
	LH0020C	0°C to 85°C
Storage Temperature		−65°C to +150°C
Lead Temperature (Soldering, 10 sec)		300°C

electrical characteristics

PARAMETER	CONDITIONS	LH0020				LH0020C				UNITS
		TEMP °C	MIN	TYP	MAX	TEMP °C	MIN	TYP	MAX	
Input Offset Voltage	$R_S \leq 10k$	25		1.0	2.5	25		1.0	6.0	mV
		−55 to +125		2.0	4.0	0 to 85		3.0	7.5	mV
Input Offset Current		25		10	50	25		30	200	nA
		−55 to +125			100	0 to 85			300	nA
Input Bias Current		25		60	250	25		200	500	nA
		−55 to +125			500	0 to 85			800	nA
Supply Current	$V_S = \pm15V$	25		3.5	5.0	25		3.6	6.0	mA
Input Resistance		25	0.6	1.0		25	0.3	1.0		MΩ
Large Signal Voltage Gain	$V_S = \pm15V, R_L = 300\Omega, V_O = \pm10V$	25	100	300		25	50	150		V/mV
	$V_S = \pm15V, R_L = 300\Omega, V_O = \pm10V$	−55 to +125	50			0 to 85	30			V/mV
Output Voltage Swing	$V_S = \pm15V, R_L = 300\Omega$	25	14.2	14.5		25	14.0	14.2		V
		−55 to +125	14.0			0 to 85	13.5			V
Output Short Circuit Current	$V_S = \pm15V$ $R_L = 0\Omega$	25		100	130	25	25	120	140	mA
Input Voltage Range	$V_S = \pm15V$	−55 to +125	±12			0 to 85	±12			V
										V
Common Mode Rejection Ratio	$R_S \leq 10k$	−55 to +125	90	96		0 to 85	90	96		dB
Power Supply Rejection Ratio	$R_S \leq 10k$	−55 to +125	90	96		0 to 85	90	96		dB

Note 1: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 2: These specifications apply for $\pm5V \leq V_S \leq \pm22V$ for the LH0020, $\pm5V \leq V_S \leq \pm18V$ for the LH0020C, pin 9 grounded, and a 5000 pF capacitor between pins 2 and 3, unless otherwise specified.

Operational Amplifiers

LH0021/LH0021C 1.0 amp power operational amplifier
LH0041/LH0041C 0.2 amp power operational amplifier

general description

The LH0021/LH0021C and LH0041/LH0041C are general purpose operational amplifiers capable of delivering large output currents not usually associated with conventional IC Op Amps. The LH0021 will provide output currents in excess of one ampere at voltage levels of ±12V; the LH0041 delivers currents of 200 mA at voltage levels closely approaching the available power supplies. In addition, both the inputs and outputs are protected against overload. The devices are compensated with a single external capacitor and are free of any unusual oscillation or latch-up problems.

features

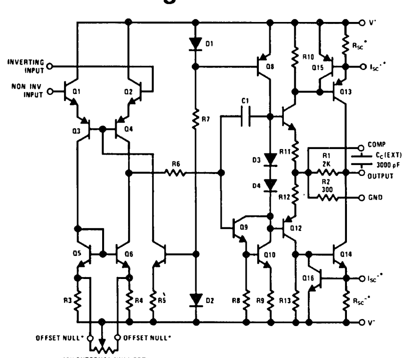
- Output current — 1.0 Amp (LH0021); 0.2 Amp (LH0041)
- Output voltage swing — ±12V into 10Ω (LH0021); ±14V into 100Ω (LH0041)
- Wide full power bandwidth — 15 kHz
- Low standby power — 100 mW at ±15V
- Low input offset voltage and current — 1 mV and 20 nA
- High slew rate — 3.0V/μs
- High open loop gain — 100 dB

The excellent input characteristics and high output capability of the LH0021 make it an ideal choice for power applications such as DC servos, capstan drivers, deflection yoke drivers, and programmable power supplies.

The LH0041 is particularly suited for applications such as torque driver for internal guidance systems, diddle yoke driver for alpha-numeric CRT displays, cable drivers, and programmable power supplies for automatic test equipment.

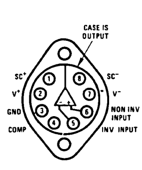
The LH0021 is supplied in a 8 pin TO-3 package rated at 20 watts with suitable heatsink. The LH0041 is supplied in both 12 pin TO-8 (2.5 watts with clip on heatsink) and a power 8 pin ceramic DIP (2 watts with suitable heatsink). The LH0021 and LH0041 are guaranteed over the temperature range of −55°C to +125°C while the LH0021C and LH0041C are guaranteed from −25°C to +85°C

schematic and connection diagrams



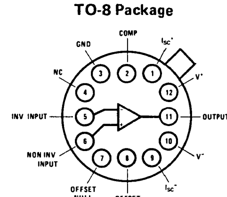
*R_{SC} external on TO-8 and TO-3 packages. R_{SC} internal on "J" package. Offset Null connections available only on TO-8 "G" package.

TO-3 Package



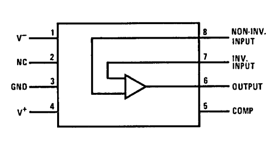
Order Number LH0021K or LH0021CK
See Package 19

TO-8 Package



Order Number LH0041G or LH0041CG
See Package 6

Ceramic DIP



Order Number LH0041CJ
See Package 15

absolute maximum ratings

Supply Voltage		±18V
Power Dissipation		See curves
Differential Input Voltage		±30V
Input Voltage (Note 1)		±15V
Peak Output Current (Note 2)	LH0021/LH0021C	2.0 Amps
	LH0041/LH0041C	0.5 Amps
Output Short Circuit Duration (Note 3)		Continuous
Operating Temperature Range	LH0021/LH0041	−55°C to +125°C
	LH0021C/LH0041C	−25°C to +85°C
Storage Temperature Range		−65°C to +150°C
Lead Temperature (Soldering, 10 sec)		300°C

dc electrical characteristics for LH0021/LH0021C (Note 4)

PARAMETER	CONDITIONS	LIMITS LH0021 MIN	LH0021 TYP	LH0021 MAX	LH0021C MIN	LH0021C TYP	LH0021C MAX	UNITS
Input Offset Voltage	$R_S \leq 10\ k\Omega$, $T_C = 25°C$		1.0	3.0		3.0	6.0	mV
	$R_S \leq 10\ k\Omega$			5.0			7.5	mV
Voltage Drift with Temperature	$R_S \leq 10\ k\Omega$		3	25		5	30	μV/°C
Offset Voltage Drift with Time			5			5		μV/week
Offset Voltage Change with Output Power			5	15		5	20	μV/watt
Input Offset Current	$T_C = 25°C$		30	100		50	200	nA
				300			500	nA
Offset Current Drift with Temperature			0.1	1.0		0.2	1.0	nA/°C
Offset Current Drift with Time			2			2		nA/week
Input Bias Current	$T_C = 25°C$		100	300		200	500	nA
				1.0			1.0	μA
Input Resistance	$T_C = 25°C$	0.3	1.0		0.3	1.0		MΩ
Input Capacitance			3			3		pF
Common Mode Rejection Ratio	$R_S \leq 10\ k\Omega$, $\Delta V_{CM} = \pm 10V$	70	90		70	90		dB
Input Voltage Range	$V_S = \pm 15V$	±12			±12			V
Power Supply Rejection Ratio	$R_S \leq 10\ k\Omega$, $\Delta V_S = \pm 10V$	80	96		70	90		dB
Voltage Gain	$V_S = \pm 15V$, $V_O = \pm 10V$ $R_L = 1\ k\Omega$, $T_C = 25°C$,	100	200		100	200		V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$ $R_L = 100\Omega$,	25			20			V/mV
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 100\Omega$	±13.5	14		±13	±14		V
	$V_S = \pm 15V$, $R_L = 10\Omega$	±11.0	±12		±10	±12		V
Output Short Circuit Current	$V_S = \pm 15V$, $T_C = 25°C$, $R_{SC} = 0.5\Omega$	0.8	1.2	1.6	0.8	1.2	1.6	Amps
Power Supply Current	$V_S = \pm 15V$, $V_{OUT} = 0$		2.5	3.5		3.0	4.0	mA
Power Consumption	$V_S = \pm 15V$, $V_{OUT} = 0$		75	105		90	120	mW

ac electrical characteristics for LH0021/LH0021C ($T_A = 25°C$, $V_S = \pm 15V$, $C_C = 3000\ pF$)

PARAMETER	CONDITIONS	LH0021 MIN	LH0021 TYP	LH0021 MAX	LH0021C MIN	LH0021C TYP	LH0021C MAX	UNITS
Slew Rate	$A_V = +1$, $R_L = 100\Omega$	1.5	3.0		1.0	3.0		V/μs
Power Bandwidth	$R_L = 100\Omega$		40			40		kHz
Small Signal Transient Response			0.3	1.0		0.3	1.5	μs
Small Signal Overshoot			5	20		10	30	%
Settling Time (0.1%)	$\Delta V_{IN} = 10V$, $A_V = +1$		4			4		μs
Overload Recovery Time			3			3		μs
Harmonic Distortion	f = 1 kHz, $P_O = 0.5W$		0.2			0.2		%
Input Noise Voltage	$R_S = 50\Omega$, B.W. = 10 Hz to 10 kHz		5			5		μV/rms
Input Noise Current	B.W. = 10 Hz to 10 kHz		0.05			0.05		nA/rms

dc electrical characteristics for LH0041/LH0041C (Note 4)

PARAMETER	CONDITIONS	LIMITS LH0041 MIN	LH0041 TYP	LH0041 MAX	LH0041C MIN	LH0041C TYP	LH0041C MAX	UNITS
Input Offset Voltage	$R_S \leq 10\ k\Omega$, $T_A = 25°C$ $R_S \leq 10\ k\Omega$		1.0	3.0 5.0		3.0	6.0 7.5	mV mV
Voltage Drift with Temperature	$R_S \leq 10\ k\Omega$		3			5		μV/°C
Offset Voltage Drift with Time			5			5		μV/week
Offset Voltage Change with Output Power			15			15		μV/watt
Offset Voltage Adjustment Range	(Note 5)		20			20		mV
Input Offset Current	$T_A = 25°C$		30	100 300		50	200 500	nA nA
Offset Current Drift with Temperature			0.1	1.0		0.2	1.0	nA/°C
Offset Current Drift with Time			2			2		nA/week
Input Bias Current	$T_A = 25°C$		100	300 1.0		200	500 1.0	nA μA
Input Resistance	$T_A = 25°C$	0.3	1.0		0.3	1.0		MΩ
Input Capacitance			3			3		pF
Common Mode Rejection Ratio	$R_S \leq 10\ k\Omega$, $\Delta V_{CM} = \pm10V$	70	90		70	90		dB
Input Voltage Range	$V_S = \pm15V$	±12			±12			V
Power Supply Rejection Ratio	$R_S \leq 10\ k\Omega$, $\Delta V_S = \pm10V$	80	96		70	90		dB
Voltage Gain	$V_S = \pm15V$, $V_O = \pm10V$ $R_L = 1\ k\Omega$, $T_A = 25°C$	100	200		100	200		V/mV
	$V_S = \pm15V$, $V_O = \pm10V$ $R_L = 100\Omega$	25			20			V/mV
Output Voltage Swing	$V_S = \pm15V$, $R_L = 100\Omega$	±13.0	14.0		±13.0	±14.0		V
Output Short Circuit Current	$V_S = \pm15V$, $T_A = 25°C$ (Note 6)		200	300		200	300	mA
Power Supply Current	$V_S = \pm15V$, $V_{OUT} = 0$		2.5	3.5		3.0	4.0	mA
Power Consumption	$V_S = \pm15V$, $V_{OUT} = 0$		75	105		90	120	mW

ac electrical characteristics for LH0041/LH0041C ($T_A = 25°C$, $V_S = \pm15V$, $C_C = 3000\ pF$)

PARAMETER	CONDITIONS	LH0041 MIN	LH0041 TYP	LH0041 MAX	LH0041C MIN	LH0041C TYP	LH0041C MAX	UNITS
Slew Rate	$A_V = +1$, $R_L = 100\Omega$	1.5	3.0		1.0	3.0		V/μs
Power Bandwidth	$R_L = 100\Omega$		40			40		kHz
Small Signal Transient Response			0.3	1.0		0.3	1.5	μs
Small Signal Overshoot			5	20		10	30	%
Settling Time (0.1%)	$\Delta V_{IN} = 10V$, $A_V = +1$		4			4		μs
Overload Recovery Time			3			3		μs
Harmonic Distortion	f = 1 kHz, $P_O = 0.5W$		0.2			0.2		%
Input Noise Voltage	$R_S = 50\Omega$, B.W. = 10 Hz to 10 kHz		5			5		μV/rms
Input Noise Current	B.W. = 10 Hz to 10 kHz		0.05			0.05		nA/rms

Note 1: Rating applies for supply voltages above ±15V. For supplies less than ±15V, rating is equal to supply voltage.

Note 2: Rating applies for LH0041G and LH0021K with $R_{SC} = 0\Omega$.

Note 3: Rating applies as long as package power rating is not exceeded.

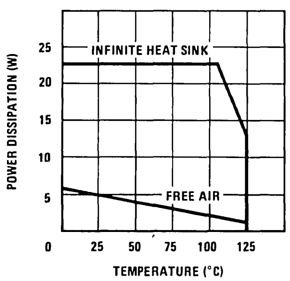
Note 4: Specifications apply for $\pm5V \leq V_S \pm18V$, and $-55°C \leq T_C = \leq 125°C$ for LH0021K and LH0041G, and $-25°C \leq T_C \leq +85°C$ for LH0021CK, LH0041CG and LH0041CJ unless otherwise specified. Typical values are for 25°C only.

Note 5: TO-8 "G" packages only.

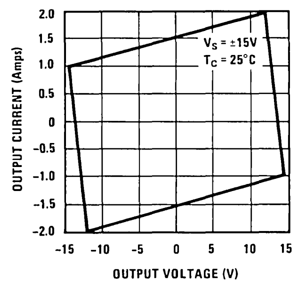
Note 6: Rating applies for "J" DIP package and for TO-8 "G" package with $R_{SC} = 3.3$ ohms.

typical performance characteristics

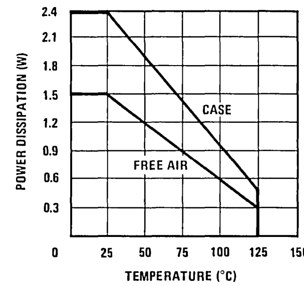
Power Derating-LH0021



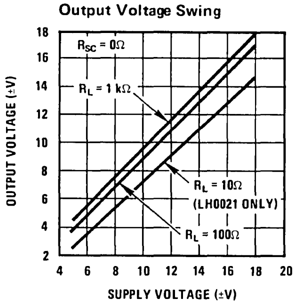
Safe Operating Area – LH0021



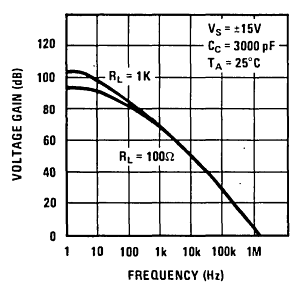
Package Power Dissipation LH0041/LH0041C



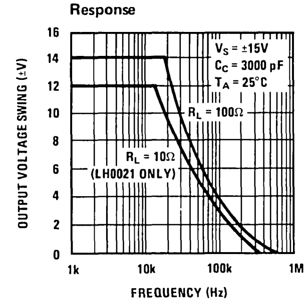
Output Voltage Swing



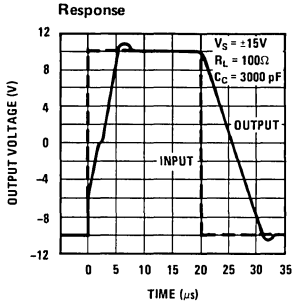
Open Loop Frequency Response



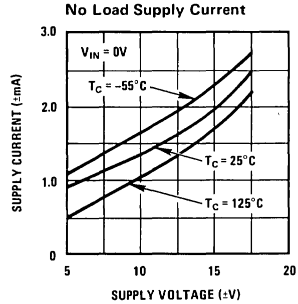
Large Signal Frequency Response



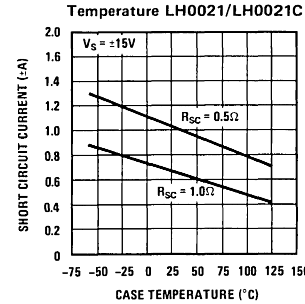
Voltage Follower Pulse Response



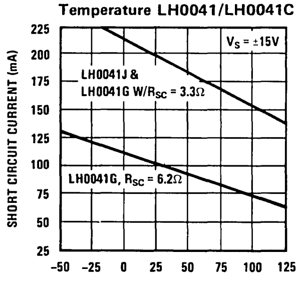
No Load Supply Current



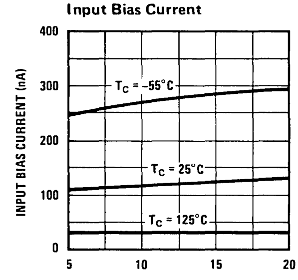
Short Circuit Current vs Temperature LH0021/LH0021C



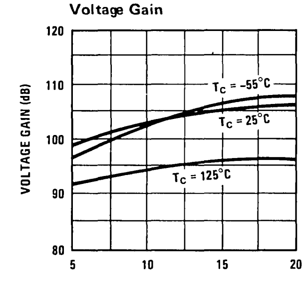
Short Circuit Current vs Temperature LH0041/LH0041C



Input Bias Current

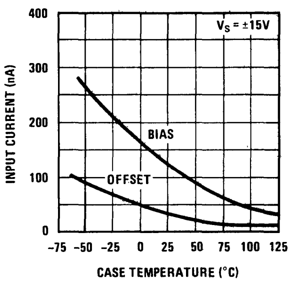


Voltage Gain

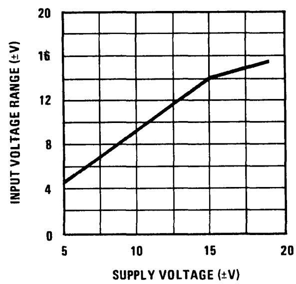


typical performance characteristics (con't)

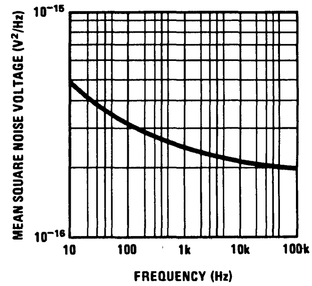
Input Current



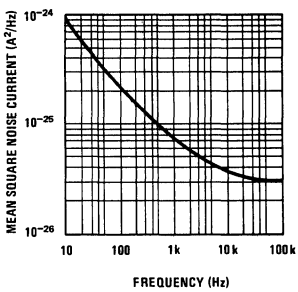
Input Voltage Range



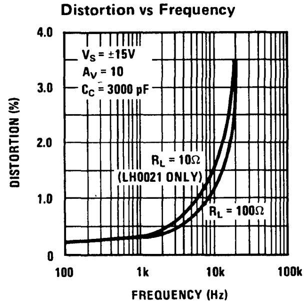
Input Noise Voltage



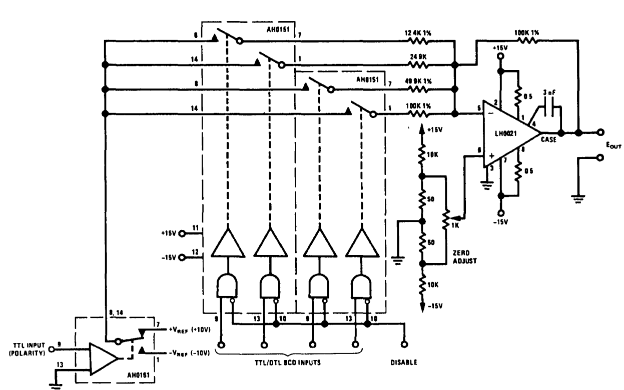
Input Noise Current



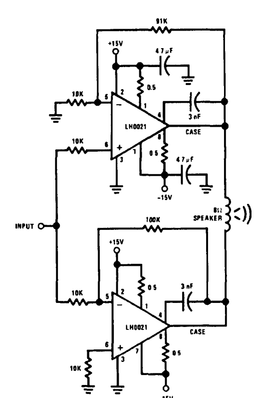
Distortion vs Frequency



typical applications

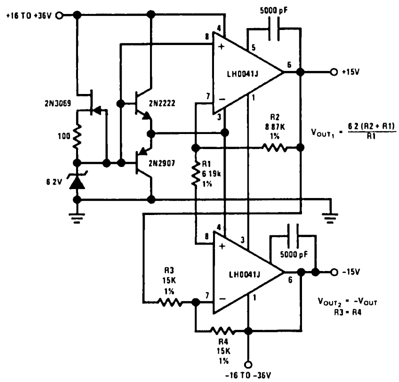


Programmable One Amp Power Supply

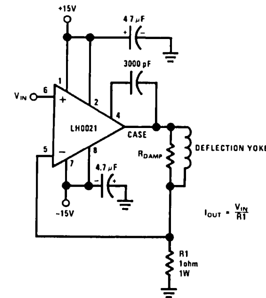


35 WATT (rms) Audio Amplifier

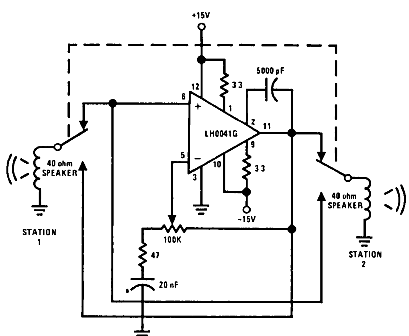
typical applications (con't)



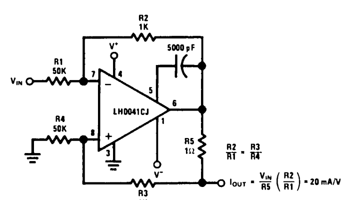
Dual Tracking One Amp Power Supply



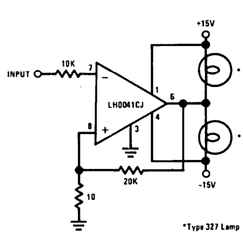
CRT Deflection Yoke Driver



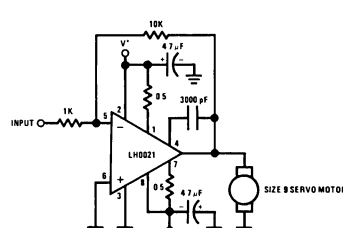
Two Way Intercom



Programmable High Current Source/Sink

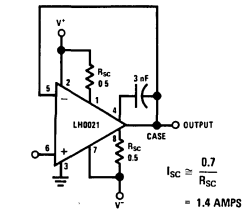


Power Comparator

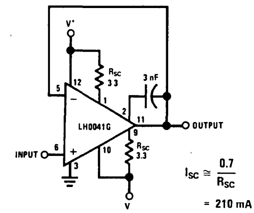


DC Servo Amplifier

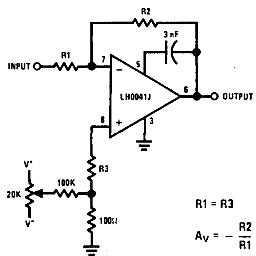
auxiliary circuits



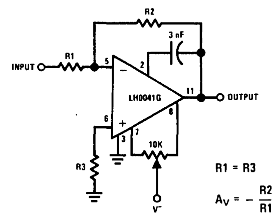
LH0021 Unity Gain Circuit with Short Circuit Limiting



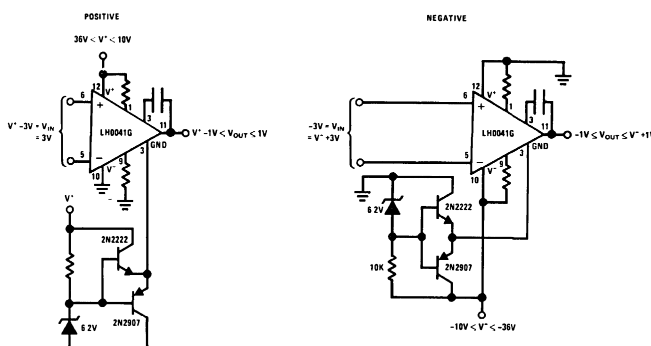
LH0041G Unity Gain with Short Circuit Limiting



LH0041/LH0021 Offset Voltage Null Circuit (LH0041CJ Pin Connections Shown)*

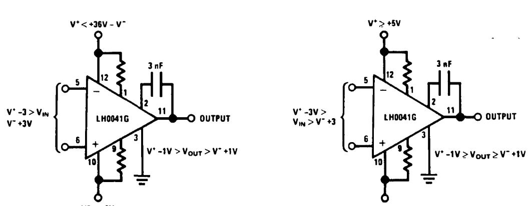


LH0041G Offset Voltage Null Circuit*



*Pins shown for TO-8 package.

Operation from Single Supplies



Operation from Non-Symmetrical Supplies

*For additional offset null circuit techniques see National Linear Applications Handbook.

Operational Amplifiers

LH0022/LH0022C* high performance FET op amp
LH0042/LH0042C low cost FET op amp
LH0052/LH0052C precision FET op amp

general description

The LH0022/LH0042/LH0052 are a family of FET input operational amplifiers with very closely matched input characteristics, very high input impedance, and ultra-low input currents with no compromise in noise, common mode rejection ratio, open loop gain, or slew rate. The internally laser nulled LH0052 offers 200 microvolts maximum offset and 5 μV/°C offset drift. Input offset current is less than 100 femtoamps at room temperature and 100 pA maximum at 125°C. The LH0022 and LH0042 are not internally nulled but offer comparable matching characteristics. All devices in the family are internally compensated and are free of latch-up and unusual oscillation problems. The devices may be offset nulled with a single 10k trimpot with neglible effect in CMRR.

The LH0022, LH0042 and LH0052 are specified for operation over the –55°C to +125°C military temperature range. The LH0022C, LH0042C and LH0052C are specified for operation over the –25°C to +85°C temperature range.

features

- Low input offset current — 100 femtoamps max. (LH0052)
- Low input offset drift — 5μV/°C max (LH0052)
- Low input offset voltage — 100 microvolts-typ.
- High open loop gain — 100 dB typ.
- Excellent slew rate — 3.0 V/μs typ.
- Internal 6 dB/octave frequency compensation
- Pin compatible with standard IC op amps (TO-5 package)

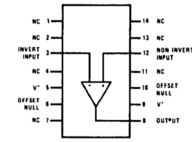
The LH0022/LH0042/LH0052 family of IC op amps are intended to fulfill a wide variety of applications for process control, medical instrumentation, and other systems requiring very low input currents and tightly matched input offsets. The LH0052 is particularly suited for long term high accuracy integrators and high accuracy sample and hold buffer amplifiers. The LH0022 and LH0042 provide low cost high performance for such applications as electrometer and photocell amplification, pico-ammeters, and high input impedance buffers.

Special electrical parameter selection and custom built circuits are available on special request.

2

schematic and connection diagrams

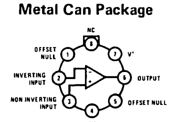
Dual-In-Line Package



TOP VIEW

Order Number LH0022D or LH0022CD or LH0042D or LH0042CD or LH0052D or LH0052CD
See Package 1

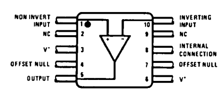
Metal Can Package



TOP VIEW

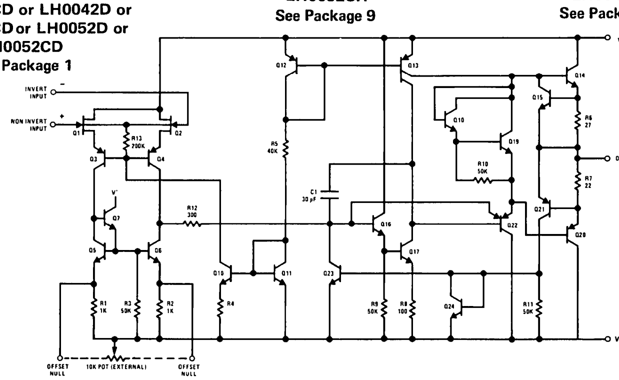
Order Number LH0022H or LH0022CH or LH0042H or LH0042CH or LH0052H or LH0052CH
See Package 9

Flat-Package



TOP VIEW

Order Number LH0022F or LH0022CF or LH0042F or LH0042CF
See Package 3



*Previously Called NH0022/NH0022C

absolute maximum ratings

Supply Voltage	±22V
Power Dissipation (see graph)	500 mW
Input Voltage (Note 1)	±15V
Differential Input Voltage (Note 2)	±30V
Voltage Between Offset Null and V^-	±0.5V
Short Circuit Duration	Continuous
Operating Temperature Range	
LH0022, LH0042, LH0052	-55°C to +125°C
LH0022C, LH0042C, LH0052C	-25°C to +85°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

dc electrical characteristics For LH0022/LH0022C (Note 3)

PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0022			LH0022C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$R_S \le 100\ k\Omega$; $T_A = 25°C$		2.0	4.0		3.5	6.0	mV
	$R_S \le 100\ k\Omega$			5.0			10.0	mV
Temperature Coefficient of Input Offset Voltage	$R_S \le 100\ k\Omega$		5	10		5	15	μV/°C
Offset Voltage Drift with Time			3			4		μV/week
Input Offset Current	$T_A = 25°C$		0.2	2.0		1.0	5.0	pA
				200			200	pA
Temperature Coefficient of Input Offset Current			Doubles every 10°C			Doubles every 10°C		
Offset Current Drift with Time			0.1			0.1		pA/week
Input Bias Current	$T_A = 25°C$		5	10		10	25	pA
				10			22	nA
Temperature Coefficient of Input Bias Current			Doubles every 10°C			Doubles every 10°C		
Differential Input Resistance			10^{12}			10^{12}		Ω
Common Mode Input Resistance			10^{12}			10^{12}		Ω
Input Capacitance			4.0			4.0		pF
Input Voltage Range	$V_S = \pm 15V$	±12	±13.5		±12	±13.5		V
Common Mode Rejection Ratio	$R_S \le 10\ k\Omega$, $V_{IN} = \pm 10V$	80	90		70	90		dB
Supply Voltage Rejection Ratio	$R_S \le 10\ k\Omega$, $\pm 5V \le V_S \le \pm 15V$	80	90		70	90		dB
Large Signal Voltage Gain	$R_L = 2\ k\Omega$, $V_{OUT} = \pm 10V$, $T_A = 25°C$, $V_S = \pm 15V$	100	200		75	160		V/mV
	$R_L = 2\ k\Omega$, $V_{OUT} = \pm 10V$, $V_S = \pm 15V$	50			50			V/mV
Output Voltage Swing	$R_L = 1\ k\Omega$, $T_A = 25°C$, $V_S = \pm 15V$	±10	±12.5		±10	±12		V
	$R_L = 2\ k\Omega$, $V_S = \pm 15V$	±10			±10			V
Output Current Swing	$V_{OUT} = \pm 10V$, $T_A = 25°C$	±10	±15		±10	±15		mA
Output Resistance			75			75		Ω
Output Short Circuit Current			25			25		mA
Supply Current	$V_S = \pm 15V$		2.0	2.5		2.4	2.8	mA
Power Consumption	$V_S = \pm 15V$			75			85	mW

dc electrical characteristics for LH0042/LH0042C

(T_A = 25°C, V_S = ±15V; unless otherwise specified)

PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0042			LH0042C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$R_S \leq 100\ k\Omega$; $\pm 5V \leq V_S \leq 20V$		5.0	20		6.0	20	mV
Temperature Coefficient of Input Offset Voltage	$R_S \leq 100\ k\Omega$		5			10		µV/°C
Offset Voltage Drift with Time			7			10		µV/week
Input Offset Current			1	5		2	10	pA
Temperature Coefficient of Input Offset Current		Doubles every 10°C			Doubles every 10°C			
Offset Current Drift with Time			0.1			0.1		pA/week
Input Bias Current			10	25		15	50	pA
Temperature Coefficient of Input Bias Current		Doubles every 10°C			Doubles every 10°C			
Differential Input Resistance			10^{12}			10^{12}		Ω
Common Mode Input Resistance			10^{12}			10^{12}		Ω
Input Capacitance			4.0			4.0		pF
Input Voltage Range		±12	±13.5		±12	±13.5		V
Common Mode Rejection Ratio	$R_S \leq 10\ k\Omega$, V_{IN} = ±10V	70	86		70	80		dB
Supply Voltage Rejection Ratio	$R_S \leq 10\ k\Omega$, $\pm 5V \leq V_S \leq \pm 15V$	70	86		70	80		dB
Large Signal Voltage Gain	R_L = 1 kΩ, V_{OUT} = ±10V	50	150		25	100		V/mV
Output Voltage Swing	R_L = 1 kΩ	±10	±12.5		±10	±12		V
Output Current Swing	V_{OUT} = ±10V	±10	±15		±10	±15		mA
Output Resistance			75			75		Ω
Output Short Circuit Current			20			20		mA
Supply Current			2.5	3.5		2.8	4.0	mA
Power Consumption				105			120	mW

dc electrical characteristics For LH0052/LH0052C (Note 3)

PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0052			LH0052C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$R_S \leq 100\ k\Omega$; V_S = ±15V, T_A = 25°C		0.1	0.5		0.2	1.0	mV
	$R_S \leq 100\ k\Omega$, V_S = ±15V			1.0			1.5	mV
Temperature Coefficient of Input Offset Voltage	$R_S \leq 100\ k\Omega$		2	5		5	10	µV/°C
Offset Voltage Drift with Time			2			4		µV/week
Input Offset Current	T_A = 25°C		0.01	0.1		0.02	0.2	pA
				100			100	pA
Temperature Coefficient of Input Offset Current		Doubles every 10°C			Doubles every 10°C			
Offset Current Drift with Time			<0.1			<0.1		pA/week
Input Bias Current	T_A = 25°C		0.5	1.0		1.0	5.0	pA
				500			500	pA
Temperature Coefficient of Input Bias Current		Doubles every 10°C			Doubles every 10°C			
Differential Input Resistance			10^{12}			10^{12}		Ω
Common Mode Input Resistance			10^{12}			10^{12}		Ω
Input Capacitance			4.0			4.0		pF
Input Voltage Range	V_S = ±15V	±12	±13.5		±12	±13.5		V
Common Mode Rejection Ratio	$R_S \leq 10\ k\Omega$, V_{IN} = ±10V	80	90		76	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 10\ k\Omega$, $\pm 5V \leq V_S \leq \pm 15V$	80	90		76	90		dB
Large Signal Voltage Gain	R_L = 2 kΩ, V_{OUT} = ±10V, V_S = ±15V, T_A = 25°C	100	200		75	160		V/mV
	R_L = 2 kΩ, V_{OUT} = ±10V, V_S = ±15V	50			50			V/mV
Output Voltage Swing	R_L = 1 kΩ, T_A = 25°C V_S = ±15V	±10	±12.5		±10	±12		V
	R_L = 2 kΩ, V_S = ±15V	±10			±10			V
Output Current Swing	V_{OUT} = ±10V, T_A = 25°C	±10	±15		±10	±15		mA
Output Resistance			75			75		Ω
Output Short Circuit Current			25			25		mA
Supply Current	V_S = ±15V		3.0	3.5		3.0	3.8	mA
Power Consumption	V_S = ±15V			10.5			114	mW

ac electrical characteristics For all amplifiers ($T_A = 25°C$, $V_S = \pm15V$)

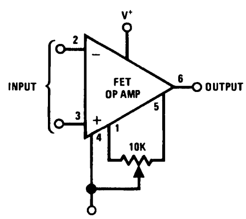
PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0022/42/52			LH0022C/42C/52C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Slew Rate	Voltage Follower	1.5	3.0		1.0	3.0		V/μs
Large Signal Bandwidth	Voltage Follower		40			40		kHz
Small Signal Bandwidth			1.0			1.0		MHz
Rise Time			0.3	1.5		0.3	1.5	μs
Overshoot			10	30		15	40	%
Settling Time (0.1 %)	$\Delta V_{IN} = 10V$		4.5			4.5		μs
Overload Recovery			4.0			4.0		μs
Input Noise Voltage	$R_S = 10\ k\Omega$, $f_o = 10\ Hz$		150			150		$nV/\sqrt{Hz}$
Input Noise Voltage	$R_S = 10\ k\Omega$, $f_o = 100\ Hz$		55			55		$nV/\sqrt{Hz}$
Input Noise Voltage	$R_S = 10\ k\Omega$, $f_o = 1\ kHz$		35			35		$nV/\sqrt{Hz}$
Input Noise Voltage	$R_S = 10\ k\Omega$, $f_o = 10\ kHz$		30			30		$nV/\sqrt{Hz}$
Input Noise Voltage	BW = 10 Hz to 10 kHz, $R_S = 10\ k\Omega$		12			12		μVrms
Input Noise Current	BW = 10 Hz to 10 kHz		<.1			<.1		pArms

Note 1: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

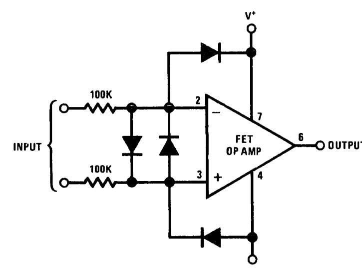
Note 2: Rating applies for minimum source resistance of 10 kΩ, for source resistances less than 10 kΩ, maximum differential input voltage is ±5V.

Note 3: Unless otherwise specified, these specifications apply for $\pm5V \le V_S \le \pm20V$ and $-55°C \le T_A \le \pm125°C$ for the LH0022, LH0042 and LH0052 and $-25°C \le T_A$ +85°C for the LH0022C and LH0052C. Typical values are given for $T_A = 25°C$.

auxiliary circuits (shown for TO-5 pin out)

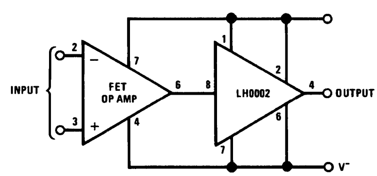


Offset Null



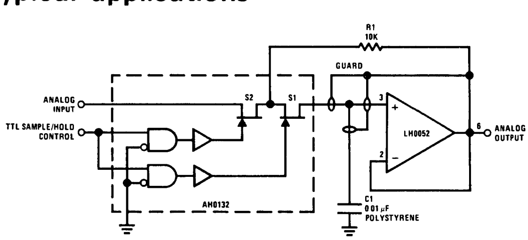
Note: All diodes are ultra low leakage.

Protecting Inputs From ±150V Transients

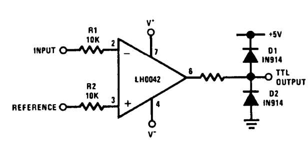


Boosting Output Drive to ±100 mA

typical applications

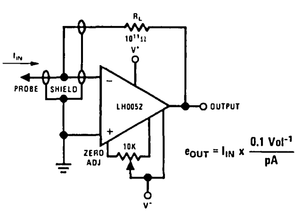


Alternate Low Drift Sample

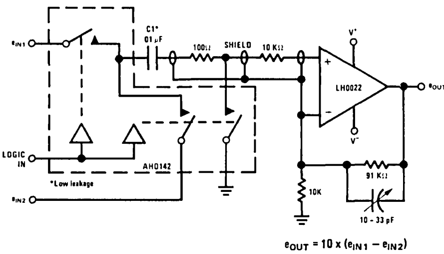


Precision Voltage Comparator

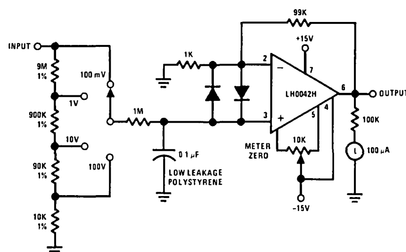
typical applications (con't)



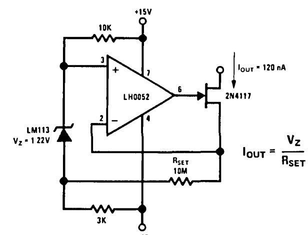
Picoamp Amplifier for pH Meters
and Radiation Detectors



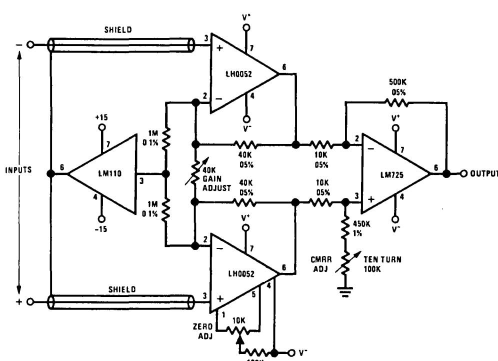
Precision Subtractor for
Automatic Test Gear



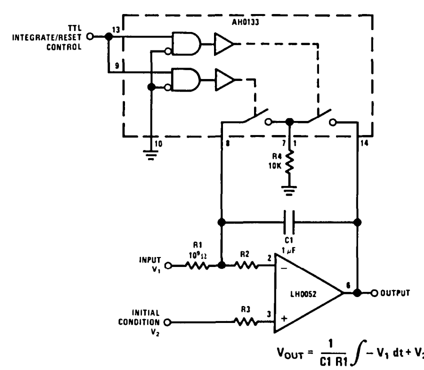
Sensitive Low Cost "VTVM"



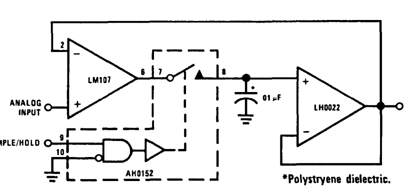
Ultra Low Level Current Source



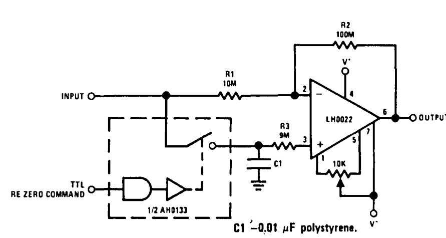
True Instrumentation Amplifier



Precision Integrator



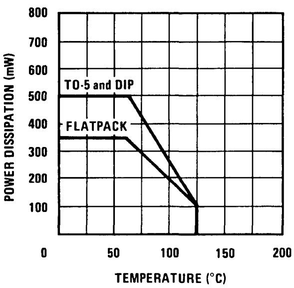
Precision Sample and Hold



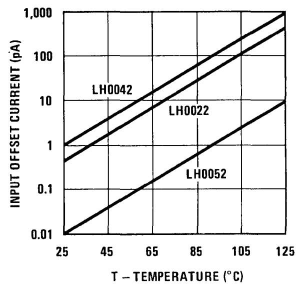
Re-Zeroing Amplifier

typical performance characteristics

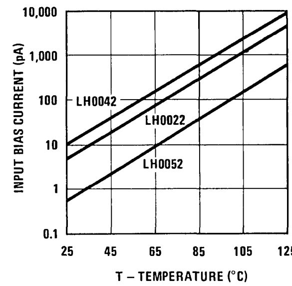
Maximum Power Dissipation



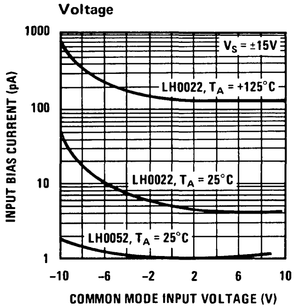
Input Offset Current vs Temperature



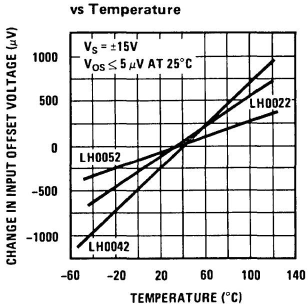
Input Bias Current vs Temperature



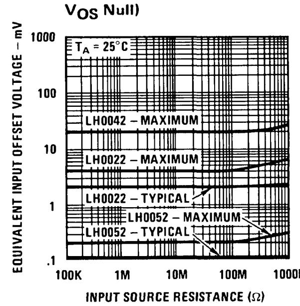
Input Bias Current vs Input Voltage



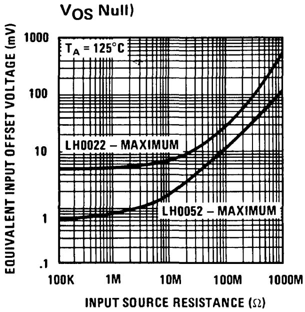
Input Offset Current vs Temperature



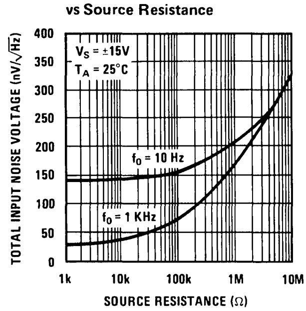
Offset Error (Without V_{OS} Null)



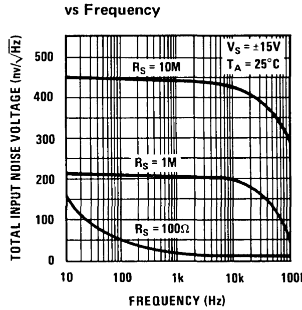
Offset Error (Without V_{OS} Null)



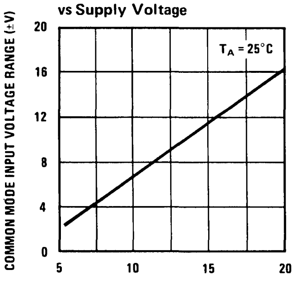
Total Input Noise Voltage* vs Source Resistance



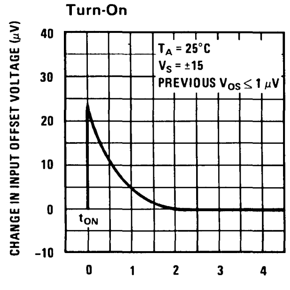
Total Input Noise Voltage* vs Frequency



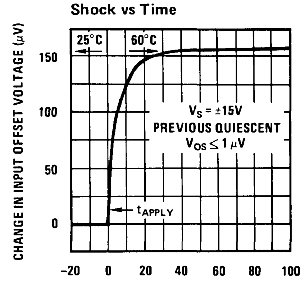
Common Mode Input Voltage vs Supply Voltage



Stabilization Time of Input Offset Voltage from Power Turn-On



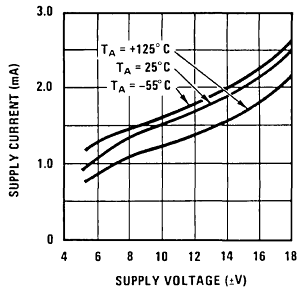
Change in Input Offset Voltage Due to Thermal Shock vs Time



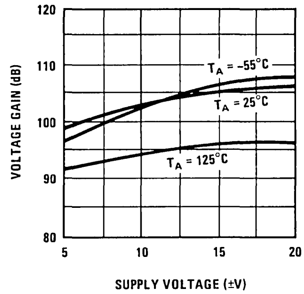
*Noise Voltage Includes Contribution from Source Resistance

typical performance characteristics (con't)

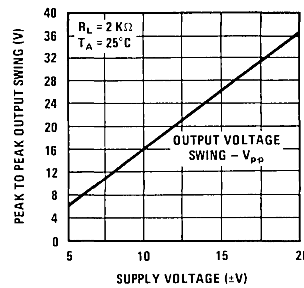
Supply Voltage vs Supply Current



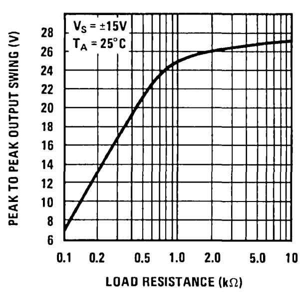
Voltage Gain



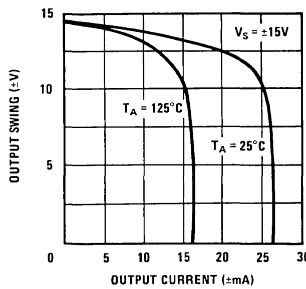
Output Swing vs Supply Voltage



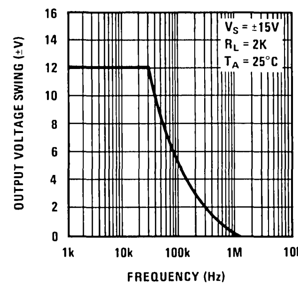
Output Voltage Swing vs Load Resistance



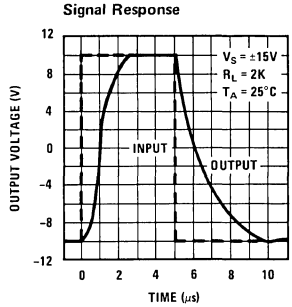
Current Limiting



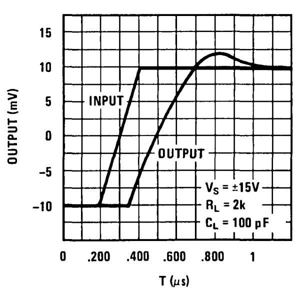
Output Voltage Swing vs Frequency



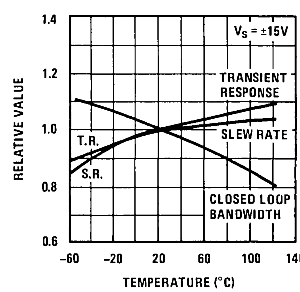
Voltage Follower Large Signal Response



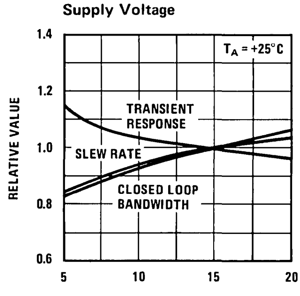
Transient Response



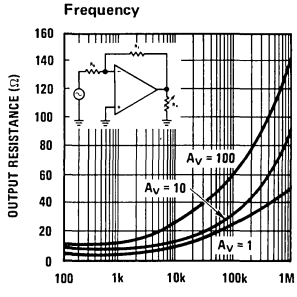
Frequency Characteristics vs Ambient Temperature



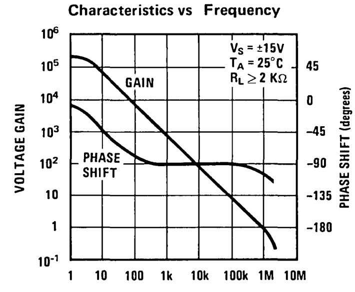
Frequency Characteristics vs Supply Voltage



Output Resistance vs Frequency



Open Loop Transfer Characteristics vs Frequency



Operational Amplifiers

LH0023/LH0023C, LH0043/LH0043C sample and hold circuits

general description

The LH0023/LH0023C and LH0043/LH0043C are complete sample and hold circuits including input buffer amplifier, FET output amplifier, analog signal sampling gate, TTL compatible logic circuitry and level shifting. They are designed to operate from standard ±15V DC supplies, but provision is made on the LH0023/LH0023C for connection of a separate +5V logic supply in minimum noise applications. The principal difference between the LH0023/LH0023C and the LH0043/LH0043C is a 10:1 trade-off in performance on sample accuracy vs sample acquisition time. Devices are pin compatible except that TTL logic is inverted between the two types.

The LH0023/LH0023C and LH0043/LH0043C are ideally suited for a wide variety of sample and hold applications including data acquisition, analog to digital conversion, synchronous demodulation, and automatic test setup. They offer significant cost and size reduction over equivalent module or discrete designs. Each device is available in a hermetic TO-8 package and are completely specified over both full military and instrument temperature ranges.

The LH0023 and LH0043 are specified for operation over the −55°C to +125°C military temperature range. The LH0023C and LH0043C are specified for operation over the −25°C to +85°C temperature range.

features

LH0023/LH0023C

- Sample accuracy—0.01% max
- Hold drift rate—0.5 mV/sec typ
- Sample acquisition time—100 μs max for 20V
- Aperture time—150 ns typ
- Wide analog range—±10V min
- Logic input—TTL/DTL
- Offset adjustable to zero with single 10k pot
- Output short circuit proof

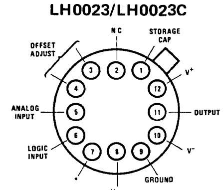
features

LH0043/LH0043C

- Sample acquisition time—15 μs max for 20V; 4 μs typ for 5V
- Aperture time—20 nS typ
- Hold drift rate—1 mV/sec typ
- Sample accuracy—0.1% max
- Wide analog range—±10V min
- Logic input—TTL/DTL
- Offset adjustable to zero with single 10k pot
- Output short circuit proof

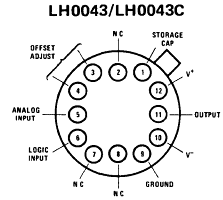
block and connection diagrams

LH0023/LH0023C

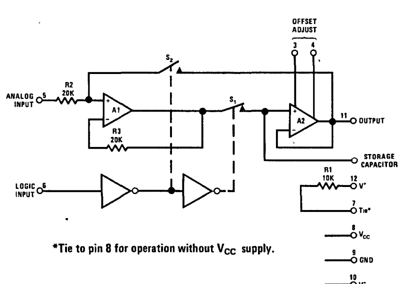


*Tie for operation with V+ = 15V only

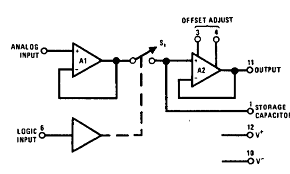
LH0043/LH0043C



Order Number LH0023G or LH0023CG or LH0043G or LH0043CG
See Package 6



*Tie to pin 8 for operation without V_{CC} supply.



absolute maximum ratings

Supply Voltage (V^+ and V^-)		±20V
Logic Supply Voltage (V_{CC}) LH0023, LH0023C		+7.0V
Logic Input Voltage (V_6)		+5.5V
Analog Input Voltage (V_5)		±15V
Power Dissipation		See graph
Output Short Circuit Duration		Continuous
Operating Temperature Range	LH0023, LH0043	−55°C to +125°C
	LH0023C, LH0043C	−25°C to +85°C
Storage Temperature Range		−65°C to +150°C
Lead Soldering (10 sec)		300°C

electrical characteristics LH0023/LH0023C (Note 1)

PARAMETER	CONDITIONS	LIMITS LH0023 MIN	TYP	MAX	LH0023C MIN	TYP	MAX	UNITS
Sample (Logic "1") Input Voltage	V_{CC} = 4.5V	2.0			2.0			V
Sample (Logic "1") Input Current	V_6 = 2.4V, V_{CC} = 5.5V			5.0			5.0	µA
Hold (Logic "0") Input Voltage	V_{CC} = 4.5V			0.8			0.8	V
Hold (Logic "0") Input Current	V_6 = 0.4V, V_{CC} = 5.5V			0.5			0.5	mA
Analog Input Voltage Range		±10	±11		±10	±11		V
Supply Current — I_{10}	V_5 = 0V, V_6 = 2V, V_{11} = 0V		4.5	6		4.5	6	mA
Supply Current — I_{12}	V_5 = 0V, V_6 = 0.4V, V_{11} = 0V		4.5	6		4.5	6	mA
Supply Current — I_8	V_8 = 5.0V, V_5 = 0		1.0	1.6		1.0	1.6	mA
Sample Accuracy	V_{OUT} = ±10V (Full Scale)		0.002	0.01		0.002	0.02	%
DC Input Resistance	Sample Mode	500	1000		300	1000		kΩ
	Hold Mode	20	25		20	25		kΩ
Input Current — I_5	Sample Mode		0.2	1.0		0.3	1.5	µA
Input Capacitance			3.0			3.0		pF
Leakage Current — pin 1	V_5 = ±10V; V_{11} = ±10V, T_A = 25°C		100	200		200	500	pA
	V_5 = ±10V; V_{11} = ±10V		0.6	1.0		1.0	2	nA
Drift Rate	V_{OUT} = ±5V, C_S = 0.01 µF, T_A = 25°C		0.5			0.5		mV/s
Drift Rate	V_{OUT} = ±10V, C_S = 0.01 µF, T_A = 25°C		10	20		20	50	mV/s
Drift Rate	V_{OUT} = ±10V, C_S = 0.01 µF			0.1			0.2	mV/ms
Aperture Time			150			150		ns
Sample Acquisition Time	ΔV_{OUT} = 20V, C_S = 0.01 µF		50	100		50	100	µs
Output Amplifier Slew Rate		1.5	3.0		1.5	3.0		V/µs
Output Offset Voltage (without null)	$R_S \leq$ 10k, V_5 = 0V, V_6 = 0V			±20			±20	mV
Analog Voltage Output Range	$R_L \geq$ 1k, T_A = 25°C	±10	±11		±10	±11		V
	$R_L \geq$ 2k	±10	±12		±10	±12		V

Note 1: Unless otherwise noted, these specifications apply for V^+ = +15V, V_{CC} = +5V, V^- = −15V, pin 9 grounded, a 0.01µF capacitor connected between pin 1 and ground over the temperature range −55°C to +125°C for the LH0023, and −25°C to +85°C for the LH0023C. All typical values are for T_A = 25°C.

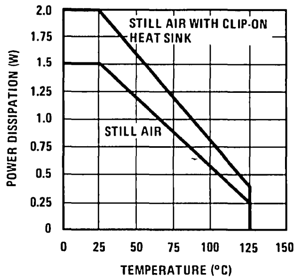
electrical characteristics LH0043/LH0043C: (Note 2)

PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0043			LH0043C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Hold (Logic "1") Input Voltage		2.0			2.0			V
Hold (Logic "1") Input Current	$V_6 = 2.4V$			5.0			5.0	μA
Sample (Logic "0") Input Voltage				0.8			0.8	V
Sample (Logic "0") Input Current	$V_6 = 0.4V$			1.5			1.5	mA
Analog Input Voltage Range		±10	±11		±10	±11		V
Supply Current	$V_5 = 0V$, $V_6 = 2V$, $V_{11} = 0V$		20	22		20	22	mA
	$V_5 = 0V$, $V_6 = 0.4V$, $V_{11} = 0V$		14	18		14	18	mA
Sample Accuracy	$V_{OUT} = \pm 10V$ (Full Scale)		0.02	0.1		0.02	0.3	%
DC Input Resistance	$T_C = 25°C$	10^{10}	10^{12}		10^{10}	10^{12}		Ω
Input Current – I_5			1.0	5.0		2.0	10.0	nA
Input Capacitance			1.5			1.5		pF
Leakage Current–pin 1	$V_5 = \pm 10V$; $V_{11} = \pm 10$, $T_C = 25°C$		10	25		20	50	pA
	$V_5 = \pm 10V$; $V_{11} = \pm 10V$		10	25		2	5	nA
Drift Rate	$V_{OUT} = \pm 10V$, $C_S = 0.001\ \mu F$, $T_A = 25°C$		10	25		20	50	mV/s
Drift Rate	$V_{OUT} = \pm 10V$, $C_S = 0.001\ \mu F$		10	25		2	5	mV/ms
Drift Rate	$V_{OUT} = \pm 10V$, $C_S = 0.01\ \mu F$, $T_A = 25°C$		1	2.5		2	5	mV/s
Drift Rate	$V_{OUT} = \pm 10V$, $C_S = 0.01\ \mu F$		1	2.5		0.2	0.5	mV/ms
Aperture Time			20	60		20	60	ns
Sample Acquisition Time	$\Delta V_{OUT} = 20V$, $C_S = 0.001\ \mu F$		10	15		10	15	μs
	$\Delta V_{OUT} = 20V$, $C_S = 0.01\ \mu F$		30	50		30	50	μs
	$\Delta V_{OUT} = 5V$, $C_S = 0.001\ \mu F$		4			4		μs
Output Amplifier Slew Rate	$V_{OUT} = 5V$, $C_S = 0.001\ \mu F$	1.5	3.0		1.5	3.0		$V/\mu s$
Output Offset Voltage (without null)	$R_S \leq 10k$, $V_5 = 0V$, $V_6 = 0V$			±40			±40	mV
Analog Voltage Output Range	$R_L \geq 1k$, $T_A = 25°C$	±10	±11		±10	±11		V
	$R_L \geq 2k$	±10	±12		±10	±12		V

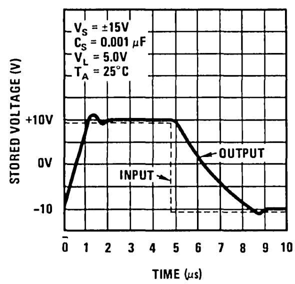
Note 2: Unless otherwise noted, these specifications apply for $V^+ = +15V$, $V^- = -15V$, pin 9 grounded, a 5000 pF capacitor connected between pin 1 and ground over the temperature range –55°C to +125°C for the LH0043, and –25°C to +85°C for the LH0043C. All typical values are for $T_C = 25°C$.

typical performance characteristics

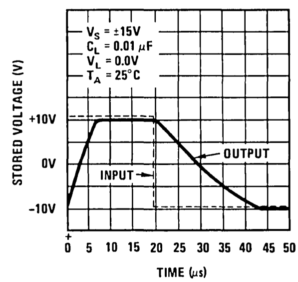
Power Dissipation



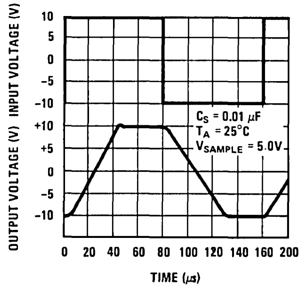
Sample Acquisition Time—LH0043



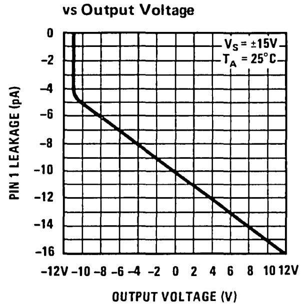
Sample Acquisition Time—LH0043



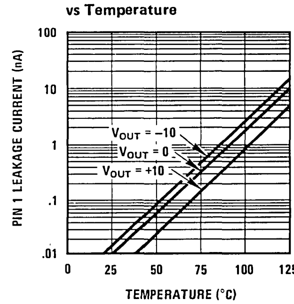
Sample Acquisition Time—LH0023



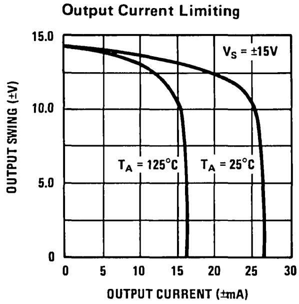
Pin 1 Leakage Current vs Output Voltage



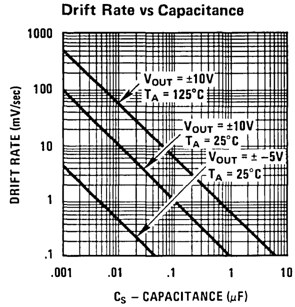
Pin 1 Leakage Current vs Temperature



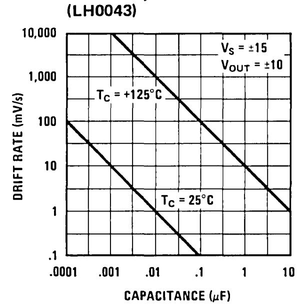
Output Current Limiting



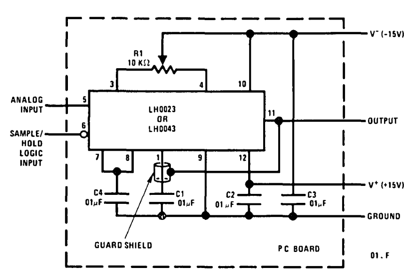
Drift Rate vs Capacitance



Drift vs Capacitance (LH0043)



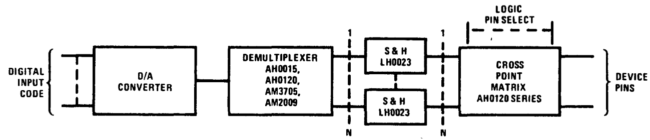
typical applications



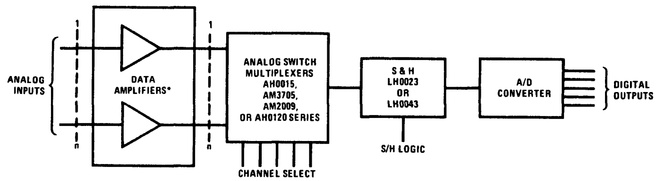
Note 1: C1 is polystyrene.
Note 2: C2, C3, C4 are cermic disc.
Note 3: Jumper 7–8 and C4 not required for LH0043.
Note 4: R1 optional if zero trim is required.

How to Build a Sample and Hold Module

typical applications (con't)

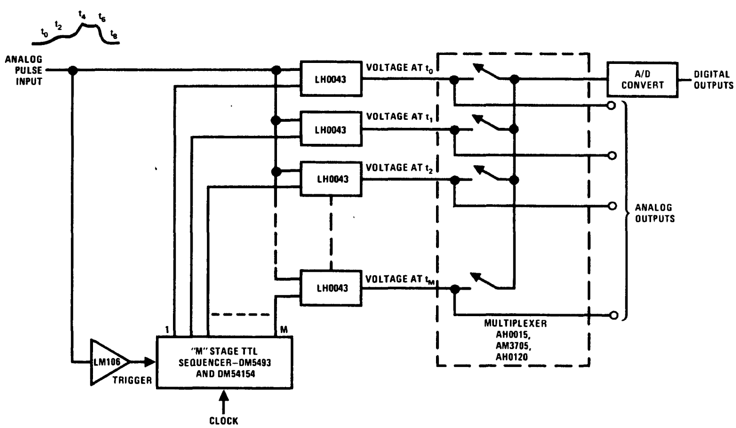


Forcing Function Setup for Automatic Test Gear

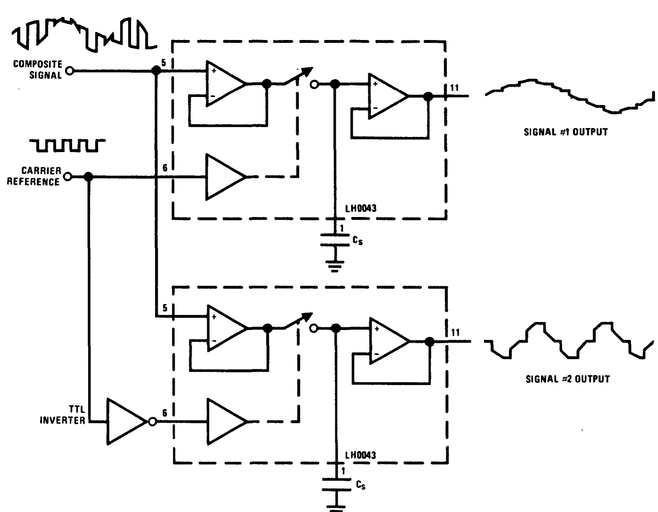


*See op amp selection guide for details. Most popular types include LH0052, LH175, LM108, LM112 and LM116.

Data Acquisition System



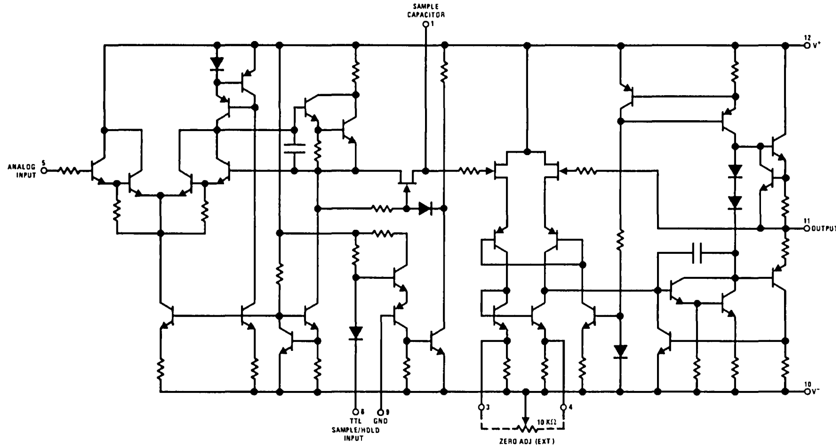
Single Pulse Sampler



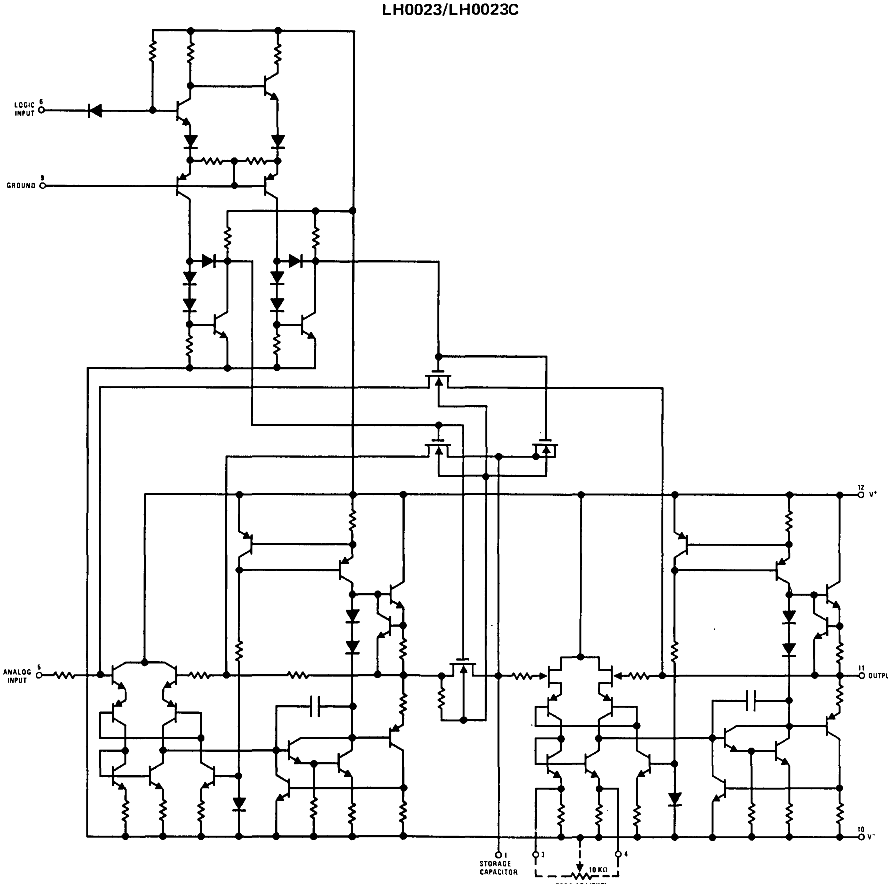
Two Channel Double Sideband Demodulator

schematic diagrams

LH0043/LH0043C



LH0023/LH0023C



2

applications information

1.0 Drift Error Minimization

In order to minimize drift error, care in selection of C_S and layout of the printed circuit board is required. The capacitor should be of high quality Teflon, polycarbonate, or polystyrene construction. Board cleanliness and layout are critical particularly at elevated temperatures. See AN-63 for detailed recommendations. A guard conductor connected to the output surrounding the storage node (pin 1) will be helpful in meeting severe environmental conditions which would otherwise cause leakage across the printed circuit board.

2.0 Capacitor Selection

The size of the capacitor is dictated by the required drift rate and acquisition time. The drift is determined by the leakage current at pin 1 and may be calculated by $\frac{dV}{dt} = \frac{I_L}{C_S}$, where I_L is the total leakage current at pin 1 of the device, and C_S is the value of the storage capacitor.

2.1 Capacitor Selection – LH0023

At room temperature leakage current for the LH0023 is approximately 100 pA. A drift rate of 10 mV/sec would require a 0.01 μF capacitor.

For values of C_S up to 0.01 μF the acquisition time is limited by the slew rate of the input buffer amplifier, A1, typically 0.5 V/μs. Beyond this point, current availability to charge C_S also enters the picture. The acquisition time is given by:

$$t_A \cong \sqrt{\frac{2\Delta e_O RC_S}{0.5 \times 10^6}} = 2 \times 10^{-3}\sqrt{\Delta e_O RC_S}$$

where: R = the internal resistance in series with C_S

Δe_O = change in voltage sampled

An average value for R is approximately 600 ohms. The expression for t_A reduces to:

$$t_A \cong \frac{\sqrt{\Delta e_O C_S}}{20}$$

For a –10V to +10V change and C_S = .05 μF, acquisition time is typically 50 μs.

2.2 Capacitor Selection–LH0043

At 25°C case temperature, the leakage current for the LH0043G is approximately 10 pA, so a drift rate of 5 mV/s would require a capacitor of $C_S = 10 \cdot 10^{-12}/5 \cdot 10^{-3}$ = 2000 pF or larger.

For values of C_S below about 5000 pF, the acquisition time of the LH0043G will be limited by the slew rate of the output amplifier (the signal will be acquired, in the sense that the voltage will be stored on the capacitor, in much less time as dictated by the slew rate and current capacity of the input amplifier, but it will not be available at the output). For larger values of storage capacitance, the limitation is the current sinking capability of the input amplifier, typically 10 mA. With C_S = 0.01 μF, the slew rate can be estimated by $\frac{dV}{dt} = \frac{10 \cdot 10^{-3}}{0.01 \cdot 10^{-6}}$ = 1V/μs or a slewing time for a 5 volt signal change of 5μs.

3.0 Offset Null

Provision is made to null both the LH0023 and LH0043 by use of a 10k pot between pins 3 and 4. Offset null should be accomplished in the sample mode at one half the input voltage range for minimum average error.

4.0 Switching Spike Minimization–LH0043

A capacitive divider is formed by the storage capacitor and the capacitance of the internal FET switch which causes a small error current to be injected into the storage capacitor at the termination of the sample interval. This can be considered a negative DC offset and nulled out as described in (3.0), or the transient may be nulled by coupling an equal but opposite signal to the storage capacitor. This may be accomplished by connecting a capacitor of about 30 pF (or a trimmer) between the logic input (pin 6) and the storage capacitor (pin 1). Note that this capacitor must be chosen as carefully as the storage capacitor itself with respect to leakage. The LH0023 has switch spike minimization circuitry built into the device.

5.0 Elimination of the 5V Logic Supply–LH0023

The 5V logic supply may be eliminated by shorting pin 7 to pin 8 which connects a 10k dropping resistor between the +15V and V_C. Decoupling pin 8 to ground through 0.1 μF disc capacitor is recommended in order to minimize transients in the output.

6.0 Heat Sinking

The LH0023 and LH0043G may be operated without damage throughout the military temperature range of –55 to +125°C (–25 to +85°C for the LH0023CG and LH0043CG) with no explicit heat sink, however power dissipation will cause the internal temperature to rise above ambient. A simple clip-on heat sink such as Wakefield #215–1.9 or equivalent will reduce the internal temperature about 20°C thereby cutting the leakage current and drift rate by one fourth at max. ambient. There is no internal electrical connection to the case, so it may be mounted directly to a grounded heat sink.

7.0 Theory of Operation–LH0023

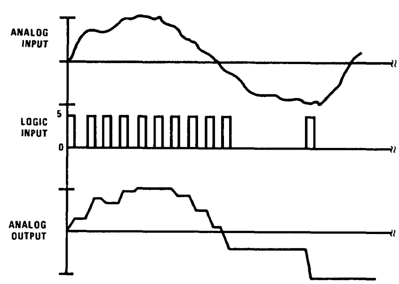
The LH0023/LH0023C is comprised of input buffer amplifier, A1, analog switches, S1 and S2, a

applications information (con't)

TTL to MOS level translator, and output buffer amplifier, A2. In the "sample" mode, the logic input is raised to logic "1" ($V_6 \leq 2.0V$) which closes S1 and opens S2. Storage capacitor, C_S, is charged to the input voltage through S1 and the output slews to the input voltage. In the "hold" mode, the logic input is lowered to logic "0" ($V_6 \leq 0.8V$) opening S1 and closing S2. C_S retains the sample voltage which is applied to the output via A2. Since S1 is open, the input signal is overridden, and leakage across the MOS switch is therefore minimized. With S1 open, drift is primarily determined by input bias current of A2, typically 100 pA at 25°C.

7.1 Theory of Operation—LH0043

The LH0043/LH0043C is comprised of input buffer amplifier A1, FET switch S1 operated by a TTL compatible level translator, and output buffer amplifier A2. To enter the "sample" mode, the logic input is taken to the TTL logic "0" state (V_6 = 0.8V) which commands the switch S1



closed and allows A1 to make the storage capacitor voltage equal to the analog input voltage. In the "hold" mode (V_6 = 2.0V), S1 is opened isolating the storage capacitor from the input and leaving it charged to a voltage equal to the last analog input voltage before entering the hold mode. The storage capacitor voltage is brought to the output by low leakage amplifier A2.

8.0 Definitions

- V_5: The voltage at pin 5, e.g., the analog input voltage.
- V_6: The voltage at pin 6, e.g., the logic control input signal.
- V_{11}: The voltage at pin 11, e.g., the output signal.
- T_A: The temperature of the ambient air.
- T_C: The temperature of the device case at the center of the bottom of the header.

Acquisition Time:
The time required for the output (pin 11) to settle within the rated accuracy after a specified input change is applied to the input (pin 5) with the logic input (pin 6) in the low state.

Aperture Time:
The time indeterminacy when switching from sample mode to hold including the delay from the time the mode control signal (pin 6) passes through its threshold (1.4 volts) to the time the circuit actually enters the hold mode.

Output Offset Voltage:
The voltage at the output terminal (pin 11) with the analog input (pin 5) at ground and logic input (pin 6) in the "sample" mode. This will always be adjustable to zero using a 10k pot between pins 3 and 4 with the wiper arm returned to V^-.

Operational Amplifiers

LH0024/LH0024C high slew rate operational amplifier

general description

The LH0024/LH0024C is a very wide bandwidth, high slew rate operational amplifier intended to fulfill a wide variety of high speed applications such as buffers to A to D and D to A converters and high speed comparators. The device exhibits useful gain in excess of 50 MHz making it possible to use in video applications requiring higher gain accuracy than is usually associated with such amplifiers.

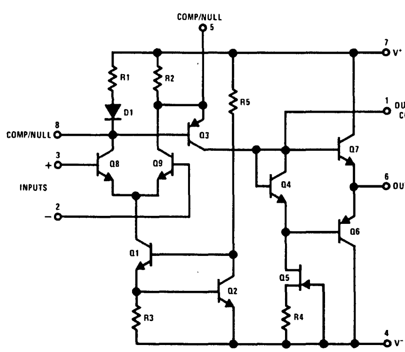
features

- Very high slew rate — 500 V/μs at Av = +1
- Wide small signal bandwidth — 70 MHz
- Wide large signal bandwidth — 15 MHz
- High output swing — ±12V into 1K
- Offset null with single pot
- Low input offset — 2 mV
- Pin compatible with standard IC op amps

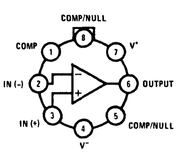
The LH0024/LH0024C's combination of wide bandwidth and high slew rate make it an ideal choice for a variety of high speed applications including active filters, oscillators, and comparators as well as many high speed general purpose applications.

The LH0024 is guaranteed over the temperature range −55°C to +125°C, whereas the LH0024C is guaranteed −25°C to +85°C.

schematic and connection diagrams



Metal Can Package

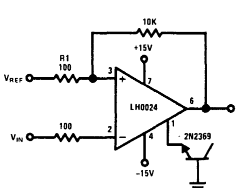


Note: For heat sink use Thermalloy 2230-5 series.

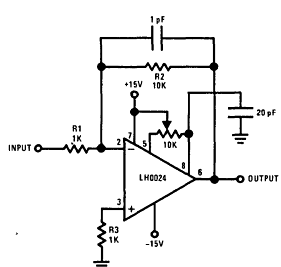
Order Number LH0024H or LH0024CH
See Package 11

typical applications

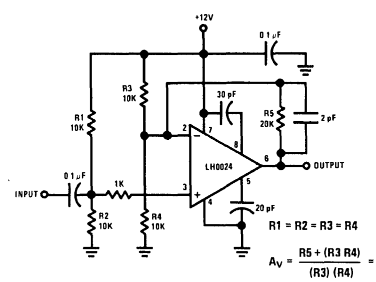
TTL Compatible Comparator



Offset Null



Video Amplifier



absolute maximum ratings

Supply Voltage		±18V
Input Voltage		Equal to Supply
Differential Input Voltage		±5V
Power Dissipation		600 mW
Operating Temperature Range	LH0024	−55°C to +125°C
	LH0024C	−25°C to +85°C
Storage Temperature Range		−65°C to +150°C
Lead Temperature (Soldering, 10 sec)		300°C

dc electrical characteristics (Note 1)

PARAMETER	CONDITIONS	LH0024			LH0024C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$R_S = 50\Omega$, $T_A = 25°C$		2.0	4.0		5.0	8.0	mV
	$R_S = 50\Omega$			6.0			10.0	mV
Average Temperature Coefficient of Input Offset Voltage	$V_S = \pm15V$, $R_S = 50\Omega$ −55°C to 125°C		20			25		μV/°C
Input Offset Current	$T_A = 25°C$		2.0	5.0		4.0	15.0	μA
				10.0			20.0	μA
Input Bias Current	$T_A = 25°C$		15	30		18	40	μA
				40			50	μA
Supply Current			12.5	13.5		12.5	13.5	mA
Large Signal Voltage Gain	$V_S = \pm15V$, $R_L = 1k$, $T_A = 25°C$	4	5		3	4		V/mV
	$V_S = \pm15V$, $R_L = 1k$	3			2.5			V/mV
Input Voltage Range	$V_S = \pm15V$	±12	±13		±12	±13		V
Output Voltage Swing	$V_S = \pm15V$, $R_L = 1k$, $T_A = 25°C$	±12	±13		±10	±13		V
	$V_S = \pm15V$, $R_L = 1k$	±10			±10			V
Slew Rate	$V_S = \pm15V$, $R_L = 1k$, $C_1 = C_2 = 30$ pF $A_V = +1$, $T_A = 25°C$	400	500		250	400		V/μs
Common Mode Rejection Ratio	$V_S = \pm15V$, $\Delta V_{IN} = \pm10V$ $R_S = 50\Omega$		60			60		dB
Power Supply Rejection Ratio	$\pm5V \le V_S \le \pm18V$ $R_S = 50\Omega$		60			60		dB

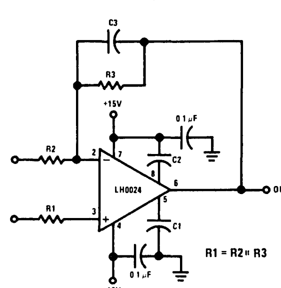
Note 1: These specifications apply for $\pm5V \le V_S \le \pm18V$ and −55°C to +125°C for the LH0024 and −25°C to +85°C for the LH0024C.

frequency compensation

TABLE I

CLOSED LOOP GAIN	C_1	C_2	C_3
100	0	0	0
20	0	0	0
10	0	20 pF	1 pF
1	30 pF	30 pF	3 pF

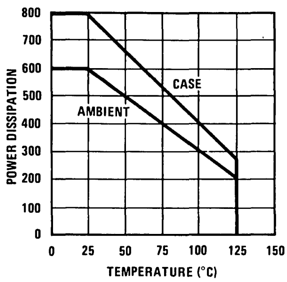
Frequency Compensation Circuit



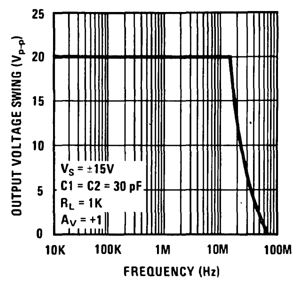
2

typical performance characteristics

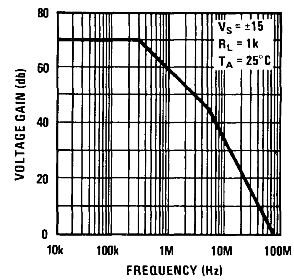
Maximum Power Dissipation



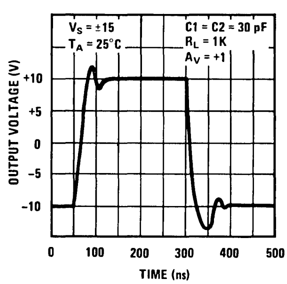
Large Signal Frequency Response



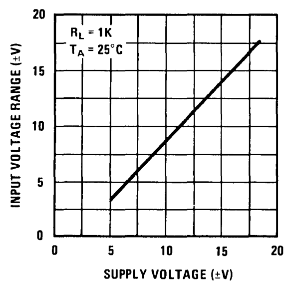
Open Loop Frequency Response



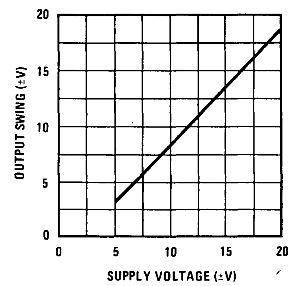
Voltage Follower Pulse Response



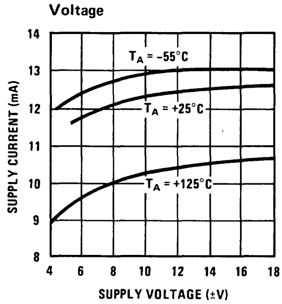
Input Voltage vs Supply Voltage



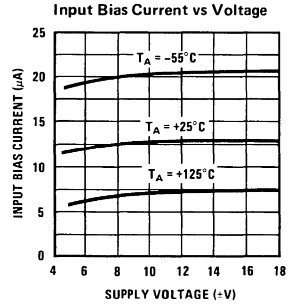
Output Voltage Swing



Supply Current vs Supply Voltage



Input Bias Current vs Voltage



applications information

1. Layout Considerations

The LH0024/LH0024C, like most high speed circuitry, is sensitive to layout and stray capacitance. Power supplies should be by-passed as near the device as is practicable with at least .01 μF disc type capacitors. Compensating capacitors should also be placed as close to device as possible.

2. Compensation Recommendations

Compensation schemes recommended in Table 1 work well under typical conditions. However, poor layout and long lead lengths can degrade the performance of the LH0024 or cause the device to oscillate. Slight adjustments in the values for C1, C2, and C3 may be necessary for a given layout. In particular, when operating at a gain of −1, C3 may require adjustment in order to perfectly cancel the input capacitance of the device.

When operating the LH0024/LH0024C at a gain of +1, the value of R1 should be at least 1K ohm.

The case of the LH0024 is electrically isolated from the circuit; hence, it may be advantageous to drive the case in order to minimize stray capacitances.

3. Heat Sinking

The LH0024/LH0024C is specified for operation without the use of an explicit heat sink. However, internal power dissipation does cause a significant temperature rise. Improved offset voltage drift can be obtained by limiting the temperature rise with a clip-on heat sink such as the Thermalloy 2228B or equivalent.

Operational Amplifiers

LH0032/LH0032C ultra fast FET operational amplifier

general description

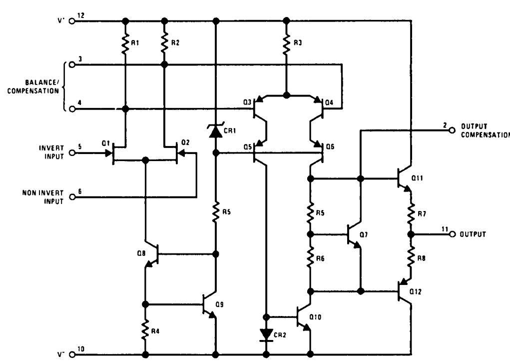
The LH0032/LH0032C is a high slew rate, high input impedance differential operational amplifier suitable for diverse application in fast signal handling. The high allowable differential input voltage, ease of output clamping, and high output drive capability particularly suit it for comparator applications. It may be used in applications normally reserved for video amplifiers allowing the use of operational gain setting and frequency response shaping into the megahertz region.

features

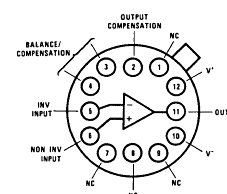
- High slew rate 500 V/μs
- High bandwidth 70 MHz
- High input impedance $10^{12}\Omega$
- Low input bias current 20 pA max
- Offset null with single pot
- Low input offset voltage 2 mV max
- No compensation for gains above 50

The LH0032's wide bandwidth, high input impedance and high output capacity make it an ideal choice for applications such as summing amplifiers in high speed D to A's, buffers in data acquisition systems, and sample and hold circuits. Additional applications include high speed integrators and video amplifiers. The LH0032 is guaranteed over the temperature range −55°C to +125°C and the LH0032C is guaranteed from −25°C to +85°C.

schematic and connection diagrams



Metal Can Package



TOP VIEW

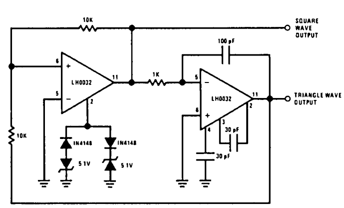
Note: For heat sink use thermalloy 2240 series or Wakefield 215-XX series.

Order Number LH0032G or LH0032CG

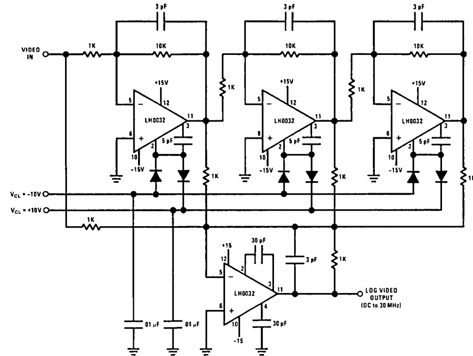
See Package 6

typical applications

1 MHz Function Generator



DC to Video Log Amplifier



Note: All diodes must be low stored charge, high speed. Decouple power supplies at each amp with 0.01μF ceramic discs.

absolute maximum ratings

Supply Voltage	±18V
Input Voltage	$\pm V_S$
Differential Input Voltage	±30V
Power Dissipation	See curve
Operating Temperature Range LH0032	−55°C to +125°C
LH0032C	−25°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

dc electrical characteristics (Note 1)

PARAMETER	CONDITIONS	LH0032			LH0032C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$V_S = \pm 15V$, $R_S \le 100k$, $T_A = 25°C$		2	5		5	15	mV
	$V_S = \pm 15V$, $R_S \le 100k$			10			20	mV
Average Offset Voltage Drift	$R_S \le 100k$		25			25		μV/°C
Input Bias Current	$T_A = 25°C$		10	100		25	200	pA
				50			15.0	nA
Input Offset Current	$T_A = 25°C$		5	25		10	50	pA
				25			5	nA
Large Signal Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$, f = 1 kHz $R_L = 1\ k\Omega$, $T_A = 25°C$	60	70		60	70		dB
	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$, f = 1 kHz $R_L = 1\ k\Omega$	57			57			dB
Input Voltage Range	$V_S = \pm 15V$	±10	±12		±10	±12		V
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 1\ k\Omega$	±10	±13.5		±10	±13		V
Power Supply Rejection Ratio	$V_S = \pm 15V$, $\Delta V_S = \pm 10V$	50	60		50	60		dB
Common Mode Rejection Ratio	$V_S = \pm 15V$, $\Delta V_{IN} = 10V$	50	60		50	60		dB
Supply Current	$V_S = \pm 15V$, $T_A = 25°C$		18	20		20	22	mA

ac electrical characteristics (Note 2)

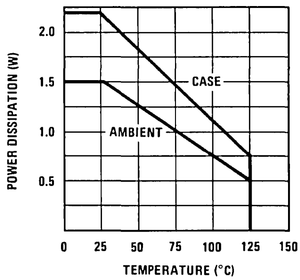
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Slew Rate	$A_V = +1$, $\Delta V_{IN} = 20V$	350	500		V/μs
Settling Time to 1% of Final Value	$A_V = -1$, $\Delta V_{IN} = 20V$		100		ns
Settling Time to 0.1% of Final Value	$A_V = -1$, $\Delta V_{IN} = 20V$		300		ns
Small Signal Rise Time	$A_V = +1$, $\Delta V_{IN} = 1V$		8	20	ns
Small Signal Delay Time	$A_V = +1$, $\Delta V_{IN} = 1V$		10	25	ns

Note 1: These specifications apply for $\pm 5V \le V_S \le \pm 18V$ and −55°C to +125°C for the LH0032 and −25°C to +85°C for the LH0032C.

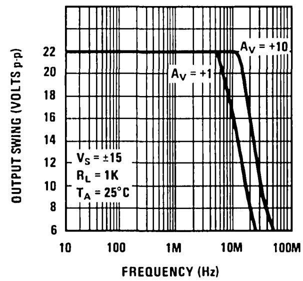
Note 2: These specifications apply for $V_S = \pm 15V$, $R_L = 1\ k\Omega$ and $T_A = 25°C$.

typical performance characteristics

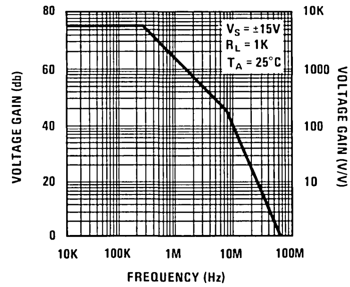
Maximum Power Dissipation



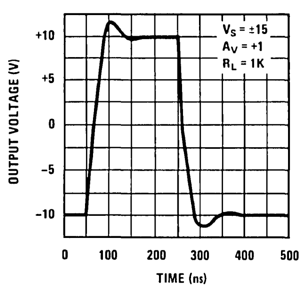
Large Signal Frequency Response



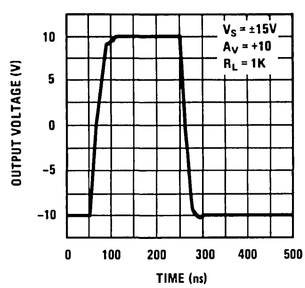
Open Loop Frequency Response



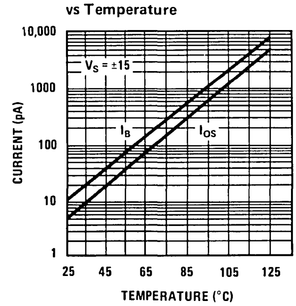
Large Signal Pulse Response



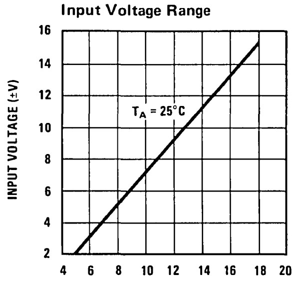
Large Signal Pulse Response



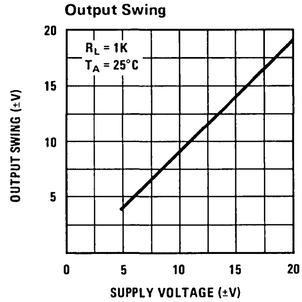
Input Bias and Offset Current vs Temperature



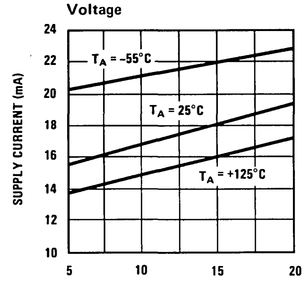
Input Voltage Range



Output Swing

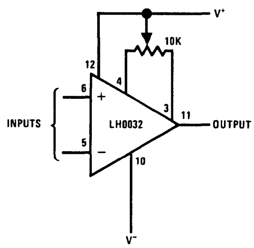


Supply Current vs Supply Voltage

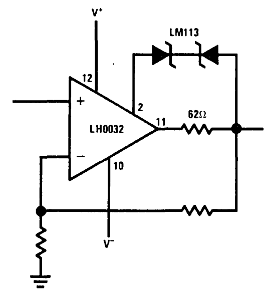


auxiliary circuits

Offset Null

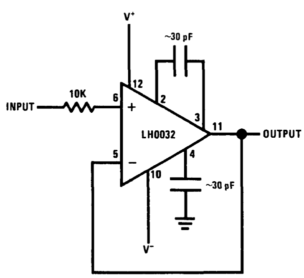


Output Short Circuit Protection

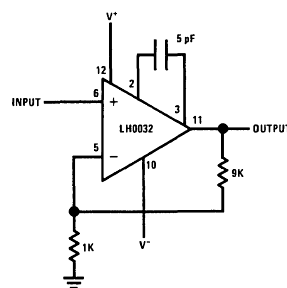


typical applications (con't)

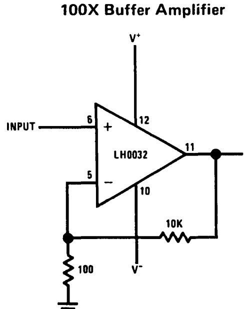
Unity Gain Amplifier



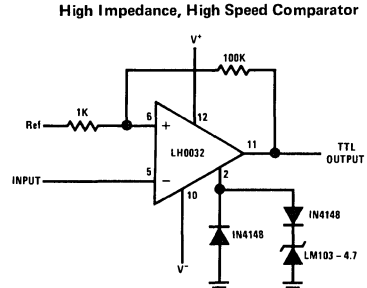
10X Buffer Amplifier



100X Buffer Amplifier

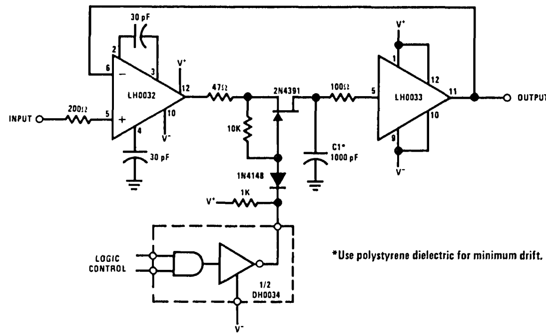


High Impedance, High Speed Comparator



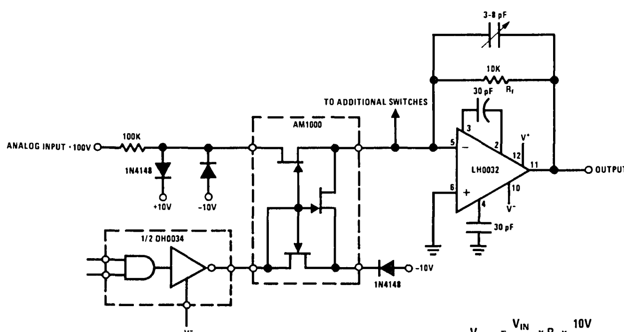
typical applications (con't)

High Speed Sample and Hold



*Use polystyrene dielectric for minimum drift.

Current Mode Multiplexer



$$V_{OUT} = \frac{V_{IN}}{R1} \times R_f \times \frac{10V}{mA}$$

2

applications information

Power Supply Decoupling

The LH0032/LH0032C like most high speed circuits is sensitive to layout and stray capacitance. Power supplies should be by-passed as near to Pins 10 and 12 as practicable with low inductance capacitors such as 0.01 μF disc ceramics. Compensation components should also be located close to the appropriate pins to minimize stray reactances.

Input Capacitance

The input capacitance to the LH0032/LH0032C is typically 5 pF and thus may form a significant time constant with high value resistors. For optimum performance, the input capacitance to the inverting input should be compensated by a small capacitor across the feedback resistor. The value is strongly dependent on layout and closed loop gain, but will typically be in the neighborhood of several picofarads.

In the non-inverting configuration, it may be advantageous to bootstrap the case and/or a guard conductor to the inverting input. This serves both to divert leakage currents away from the non-inverting input and to reduce the effective input capacitance. A unity gain follower so treated will have an input capacitance under a picofarad.

Heat Sinking

While the LH0032/LH0032C is specified for operation without any explicit head sink, internal power dissipation does cause a significant temperature rise. Improved bias current performance can thus be obtained by limiting this temperature rise with a small head sink such as the Thermalloy No. 2241 or equivalent. The case of the device has no internal connection, so it may be electrically connected to the sink if this is advantageous. Be aware, however, that this will affect the stray capacitances to all pins and may thus require adjustment of circuit compensation values.

Operational Amplifiers

LH0033/LH0033C, LH0063/LH0063C fast and damn fast buffer amplifiers

general description

The LH0033/LH0033C and LH0063/LH0063C are high speed, FET input, voltage follower/buffers designed to provide high current drive at frequencies from DC to over 100 MHz. The LH0033/LH0033C will provide ±10 mA into 1 kΩ loads (±100 mA peak) at slew rates of 1500V/μs. The LH0063/LH0063C will provide ±250 mA into 50Ω loads (±500 mA peak) at slew rates of up to 6000V/μs. In addition, both exhibit excellent phase linearity up to 20 MHz.

Both are intended to fulfill a wide range of buffer applications such as high speed line drivers, video impedance transformation, nuclear instrumentation amplifiers, op amp isolation buffer for driving reactive loads and high impedance input buffers for high speed A to D's and comparators. In addition, the LH0063/LH0063C can continuously drive 50Ω coaxial cables or be used as a diddle yoke driver for high resolution CRT displays. For additional applications information, see AN-48.

advantages

- Only +10V supply needed for 5 V_{P-P} video out
- Speed does not degrade system performance
- Wide data rate range for phase encoded systems
- Output drive adequate for most loads
- Single pre-calibrated package

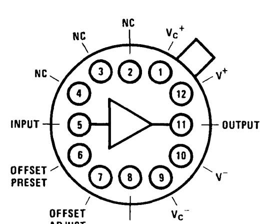
features

- Damn fast (LH0063) 6000V/μs
- Wide range single or dual supply operation
- Wide power bandwidth DC to 100 MHz
- High output drive ±10V with 50Ω load
- Low phase non-linearity 2 degrees
- Fast rise times 2 ns
- High current gain 120 dB
- High input resistance 10^{10} Ω

These devices are constructed using specially selected junction FET's and active laser trimming to achieve guaranteed performance specifications. The LH0033 and LH0063 are specified for operation from −55°C to +125°C; whereas, the LH0033C and LH0063C are specified from −25°C to +85°C. The LH0033/LH0033C is available in a 1.5W metal TO-8 package and a special 1/2 x 1 inch 8 pin ceramic dual-in-line package while the LH0063/LH0063C is available in a 5W 8-pin TO-3 package.

connection diagrams

LH0033/LH0033C
Metal Can Package

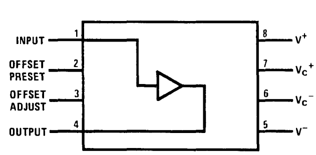


TOP VIEW

CASE IS ELECTRICALLY ISOLATED

Order Number LH0033G or LH0033CG
See Package 6

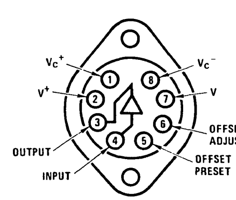
LH0033/LH0033C
Dual-In-Line Package



TOP VIEW

Order Number LH0033J or LH0033CJ
See Package 15

LH0063/LH0063C
Metal Can Package



TOP VIEW

CASE IS ELECTRICALLY ISOLATED

Order Number LH0063K or LH0063CK
See Package 19

absolute maximum ratings

Supply Voltage ($V^+ - V^-$)	40V
Maximum Power Dissipation (See Curves)	
LH0063/LH0063C	5W
LH0033/LH0033C	1.5W
Maximum Junction Temperature	175°C
Input Voltage	Equal to Supplies
Continuous Output Current	
LH0063/LH0063C	±250 mA
LH0033/LH0033C	±100 mA
Peak Output Current	
LH0063/LH0063C	±500 mA
LH0033/LH0033C	±250 mA
Operating Temperature Range	
LH0033 and LH0063	−55°C to +125°C
LH0033C and LH0063C	−25°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

dc electrical characteristics LH0033/LH0033C: (Note 1)

PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0033			LH0033C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Output Offset Voltage	R_S = 100 kΩ, T_C = 25°C		5	10		12	20	mV
	R_S = 100 kΩ			15			25	mV
Average Temperature Coefficient of Offset Voltage	R_S = 100 kΩ, −55°C ≤ T_C ≤ 125°C		25			25		μV/°C
Input Bias Current	T_C = 25°C		.05	.1		.05	.15	nA
				10			5	nA
Voltage Gain	V_{IN} = 1Vrms, f = 1 kHz, R_L = 1 kΩ, R_S = 100 kΩ	.97	.98	1	.96	.98	1	V/V
Input Impedance	V_{IN} = 1Vrms, f = 1 kHz, R_L = 1 kΩ	10^{10}	10^{11}		10^{10}	10^{11}		Ω
Output Impedance	V_{IN} = 1Vrms, f = 1 kHz, R_S = 100 kΩ, R_L = 1 kΩ		6	10		6	10	Ω
Output Voltage Swing	R_L = 1 kΩ,	±12	±13		±12	±13		V
	R_L = 100Ω, T_C = 25°C	±9			±9			V
	V_S = ±5V, R_L = 1 kΩ		6			6		V_{P-P}
Supply Current	V_{IN} = 0V, V_S = ±15V		20	22		21	24	mA
	V_S = ±5V		18			18		mA
Power Consumption	V_{IN} = 0V, V_S = ±15V		600	660		630	720	mW
	V_S = ±5V		180			180		mW

ac electrical characteristics

LH0033/LH0033C (T_C = 25°C, V_S = ±15V, R_S = 50Ω, R_L = 1 kΩ)

PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0033			LH0033C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Slew Rate	V_{IN} = ±10V	1000	1500		1000	1400		V/μs
Bandwidth	V_{IN} = 1Vrms		100			100		MHz
Phase Non-Linearity	BW = 1 to 20 MHz		2			2		degrees
Rise Time	ΔV_{IN} = 0.5V		2.9			3.2		ns
Propagation Delay	ΔV_{IN} = 0.5V		1.2			1.5		ns
Harmonic Distortion			<0.1			<0.1		%

Note 1: Unless otherwise specified, these specifications apply for +15V applied to pins 1 and 12, −15V applied to pins 8 and 10, and pin 6 shorted to pin 7 for the LH0033/LH0033C. For the LH0063/LH0063C, specifications apply for +15V applied to pins 1 and 2, −15V applied to pins 7 and 8, and pin 5 shorted to pin 6. Unless otherwise noted, specifications apply over a temperature range of −55°C ≤ T_C ≤ +125°C for the LH0033 and LH0063; and −25°C ≤ T_C ≤ +85°C for the LH0033C and LH0063C. Typical values shown are for T_C = 25°C.

dc electrical characteristics LH0063/LH0063C (Note 1)

PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0063			LH0063C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Output Offset Voltage	$R_S \le 100\ k\Omega$, $T_C = 25°C$ $R_S \le 100\ k\Omega$		10	25 100		10	50 100	mV mV
Average Temperature Coefficient of Output Offset Voltage	$R_S \le 100\ k\Omega$		300			300		μV/°C
Input Bias Current	$T_C = 25°C$		.1	.2 10		.1	.2 5	nA nA
Voltage Gain	$V_{IN} = \pm10V$, $R_S \le 100\ k\Omega$, $R_L = 1\ k\Omega$	.96	.98	1	.96	.98	1	V/V
Voltage Gain	$V_{IN} = \pm10V$, $R_S \le 100\ k\Omega$, $R_L = 50\Omega$	.94	.96	.98	193	.96	.98	V/V
Input Resistance		10^{10}	10^{11}		10^{10}	10^{11}		Ω
Input Capacitance	Case Shorted to Output		8			8		pF
Output Impedance	$V_{OUT} = \pm10V$, $R_S = 100\ k\Omega$		1	4		1	4	Ω
Output Current Swing	$V_{IN} = \pm10V$, $R_S \le 100\ k\Omega$	.2	.25		.2	.25		Amps
Output Voltage Swing	$R_L = 50\Omega$	±10	±13		±10	±13		V
Output Voltage Swing	$V_S = \pm5V$, $R_L = 50\Omega$, $T_C = 25°C$	5	7		5	7		V_{P-P}
Supply Current	$T_C = 25°C$, $R_L = \infty$, $V_S = \pm15V$		60	75		60	80	mA
Supply Current	$V_S = \pm5V$		50			50		mA
Power Consumption	$T_C = 25°C$, $R_L = \infty$, $V_S = \pm15V$		1.80	2.25		1.80	2.40	W
Power Consumption	$V_S = \pm5V$		500			500		mW

ac electrical characteristics

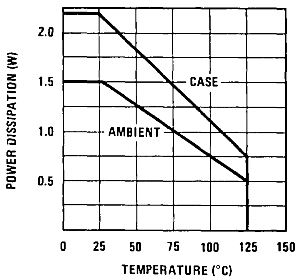
LH0063/LH0063C: ($T_C = 25°C$, $V_S = \pm15V$, $R_S = 50\Omega$, $R_L = 50\Omega$)

PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0063			LH0063C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Slew Rate	$R_L = 1\ k\Omega$, $V_{IN} = \pm10V$		6000			6000		V/μs
Slew Rate	$R_L = 50\Omega$, $V_{IN} = \pm10V$ $T_C = 25°C$	2000	4000		2000	4000		V/μs
Bandwidth	$V_{IN} = 1$ Vrms		200			200		MHz
Phase Non-Linearity	BW = 1 to 20 MHz		2			2		degrees
Rise Time	$\Delta V_{IN} = .5V$		1.6			1.9		ns
Propagation Delay	$\Delta V_{IN} = .5V$		1.9			2.1		ns
Harmonic Distortion			<0.1			<0.1		%

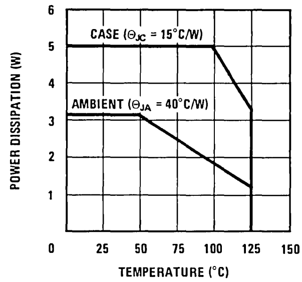
Note 1: Unless otherwise specified, these specifications apply for +15V applied to pins 1 and 12, –15V applied to pins 8 and 10, and pin 6 shorted to pin 7 for the LH0033/LH0033C. For the LH0063/LH0063C, specifications apply for +15V applied to pins 1 and 2, –15V applied to pins 7 and 8, and pin 5 shorted to pin 6. Unless otherwise noted, specifications apply over a temperature range of $-55°C \le T_C \le +125°C$ for the LH0033 and LH0063; and $-25°C \le T_C \le +85°C$ for the LH0033C and LH0063C. Typical values shown are for $T_C = 25°C$.

typical performance characteristics

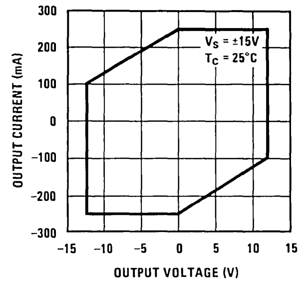
LH0033 Power Dissipation



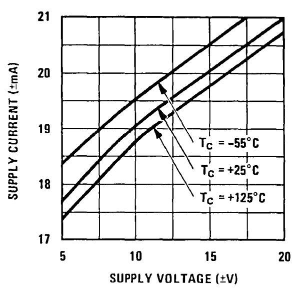
LH0063 Power Dissipation



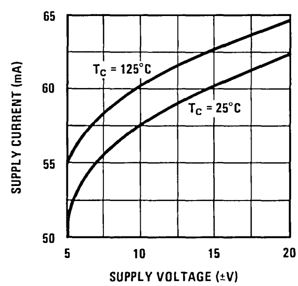
LH0063 DC Safe Operating Area



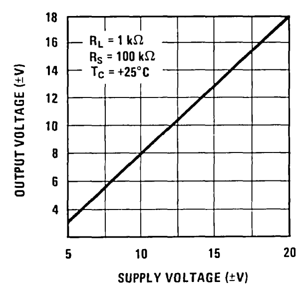
LH0033 Supply Current vs Supply Voltage



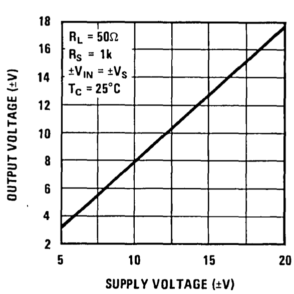
LH0063 Supply Current vs Supply Voltage



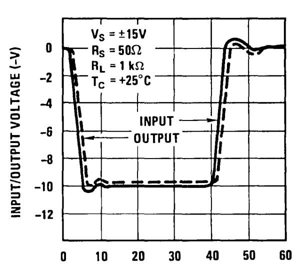
LH0033 Output Voltage vs Supply Voltage



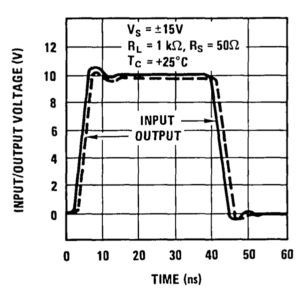
LH0063 Output Voltage vs Supply Voltage



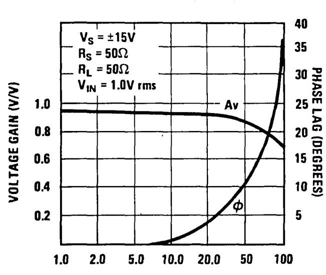
LH0033 Negative Pulse Response



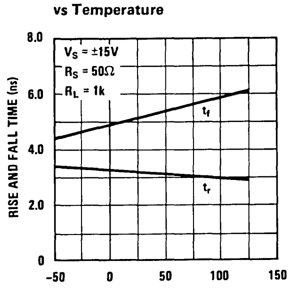
LH0033 Positive Pulse Response



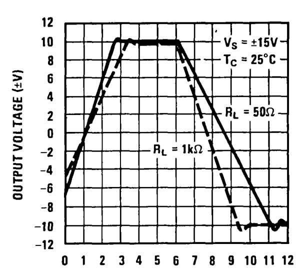
LH0033 Frequency Response



LH0033 Rise and Fall Time vs Temperature

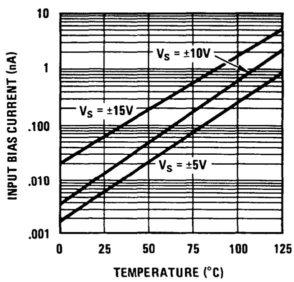


LH0063 Large Signal Pulse Response

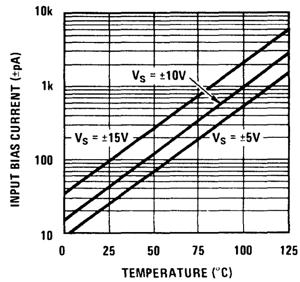


typical performance characteristics (con't)

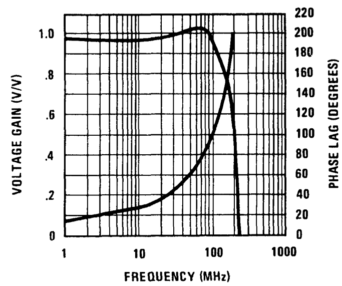
LH0033 Input Bias Current vs Temperature



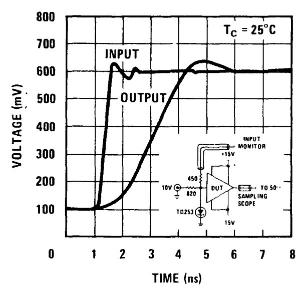
LH0063 Input Current



LH0063 Frequency Response



LH0063 Small Signal Rise Time



application hints

Recommended Layout Precautions: RF/video printed circuit board layout rules should be followed when using the LH0033 and LH0063 since they will provide power gain to frequencies over 100 MHz. Ground planes are recommended and power supplies should be decoupled at each device with low inductance 0.1μF disc capacitors. In addition, ground plane shielding may be extended to the metal case of the device since it is electrically isolated from internal circuitry. Alternatively the case should be connected to the output to minimize input capacitance.

Offset Voltage Adjustment: Both the LH0033's and LH0063's offset voltages have been actively trimmed by laser to meet guaranteed specifications when the offset preset pin is shorted to the offset adjust pin. This pre-calibration allows the devices to be used in most DC or AC applications without individually offset nulling each device. If offset null is desirable, it is simply obtained by leaving the offset preset pin open and connecting a trim pot of 100Ω for the LH0033 or 1 kΩ for the LH0063 between the offset adjust pin and V^- as illustrated in Figures 1 and 2.

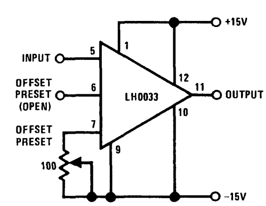


FIGURE 1. Offset Zero Adjust for LH0033 (Pin nos. shown for TO-8)

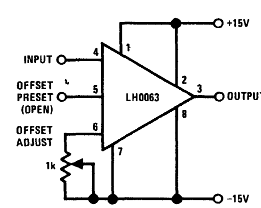


FIGURE 2. Offset Zero Adjust for LH0063

application hints (con't)

Operation from Single or Asymmetrical Power Supplies: Both device types may be readily used in applications where symmetrical supplies are unavailable or not desirable. A typical application might be an interface to a MOS shift register where $V^+ = +5V$ and $V^- = -12V$. In this case, an apparent output offset occurs due to the device's voltage gain of less than unity. This additional output offset error may be predicted by:

$$\Delta V_O \cong (1 - A_V)\,\frac{(V^+ - V^-)}{2} = .005\,(V^+ - V^-)$$

where:

A_V = No load voltage gain, typically .99

V^+ = Positive supply voltage

V^- = Negative supply voltage

For the above example, ΔV_O would be −35 mV. This may be adjusted to zero as described in Section 2. For AC coupled applications, no additional offset occurs if the DC input is properly biased as illustrated in the "typical applications" section.

Short Circuit Protection: In order to optimize transient response and output swing, output current limit has been omitted from the LH0033 and LH0063. Short circuit protection may be added by inserting appropriate value resistors between V^+ and $V_C{}^+$ pins and V^- and $V_C{}^-$ pins as illustrated in Figures 3 and 4. Resistor values may be predicted by:

$$R_{LIM} \cong \frac{V^+}{I_{SC}} = \frac{V^-}{I_{SC}}$$

where: $I_{SC} \leq 100$ mA for LH0033

$I_{SC} \leq 250$ mA for LH0063

The inclusion of limiting resistors in the collectors of the output transistors reduces output voltage swing. Decoupling $V_C{}^+$ and $V_C{}^-$ pins with capacitors to ground will retain full output swing for transient pulses. Alternate active current limit techniques that retain full DC output swing are shown in Figures 5, 6 and 7. In Figures 5 and 6, the current sources are saturated during normal operation thus apply full supply voltage to the V_C pins. Under fault conditions, the voltage decreases as required by the overload. For Figure 5:

$$R_{LIM} = \frac{V_{BE}}{I_{SC}} = \frac{.6V}{60\text{ mA}} = 10\Omega$$

In Figure 6, quad transistor arrays are used to minimize can count and:

$$R_{LIM} = \frac{V_{BE}}{1/3\,(I_{SC})} = \frac{.6V}{1/3\,(200\text{ mA})} = 8.2\Omega$$

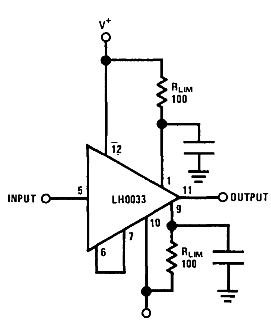


FIGURE 3. LH0033 Using Resistor Current Limiting

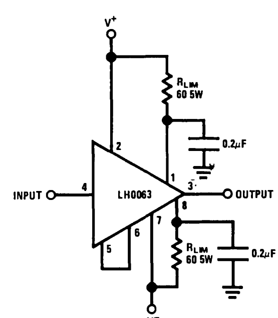


FIGURE 4. LH0063 Using Resistor Current Limiting

application hints (con't)

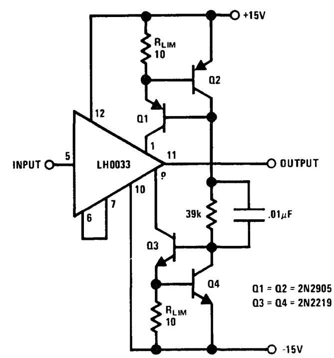


FIGURE 5. LH0033 Current Limiting Using Current Sources

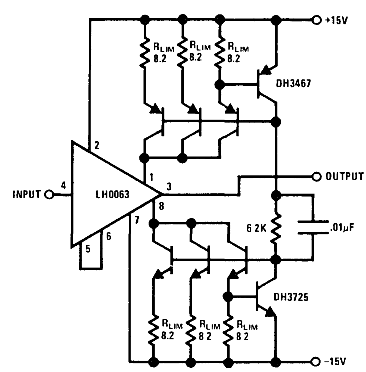


FIGURE 6. LH0063 Current Limiting Using Current Sources

Capacitive Loading: Both the LH0033 and LH0063 are designed to drive capacitive loads such as coaxial cables in excess of several thousand picofarads without susceptibility to oscillation. However, peak current resulting from ($C \times d_V/d_t$) should be limited below absolute maximum peak current ratings for the devices.

Thus for the LH0033:

$$\left(\frac{\Delta V_{IN}}{\Delta T}\right) \times C_L \leq I_{OUT} \leq \pm 250\text{ mA}$$

and for the LH0063:

$$\left(\frac{\Delta V_{IN}}{\Delta T}\right) \times C_L \leq I_{OUT} \leq \pm 500\text{ mA}$$

Peak current limiting may be accomplished by controlling input large signal rise time, inserting 20 to 100Ω resistors between V^+ and V_C^+ pins and V^- and V_C^- pins, using active current limit as described in Section 4, Figures 5, 6 and 7, or inserting a small value resistor in series with the output.

application hints (con't)

In addition, power dissipation resulting from driving capacitative loads plus standby power should be kept below total package power rating:

$$P_{\substack{diss\\pkg}} \geq P_{DC} + P_{AC}$$

$$P_{\substack{diss\\pkg}} \geq (V^+ - V^-) \times I_S + P_{AC}$$

$$P_{AC} \cong (V_{P\text{-}P})^2 \times f \times C_L$$

where $V_{P\text{-}P}$ = Peak-to-peak output voltage swing
f = frequency
C_L = Load Capacitance

Operation Within an Op Amp Loop: Both devices may be used as a current booster or isolation buffer within a closed loop with op amps such as LH0032, LH0062, or LM118. An isolation resistor of 47Ω should be used between the op amp output and the input of LH0033. The wide bandwidths and high slew rates of the LH0033 and LH0063 assure that the loop has the characteristics of the op amp and that additional rolloff is not required.

Hardware: In order to utilize the full drive capabilities of both devices, each should be mounted with a heat sink particularly for extended temperature operation. The cases of both are isolated from the circuit and may be connected to system chassis. Heat sinks are commercially available at low cost; the following or their equivalents are recommended:

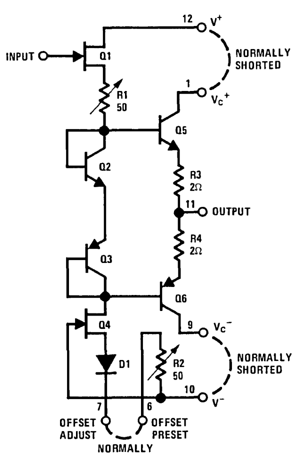
LH0033G (TO-8 pkg):	Thermalloy #2240A Wakefield #215-CB
LH0063K (TO-3 pkg):	IERC #LAIC3B4V

Mounting and test sockets are available from:

LH0033G (TO-8 pkg):	Barnes Corp. #MGX-12
LH0063K (TO-3 pkg):	Keystone Elect. (N.Y.) #4626 or #4627

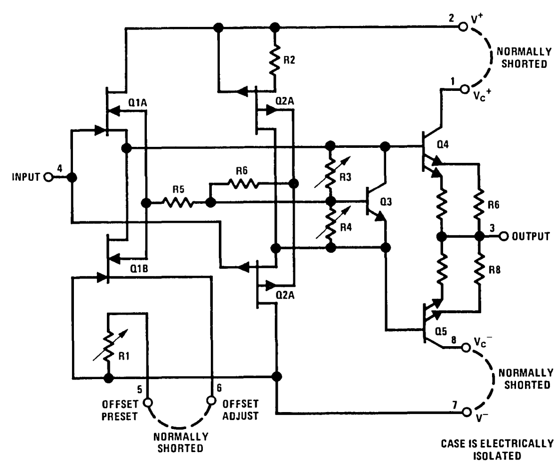
schematic diagrams

LH0033/LH0033C



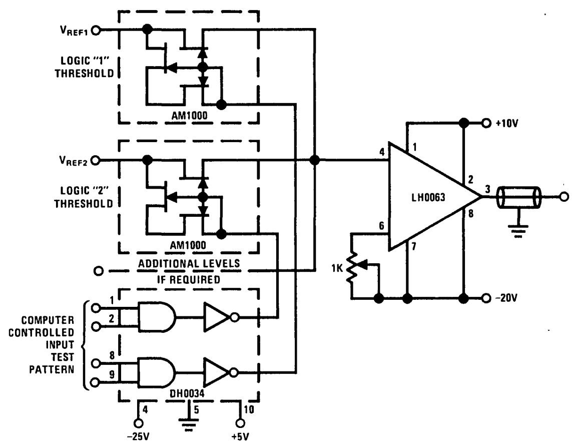
PIN NUMBERS SHOWN FOR TO-8 ("G") PACKAGE.

LH0063/LH0063C

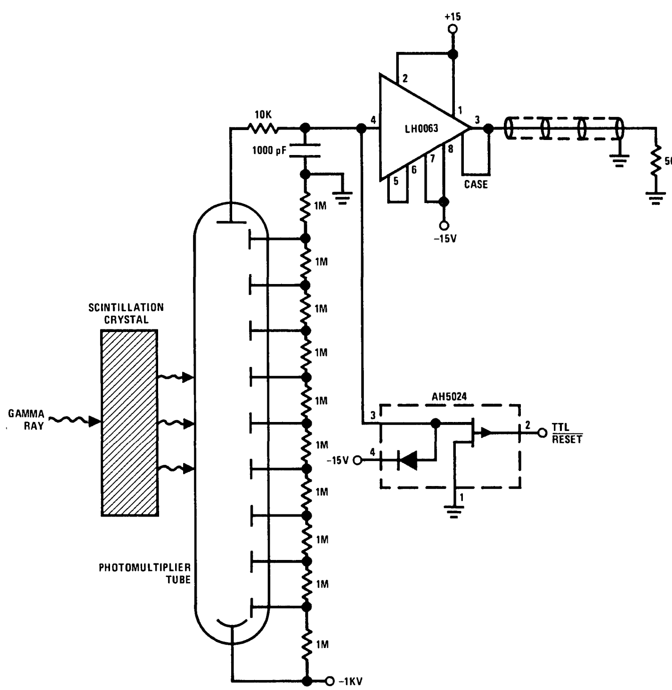


typical applications

High Speed Automatic Test Equipment Forcing Function Generator

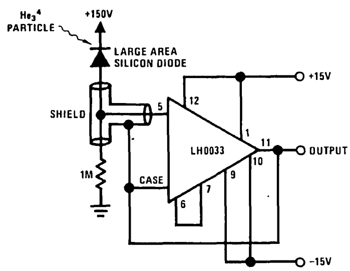


Gamma Ray Pulse Integrator

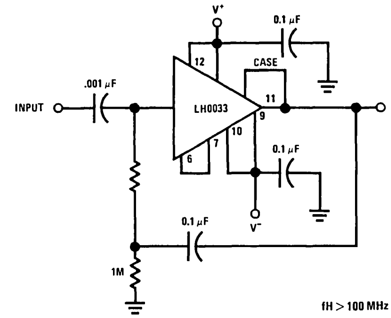


typical applications (con't)

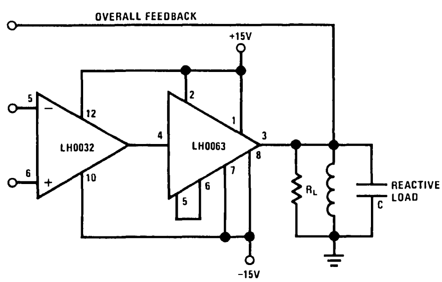
Nuclear Particle Detector



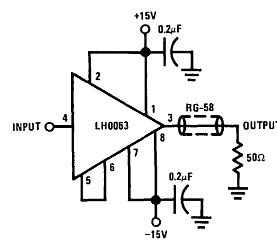
High Input Impedance AC Coupled Amplifier



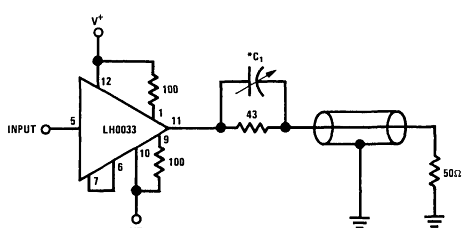
Isolation Buffer



Coaxial Cable Driver

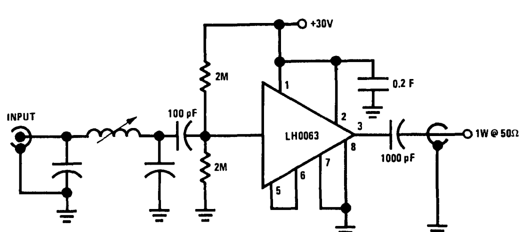


Coaxial Cable Driver



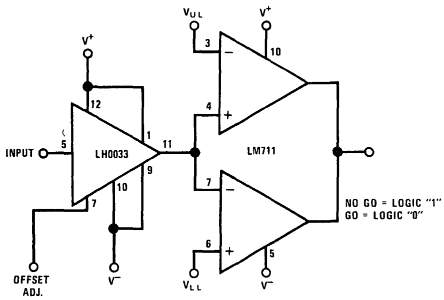
*Select C_1 for optimum pulse response.

1W CW Final Amplifier

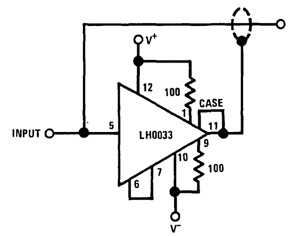


typical applications (con't)

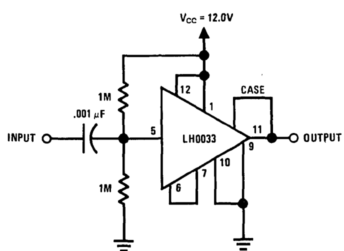
High Input Impedance Comparator With Offset Adjust



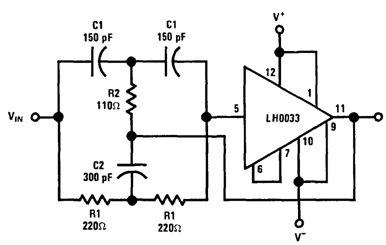
Instrumentation Shield/Line Driver



Single Supply AC Amplifier



4.5 MHz Notch Filter

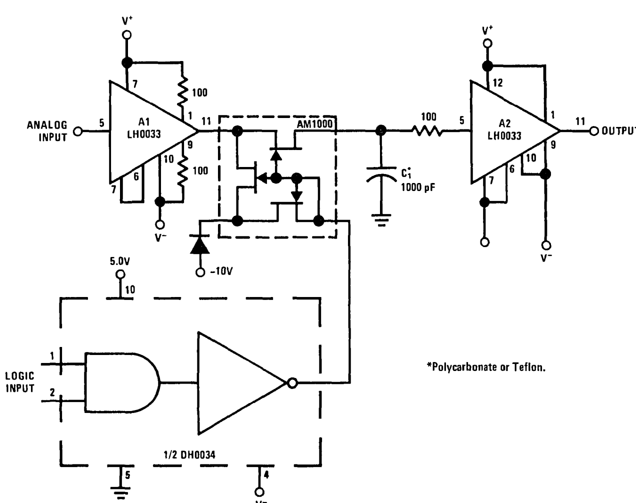


$f_O = \frac{1}{2\pi R1\, C1}$

$R1 = 2\, R2$

$C1 = \frac{C2}{2}$

High Speed Sample & Hold



*Polycarbonate or Teflon.

Operational Amplifiers

LH0036G/LH0036CG instrumentation amplifier

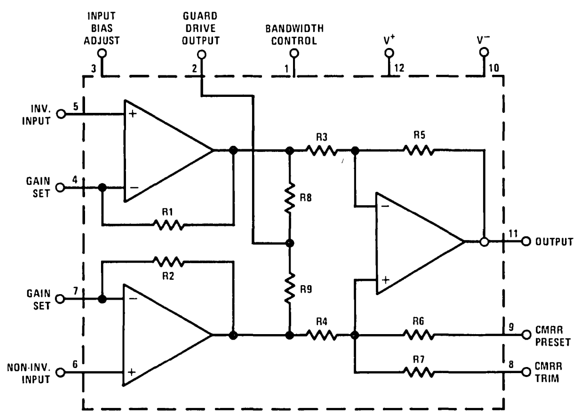
general description

The LH0036G/LH0036CG is a true micro power instrumentation amplifier designed for precision differential signal processing. Extremely high accuracy can be obtained due to the 300 MΩ input impedance and excellent 100 dB common mode rejection ratio. It is packaged in a hermetic TO-8 package. Gain is programmable with one external resistor from 1 to 1000. Power supply operating range is between ±1V and ±18V. Input bias current and output bandwidth are both externally adjustable or can be set by internally set values. The LH0036G is specified for operation over the −55°C to +125°C temperature range and the LH0036CG is specified for operation over the −25°C to +85°C temperature range.

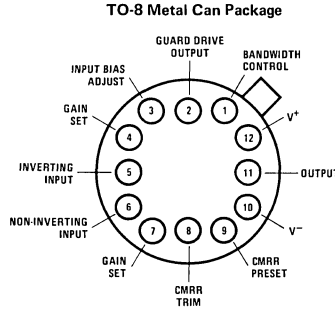
features

- High input impedance 300 MΩ
- High CMRR 100 dB
- Single resistor gain adjust 1 to 1000
- Low power 90μW
- Wide supply range ±1V to ±18V
- Adjustable input bias current
- Adjustable output bandwidth
- Guard drive output

equivalent circuit and connection diagrams



TO-8 Metal Can Package



TOP VIEW

Order Number LH0036G or LH0036CG
See Package 6

absolute maximum ratings

Supply Voltage	±18V	Short Circuit Duration	Continuous
Differential Input Voltage	±30V	Operating Temperature Range	
Input Voltage Range	$\pm V_S$	LH0036	−55°C to +125°C
Shield Drive Voltage	$\pm V_S$	LH0036C	−25°C to +85°C
CMRR Preset Voltage	$\pm V_S$	Storage Temperature Range	−65°C to +150°C
CMRR Trim Voltage	$\pm V_S$	Lead Temperature, Soldering 10 seconds	300°C
Power Dissipation (Note 3)	1.5W		

electrical characteristics (Notes 1 and 2)

PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0036			LH0036C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage (V_{IOS})	R_S = 1.0kΩ, T_A = 25°C R_S = 1.0kΩ		0.5	1.0 2.0		1.0	2.0 3.0	mV mV
Output Offset Voltage (V_{OOS})	R_S = 1.0kΩ, T_A = 25°C R_S = 1.0kΩ		2.0	5.0 6.0		5.0	10 12	mV mV
Input Offset Voltage Tempco ($\Delta V_{IOS}/\Delta T$)	$R_S \leq$ 1.0kΩ		10			10		µV/°C
Output Offset Voltage Tempco ($\Delta V_{OOS}/\Delta T$)			15			15		µV/°C
Overall Offset Referred to Input (V_{OS})	A_V = 1.0 A_V = 10 A_V = 100 A_V = 1000		2.5 0.7 0.52 0.502			6.0 1.5 1.05 1.005		mV mV mV mV
Input Bias Current (I_B)	T_A = 25°C		40	100 150		50	125 200	nA nA
Input Offset Current (I_{OS})	T_A = 25°C		10	40 80		20	50 100	nA nA
Small Signal Bandwidth	A_V = 1.0, R_L = 10kΩ A_V = 10, R_L = 10kΩ A_V = 100, R_L = 10kΩ A_V = 1000, R_L = 10kΩ		350 35 3.5 350			350 35 3.5 350		kHz kHz kHz Hz
Full Power Bandwidth	V_{IN} = ±10V, R_L = 10k, A_V = 1		5.0			5.0		kHz
Input Voltage Range	Differential Common Mode	±10 ±10	±12 ±12		±10 ±10	±12 ±12		V V
Gain Nonlinearity			0.03			0.03		%
Deviation From Gain Equation Formula	A_V = 1 to 1000		±0.3	±1.0		±1.0	±3.0	%
PSRR	$\pm 5.0V \leq V_S \leq \pm 15V$, A_V = 1.0 $\pm 5.0V \leq V_S \leq \pm 15V$, A_V = 100		1.0 0.05	2.5 0.25		1.0 0.10	5.0 0.50	mV/V mV/V
CMRR	A_V = 1.0 DC to A_V = 10 100 Hz A_V = 100 ΔR_S = 1.0k		1.0 0.1 10	2.5 0.25 25		2.5 0.25 25	5.0 0.50 50	mV/V mV/V µV/V
Output Voltage	V_S = ±15V, R_L = 10kΩ, V_S = ±1.5V, R_L = 100kΩ	±10 ±0.6	±13.5 ±0.8		±10 ±0.6	±13.5 ±0.8		V V
Output Resistance			0.5			0.5		Ω
Supply Current			300	400		400	600	µA
Equivalent Input Noise Voltage			20			20		µV/p-p
Slew Rate	ΔV_{IN} = ±10V, R_L = 10kΩ, A_V = 1.0		0.3			0.3		V/µs
Settling Time	To ±10 mV, R_L = 10kΩ, ΔV_{OUT} = 1.0V A_V = 1.0 A_V = 100		 3.8 180			 3.8 180		 µs µs

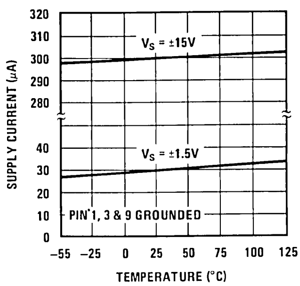
Note 1: Unless otherwise specified, all specifications apply for V_S = ±15V, Pins 1, 3, and 9 grounded, −25°C to +85°C for the LH0036C and −55°C to +125°C for the LH0036.

Note 2: All typical values are for T_A = 25°C.

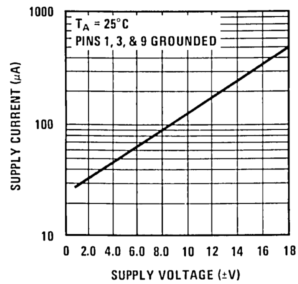
Note 3: The maximum junction temperature is 150°C. For operation at elevated temperature derate the G package on a thermal resistance of 90°C/W, above 25°C.

typical performance characteristics

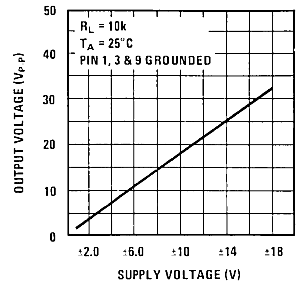
Supply Current vs Temperature



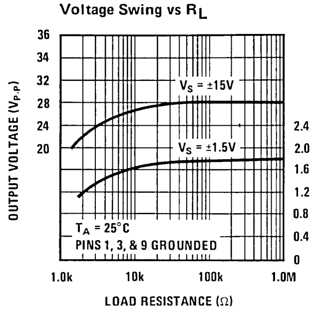
Supply Current vs Supply Voltage



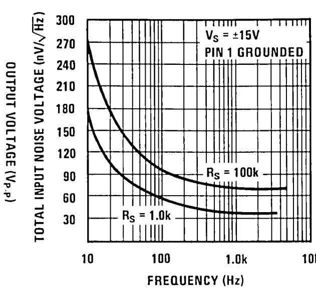
Output Voltage Swing vs Supply Voltage



Peak to Peak Output Voltage Swing vs R_L

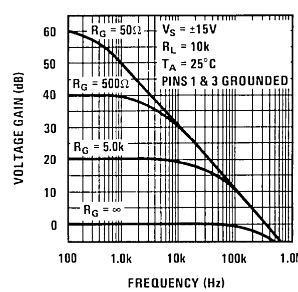


Total Input Noise Voltage* vs Frequency

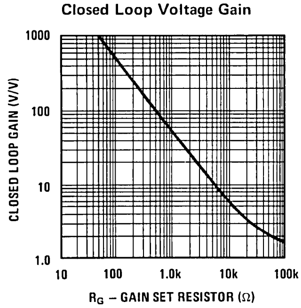


*Noise voltage includes contribution from source resistance

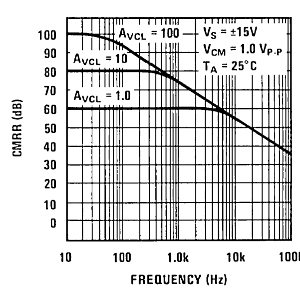
Closed Loop Voltage Gain vs Frequency



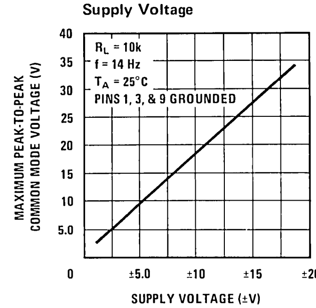
Closed Loop Voltage Gain



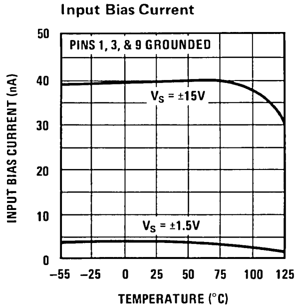
CMRR vs Frequency



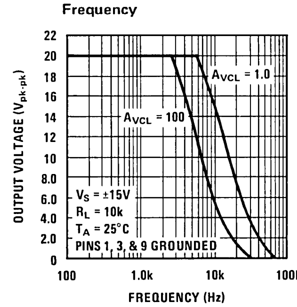
Common Mode Voltage vs Supply Voltage



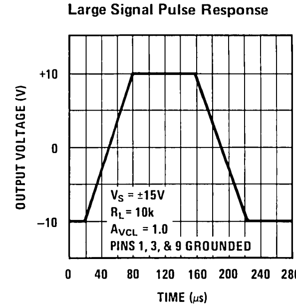
Input Bias Current



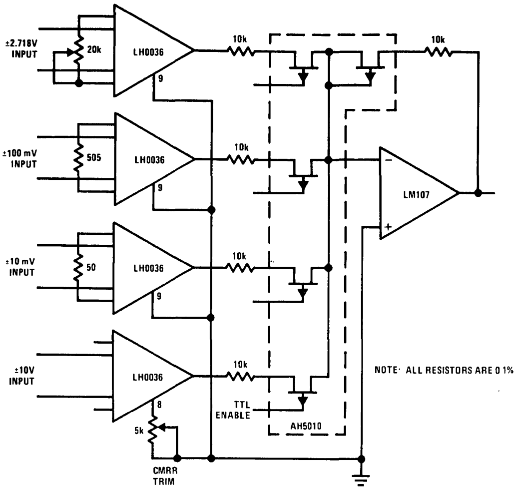
Output Voltage Swing vs Frequency



Large Signal Pulse Response

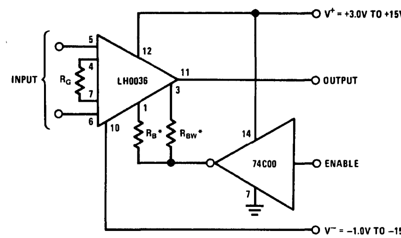


typical applications



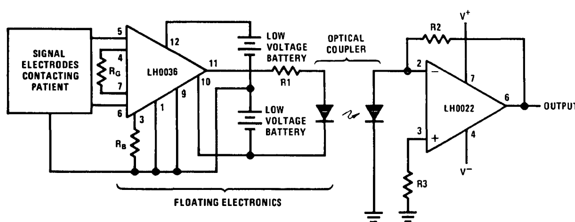
NOTE: ALL RESISTORS ARE 0.1%

Pre MUX Signal Conditioning

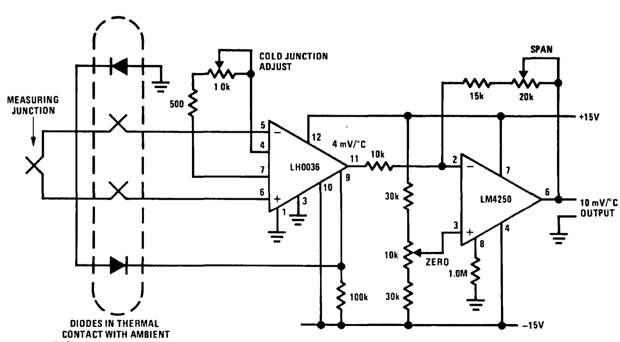


*R_{BW} AND R_B ARE OPTIONAL BANDWIDTH AND INPUT BIAS CURRENT CONTROLLING RESISTORS

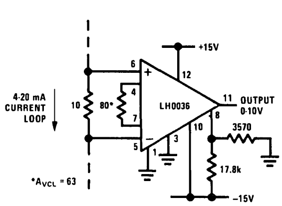
Instrumentation Amplifier with Logic Controlled Shut-Down



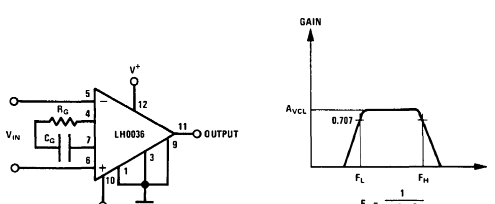
Isolation Amplifier for Medical Telemetry



Thermocouple Amplifier with Cold Junction Compensation



Process Control Interface



$F_L = \frac{1}{2\pi R_G C_G}$

F_H = A FUNCTION OF SELECTED A_{VCL}, R_B AND R_{BW}

High Pass Filter

applications information

THEORY OF OPERATION

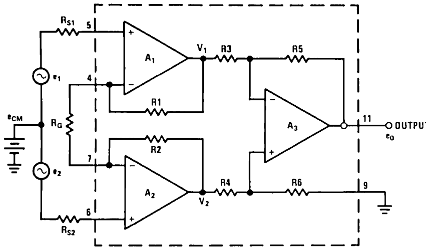


FIGURE 1. Simplified LH0036

The LH0036 is a 2 stage amplifier with a high input impedance gain stage comprised of A_1 and A_2 and a differential to single-ended unity gain stage, A_3. Operational amplifier, A_1, receives differential input signal, e_1, and amplifies it by a factor equal to $(R1 + R_G)/R_G$.

A_1 also receives input e_2 via A_2 and R2. e_2 is seen as an inverting signal with a gain of $R1/R_G$. A_1 also receives the common mode signal e_{CM} and processes it with a gain of +1.

Hence:

$$V_1 = \frac{R1 + R_G}{R_G} e_1 - \frac{R1}{R_G} e_2 + e_{CM} \quad (1)$$

By similar analysis V_2 is seen to be:

$$V_2 = \frac{R2 + R_G}{R_G} e_2 - \frac{R2}{R_G} e_1 + e_{CM} \quad (2)$$

For R1 = R2:

$$V_2 - V_1 = \left[\left(\frac{2R1}{R_G}\right) + 1\right](e_2 - e_1) \quad (3)$$

Also, for R3 = R5 = R4 = R6, the gain of $A_3 = 1$, and:

$$e_O = (1)(V_2 - V_1) = (e_2 - e_1)\left[1 + \left(\frac{2R1}{R_G}\right)\right] \quad (4)$$

As can be seen for identically matched resistors, e_{CM} is cancelled out, and the differential gain is dictated by equation (4).

For the LH0036, equation (4) reduces to:

$$A_{VCL} = \frac{e_O}{e_2 - e_1} = 1 + \frac{50k}{R_G} \quad (5a)$$

The closed loop gain may be set to any value from 1 ($R_G = \infty$) to 1000 ($R_G \cong 50\Omega$). Equation (5a) re-arranged in more convenient form may be used to select R_G for a desired gain:

$$R_G = \frac{50k}{A_{VCL} - 1} \quad (5b)$$

USE OF BANDWIDTH CONTROL (pin 1)

In the standard configuration, pin 1 of the LH0036 is simply grounded. The amplifier's slew rate in this configuration is typically 0.3V/µs and small signal bandwidth 350 kHz for A_{VCL} = 1. In some applications, particularly at low frequency, it may be desirable to limit bandwidth in order to minimize the overall noise bandwidth of the device. A resistor R_{BW} may be placed between pin 1 and ground to accomplish this purpose. Figure 2 shows typical small signal bandwidth versus R_{BW}.

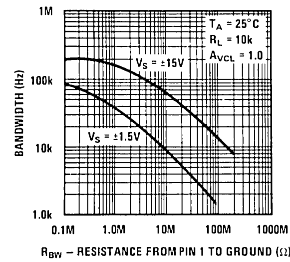


FIGURE 2. Bandwidth vs R_{BW}

It also should be noted that large signal bandwidth and slew rate may be adjusted down by use of R_{BW}. Figure 3 is plot of slew rate versus R_{BW}.

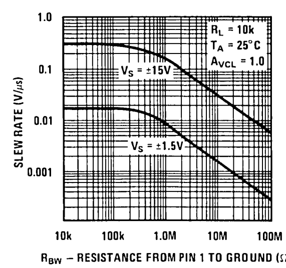


FIGURE 3. Output Slew Rate vs R_{BW}

CMRR CONSIDERATIONS

Use of Pin 9, CMRR Preset

Pin 9 should be grounded for nominal operation. An internal factory trimmed resistor, R6, will yield a CMRR in excess of 80 dB (for A_{VCL} = 100). Should a higher CMRR be desired, pin 9 should be left open and the procedure, in this section followed.

DC Off-set Voltage and Common Mode Rejection Adjustments

Off-set may be nulled using the circuit shown in Figure 4.

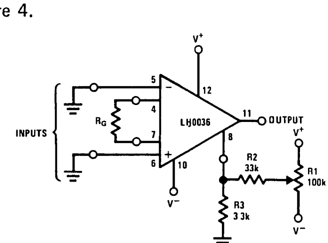


FIGURE 4. V_{OS} Adjustment Circuit

Pin 8 is also used to improve the common mode rejection ratio as shown in Figure 5. Null is

applications information (con't)

achieved by alternately applying ±10V (for V^+ & V^- = 15V) to the inputs and adjusting R1 for minimum change at the output.

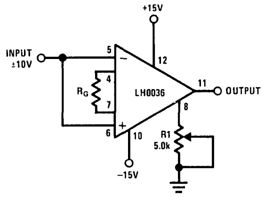


FIGURE 5. CMRR Adjustment Circuit

The circuits of Figure 4 and 5 may be combined as shown in Figure 6 to accomplish both V_{OS} and CMRR null. However, the V_{OS} and CMRR adjustment are interactive and several iterations are required. The procedure for null should start with the inputs grounded.

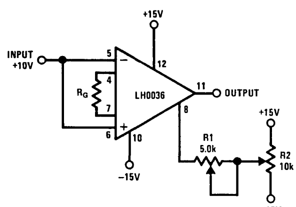
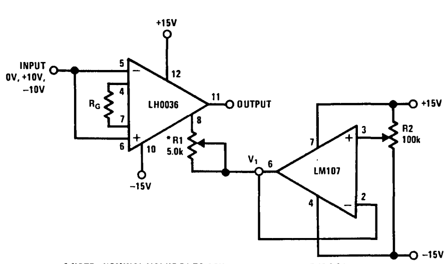


FIGURE 6. Combined CMRR, V_{OS} Adjustment Circuit

R2 is adjusted for V_{OS} null. An input of +10V is then applied and R1 is adjusted for CMRR null. The procedure is then repeated until the optimum is achieved.

A circuit which overcomes adjustment interaction is shown in Figure 7. In this case, R2 is adjusted first for output null of the LH0036. R1 is then adjusted for output null with +10V input. It is always a good idea to check CMRR null with a −10V input. The optimum null achievable will yield the highest CMRR over the amplifiers common mode range.



* NOTE: NOMINAL VALUE R1 TO ACHIEVE OPTIMUM CMRR IS 3.0 kΩ.

FIGURE 7. Improved V_{OS}, CMRR Nulling Circuit

AC CMRR Considerations

The ac CMRR may be improved using the circuit of Figure 8.

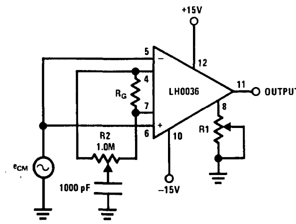


FIGURE 8. Improved AC CMRR Circuit

After adjusting R1 for best dc CMRR as before, R2 should be adjusted for minimum peak-to-peak voltage at the output while applying an ac common mode signal of the maximum amplitude and frequency of interest.

INPUT BIAS CURRENT CONTROL

Under nominal operating conditions (pin 3 grounded), the LH0036 requires input currents of 40 nA. The input current may be reduced by inserting a resistor (R_B) between 3 and ground or, alternatively, between 3 and V^-. For R_B returned to ground, the input bias current may be predicted by:

$$I_{BIAS} \cong \frac{V^+ - 0.5}{4 \times 10^8 + 800\ R_B} \qquad (6a)$$

or

$$R_B = \frac{V^+ - 0.5 - (4 \times 10^8)\ (I_{BIAS})}{800\ I_{BIAS}} \qquad (6b)$$

Where:

I_{BIAS} = Input Bias Current (nA)

R_B = External Resistor connected between pin 3 and ground (Ohms)

V^+ = Positive Supply Voltage (Volts)

Figure 9 is a plot of input bias current versus R_B.

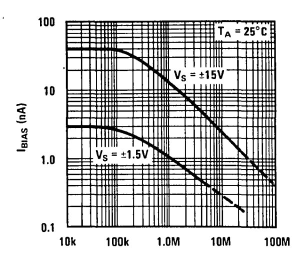


FIGURE 9. Input Bias Current as a Function of R_B

As indicated above, R_B may be returned to the negative supply voltage. Input bias current may then be predicted by:

$$I_{BIAS} \cong \frac{(V^+ - V^-) - 0.5}{4 \times 10^8 + 800\ R_B} \qquad (7)$$

applications information (con't)

or

$$R_B \cong \frac{(V^+ - V^-) - 0.5 - (4 \times 10^8)(I_{BIAS})}{800\, I_{BIAS}} \qquad (8)$$

Where:

I_{BIAS} = Input Bias Current (nA)

R_B = External resistor connected between pin 3 and V^- (Ohms)

V^+ = Positive Supply Voltage (Volts)

V^- = Negative Supply Voltage (Volts)

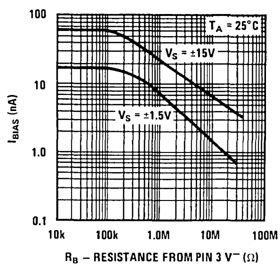


FIGURE 10. Input Bias Current as a Function of R_B

Figure 10 is a plot of input bias current versus R_B returned to V^- it should be noted that bandwidth is affected by changes in R_B. Figure 11 is a plot of bandwidth versus R_B.

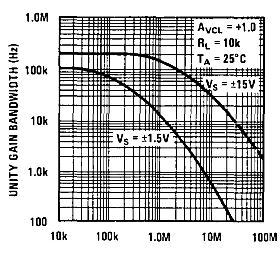


FIGURE 11. Unity Gain Bandwidth as a Function of R_B

BIAS CURRENT RETURN PATH CONSIDERATIONS

The LH0036 exhibits input bias currents typically in the 40 nA region in each input. This current must flow through R_{ISO} as shown in Figure 12.

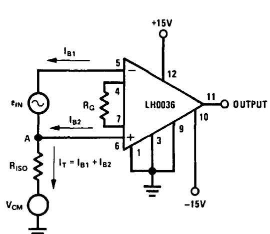


FIGURE 12. Bias Current Return Path

In a typical application, $V_S = \pm 15V$, $I_{B1} \cong I_{B2} \cong 40$ nA, the total current, I_T, would flow through R_{ISO} causing a voltage rise at point A. For values of $R_{ISO} \geq 150\ M\Omega$, the voltage at point A exceeds the +12V common range of the device. Clearly, for $R_{ISO} = \infty$, the LH0036 would be driven to positive saturation.

The implication is that a finite impedance must be supplied between the input and power supply ground. The value of the resistor is dictated by the maximum input bias current, and the common mode voltage. Under worst case conditions:

$$R_{ISO} \leq \frac{V_{CMR} - V_{CM}}{I_T} \qquad (9)$$

Where:

V_{CMR} = Common Mode Range (10V for the LH0036)

V_{CM} = Common Mode Voltage

I_T = I_{B1} + I_{B2}

In applications in which the signal source is floating, such as a thermocouple, one end of the source may be grounded directly or through a resistor.

GUARD OUTPUT

Pin 2 of the LH0036 is provided as a guard drive pin in those stringent applications which require very low leakage and minimum input capacitance. Pin 2 will always be biased at the input common mode voltage. The source impedance looking into pin 2 is approximately 15 kΩ. Proper use of the guard/shield pin is shown in Figure 13.

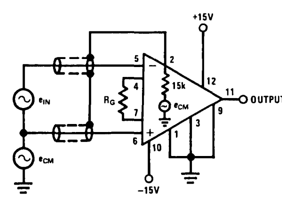


FIGURE 13. Use of Guard

For applications requiring a lower source impedance than 15 kΩ, a unity gain buffer, such as the LH0002 may be inserted between pin 2 and the input shields as shown in Figure 14.

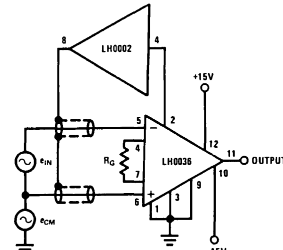


FIGURE 14. Guard Pin With Buffer

Operational Amplifiers

LH0045/LH0045C two wire transmitter

general description

The LH0045/LH0045C Two Wire Transmitters are linear integrated circuits designed to convert the voltage from a sensor to a current, and send it through to a receiver, utilizing the same simple twisted pair as the supply voltage.

The LH0045 and LH0045C contain an internal reference designed to power the sensor bridge, a sensitive input amplifier, and an output current source. The output current scale can be adjusted to match the industry standards of 4.0 mA to 20 mA or 10 mA to 50 mA.

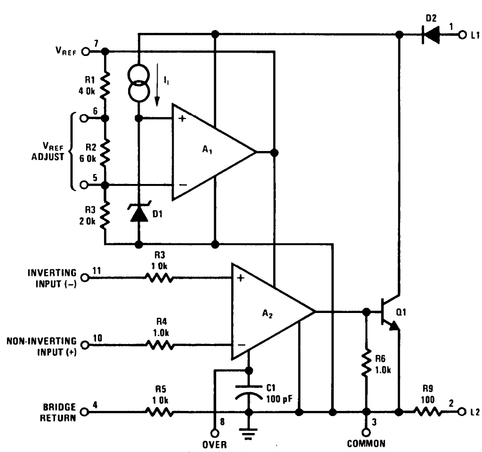
Designed for use with various sensors, the LH0045/LH0045C will interface with thermocouples, strain gauges, or thermistors. The use of the power supply leads as the signal output eliminates two or three extra wires in remote signal applications. Also, current output minimizes susceptibility to voltage noise spikes and eliminates line drop problems.

features

- High sensitivity $> 10\ \mu A/\mu V$
- Low input offset voltage 1.0 mV
- Low input bias current 2.0 nA
- Single supply operation 10V to 50V
- Programmable bridge reference (LH0045G) 5.0V to 30V
- Non-interactive span and null adjust
- Over compensation capability
- Supply reversal protection

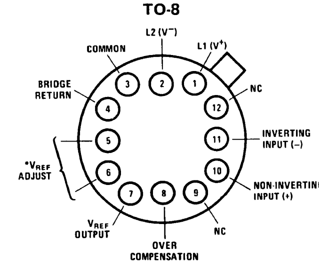
The LH0045/LH0045C is intended to fulfill a wide variety of process control, instrumentation, and data acquisition applications. The LH0045 is guaranteed over the temperature range of −55°C to +125°C; whereas the LH0045C is guaranteed from −25°C to +85°C.

equivalent schematic and connection diagrams



*NOTE: PINS SHOWN ARE FOR THE 12 PIN TO-8 ("G") PACKAGE.

TO-8

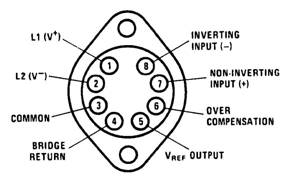


TOP VIEW

*NOTE: PIN 5 IS SHORTED TO PIN 6 TO OBTAIN A NOMINAL +5.1V, V_{REF}. LEFT OPEN V_{REF} = +10V.
THE CASE IS ISOLATED FROM THE CIRCUIT FOR BOTH TO-3 AND TO-8

Order Number LH0045G or LH0045CG
See Package 6

TO-3



TOP VIEW

Order Number LH0045K or LH0045CK
See Package 19

absolute maximum ratings

Supply Voltage (L1 to common)	+50V
Input Current	±20 mA
Input Voltage (Either Input to Common)	0V to V_{REF}
Differential Input Voltage	±20 V
Output Current (Either L1 or L2)	50 mA
Reference Output Current	5.0 mA
Power Dissipation	
LH0045G	1.5W
LH0045K	3.0W
Operating Temperature Range	
LH0045	−55°C to +125°C
LH0045C	−25°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

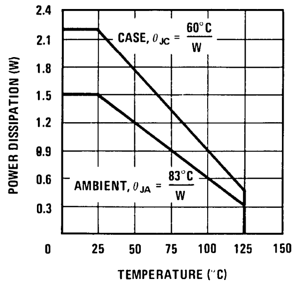
electrical characteristics (Note 1)

PARAMETER	CONDITIONS	LIMITS LH0045 MIN	LH0045 TYP	LH0045 MAX	LH0045C MIN	LH0045C TYP	LH0045C MAX	UNITS
Input Offset Voltage (V_{OS})	I_S = 4.0 mA, T_A = 25°C I_S = 4.0 mA		0.7	2.0 3.0		2.0	7.5 10	mV mV
Offset Voltage Temperature Coefficient ($\Delta V_{OS}/\Delta T$)	I_S = 4.0 mA		3.0			6.0		µV/°C
Input Bias Current (I_B)	T_A = 25°C		0.8	2.0 3.0		1.5	7.0 10	nA nA
Input Offset Current (I_{OS})	T_A = 25°C		0.05	0.2 0.4		0.2	1.0 1.5	nA nA
Open Loop Transconductance (g_{MOL})	ΔI_S = 4.0 mA to 20 mA ΔI_S = 10 mA to 50 mA	10^6 2×10^6	10^7 2×10^7		10^6 2×10^6	10^7 2×10^7		µ℧ µ℧
Supply Voltage Range (V_S)	 LH0045G pins 5 and 6 open	9.0 15		50 50	9.0 15		50 50	V V
Input Voltage Range (V_{IN})	 LH0045G pins 5 and 6 open	1.0 1.0		3.3 7.6	1.0 1.0		3.3 7.6	V V
Open Loop Output Impedance (R_{OUT})	V_S = 10V to 45V, I_S = 4.0 mA, T_A = 25°C		1.0			1.0		MΩ
Common Mode Rejection Ratio (CMRR)	ΔV_{IN} = 1.0V to 3.3V, I_S = 12 mA	0.1	0.05		0.1	0.05		mV/V
Power Supply Rejection Ratio (PSRR)	ΔV_S = 10V to 45V, I_S = 12 mA	0.1	0.01		0.1	0.01		mV/V
Open Loop Supply Current (I_{SOL})	V_S = 50V		2.0	3.0		2.0	3.0	mA
Reference Voltage Load Regulation ($\Delta V_{REF}/\Delta I_{REF}$)	ΔI_{REF} = 0 mA to 2.0 mA, T_A = 25°C		0.05	0.2		0.05	0.2	%
Reference Voltage Line Regulation ($\Delta V_{REF}/\Delta V_S$)	ΔV_S = 10V to 45V, T_A = 25°C		0.3	0.5		0.3	0.5	mV/V
Reference Voltage Temperature Coefficient ($\Delta V_{REF}/\Delta T$)	I_{REF} = 2.0 mA		0.004			0.004		%/°C
Reference Voltage (V_{REF})	I_{REF} = 2.0 mA, T_A = 25°C I_{REF} = 2.0 mA, T_A = 25°C, LH0045G pins 5 and 6 open	4.3 8.6	5.1 10.3	5.9 12	4.3 8.6	5.1 10.3	5.9 12	V V
Resistor R9	I_S = 12 mA, T_A = 25°C	95	100	105	95	100	105	Ω
Average Temperature Coefficient of R9 (TCR_9)	I_S = 12 mA		50	300		50	300	PPM/°C
Resistor R5	I_S = 1.0 mA, T_A = 25°C	950	1000	1050	950	1000	1050	Ω
Average Temperature Coefficient of R5 (TCR_5)	I_S = 1.0 mA		50	300		50	300	PPM/°C
Input Resistance (R_{IN})	T_A = 25°C		50			50		MΩ

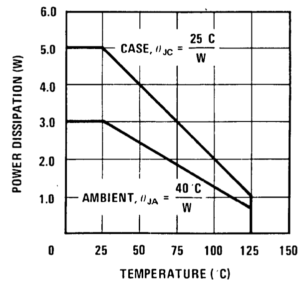
Note 1: Unless otherwise specified, these specifications apply for $+10V \le V_S \le +50V$, pin 5 shorted to pin 6 on the LH0045G, over the temperature range −55°C to +125°C for the LH0045 and −25°C to +85°C for the LH0045C.

typical performance characteristics

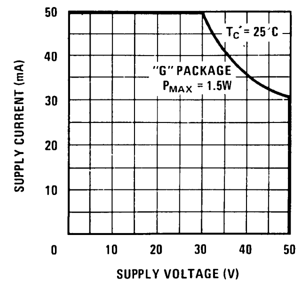
LH0045G Maximum Power Dissipation



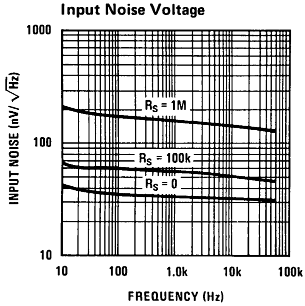
LH0045K Maximum Power Dissipation



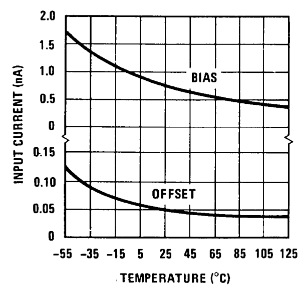
Safe Operating Area



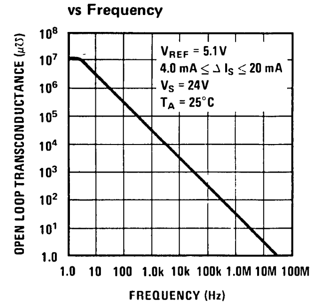
Input Noise Voltage



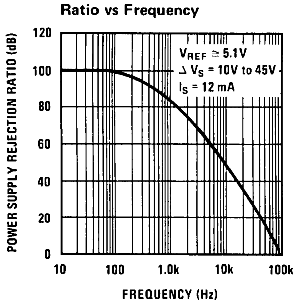
Input Currents



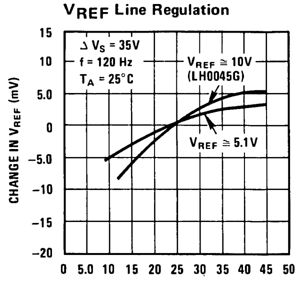
Open Loop Transconductance vs Frequency



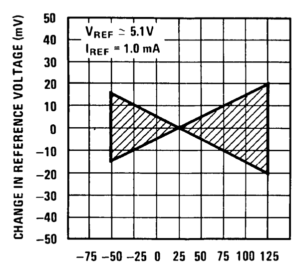
Power Supply Rejection Ratio vs Frequency



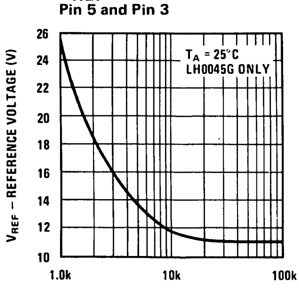
V_{REF} Line Regulation



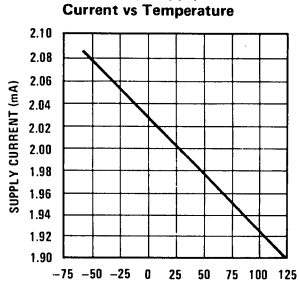
Variation of V_{REF} With Temperature Normalized to 25°C



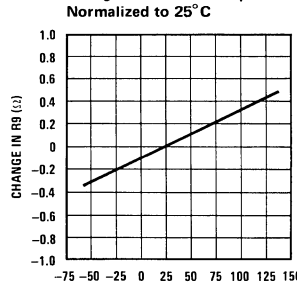
V_{REF} vs Resistance Between Pin 5 and Pin 3



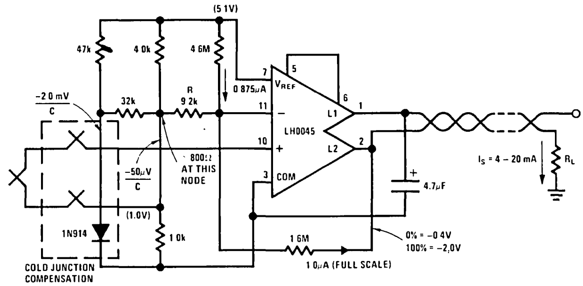
Open Loop Supply Current vs Temperature



Change in R9 With Temperature Normalized to 25°C

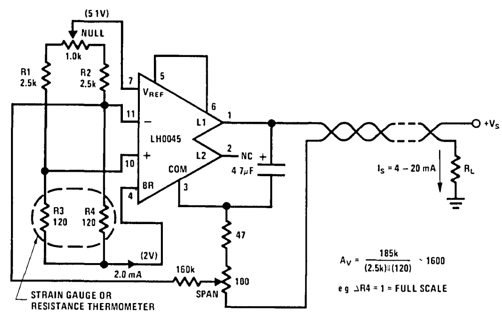


typical applications*

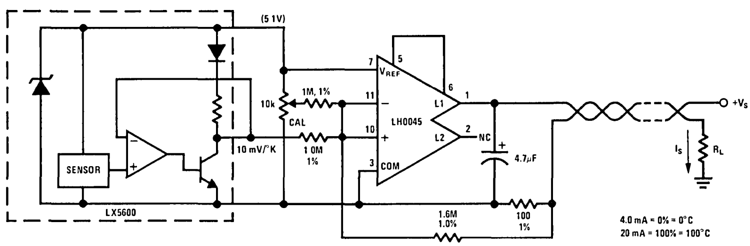


FOR 1μA FULL SCALE, $R_{IN} = V_{IN}/1\mu A$ = SOURCE IMPEDANCE @ PIN 11
e.g., V_{IN} (FULL SCALE) = 10 mV, R_{IN} = 10k
BRIDGE IMPEDANCE = 0.8k, R = 10k − 0.8k = 9.2k

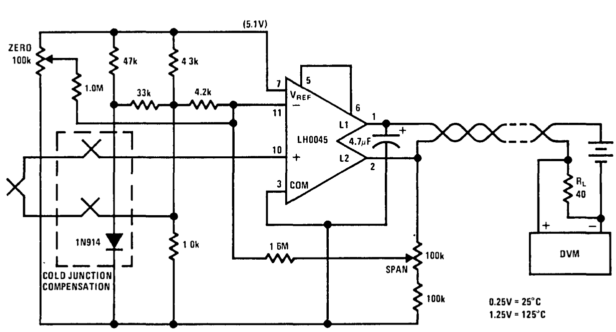
Thermocouple Input Transmitter



Resistance Bridge Input Transmitter

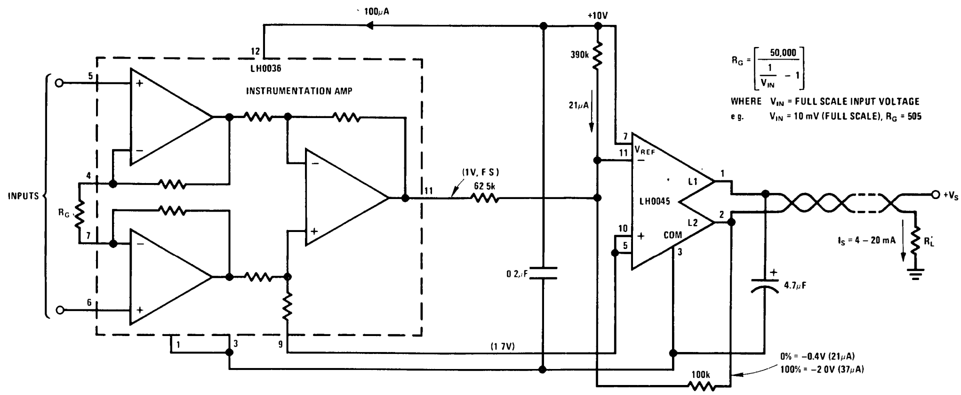


Electronic Temperature Sensor



*Pin numbers refer to 'G' package. All voltages indicated by ( ) are measured with respect to common, pin 3.

typical applications* (con't)



*Pin numbers refer to 'G' package. All voltages indicated by ( ) are measured with respect to common, pin 3.

Instrumentation Amplifier Transmitter

applications information

CIRCUIT DESCRIPTION AND OPERATION

A simplified schematic of the LH0045/LH0045C is shown in Figure 1. Differential amplifier, A_2 converts very low level signals to an output current via transistor Q1. Reference voltage diode D1 is used to supply voltage for operation of A_2 and to bias an external bridge. Current source I_1 minimizes fluctuation in the bridge reference voltage due to changes in V_S.

In normal operation, the LH0045/LH0045C is used in conjunction with an external bridge comprised of R_{B1} through R_{B4}. The bridge resistors in conjunction with bridge return resistor, R5, bias A_2 in its linear region and sense the input signal; e.g. R_{B4} might be a strain sensitive resistor in a strain gauge bridge. R_T is adjusted to purposely unbalance the bridge for 4.0 mA output (null) for zero signal input. This is accomplished by forcing 2.5μA more through R_{B3} than R_{B4}.

The 2.5μA imbalance causes a voltage rise of (2.5μA) x (100Ω) or 250μV at the top of R_{B3}. Terminal L2 may be viewed as the output of an op amp whose closed loop gain is approximately R_F/R_{B3} = 1600.

The 250μV rise at the top of R_{B3} causes a voltage drop of (1600) x (250μV) or −0.4V across R9. An output current, I_S, equal to 0.4V/R9 or 4.0 mA is thus established in Q1. If R_{B4} is now decreased by 1.0Ω (due to application of a strain force), a −1.0 mV change in input voltage will result. This causes L2 to drop to −2.0V. The output current would then be 2.0V/100Ω or 20 mA (Full Scale). If R_{B3} is a resistor of the same material as R_{B4} but not subjected to the strain, temperature drift effects will be equal in the two legs and will cancel.

In actual practice the loading effects of R_{B2} on the gain (span) and R_F on output current must be taken into account.

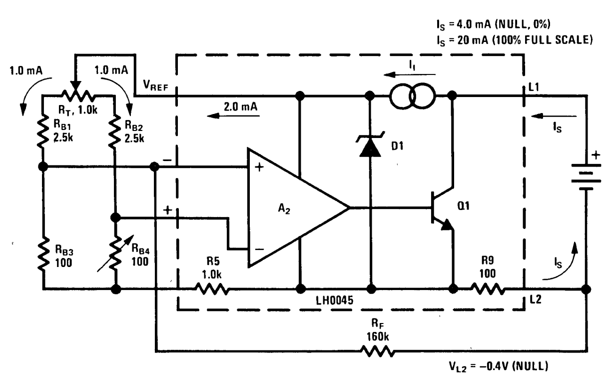


FIGURE 1. LH0045 Simplified Schematic

applications information (con't)

THERMAL CONSIDERATIONS

The power output transistor of the LH0045 is thermally isolated from the signal amplifier, A_2. Nevertheless, a change in the power dissipation will cause a change in the temperature of the package and thus may cause amplifier drift. These temperature excursions may be minimized by careful heat sinking to hold the case temperature equal to the ambient. With the TO-8 (G) package this is best accomplished by a clip-on heat sink such as the Thermalloy #2240A or the Wakefield #215-CB. The 8 lead TO-3 is particularly convenient for heat sinking, in that it may be bolted directly to many commercial aluminum heat sink extrusions, or to the chassis. In both packages the case is electrically isolated from the circuit.

In addition, the power change can be minimized by operating the device from relatively high supply voltages in series with a relatively high load resistance. When the signal forces the supply current higher, the voltage across the device will be reduced and the internal power dissipation kept nearly equal to the low current, high voltage condition.

For example, take the case of a 4.0 mA to 20 mA transmitter with a 24V supply and a 100Ω load resistance. The power at 4.0 mA is (23.6V) x (4.0 mA) = 94.4 mW while at full scale the power is (22V) x (20 mA) = 440 mW. The net change in power is 345 mW. This change in power will cause a change in temperature and thus a change in offset voltage of A_2.

If the optimum load resistance of 800Ω (from Figure 2) is used, the power at null is [24V − (4.0 mA) x (800Ω)] (4.0 mA) = 83 mW. The power at full scale is [24V − (20 mA) x (800Ω)] (20 mA) = 160 mW. The net change is 77 mW. This change is significantly less than without the resistor.

If the supply voltage is increased to 48V and the load resistance chosen to be the optimum value from Figure 2 (1.95k), then the power at null is [48V − (4.0 mA) x (1.95k)] (4.0 mA) = 160.8 mW and the power at full scale is [48 − (20) x (1.95k)] (20 mA) = 180 mW for a net change of 19.2 mW.

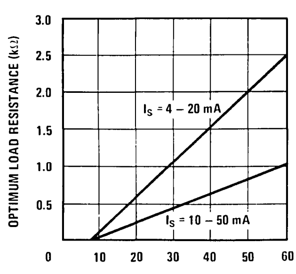


FIGURE 2. Optimum Load Resistance vs Supply Voltage

Note that the optimized load resistance is actually the sum of the line resistance, receiver resistances and added external load resistance. However, in many applications the line resistance and receiver resistances are negligible compared to the added external load resistance and thus may be omitted in calculations.

AUXILIARY PINS

The LH0045 has several auxiliary pins designed to provide the user with enhanced flexibility and performance. The following is a discussion of possible uses for these pins.

Programmable V_{REF} − Pins 5 and 6 (LH0045G Only)

The LH0045G provides pins 5 and 6 to allow the user to program the value of the reference voltage. The factory trimmed 10V value is obtained by leaving 5 and 6 open. A short between 5 and 6 will program the reference to a nominal 5.1V (equivalent to the fixed value used in the LH0045K).

A resistor or pot may be placed between pin 5 and common (pin 3) to obtain reference voltages between 10V and 30V or between pin 5 and pin 7 for reference voltages below 10V. Increased reference voltage might be useful to extend the positive common mode range or to accommodate transducers requiring higher supply voltage. A plot of resistance between pin 5 and pin 3 versus V_{REF} is given in the typical electrical characteristics section. V_{REF} may be adjusted about its nominal value by arranging a pot from V_{REF} to common and feeding a resistor from the wiper into pin 5 so that it may either inject or extract current. Lastly, pin 5 may be used as a nominal 1.7V reference point, if care is taken not to unduly load it with either dc current or capacitance. Obviously, higher supply voltages must be used to obtain the higher reference values. The minimum supply voltage to reference voltage differential is about 4.0V.

Bridge Return

An applications resistor is provided in the LH0045 with a nominal value of 1.0 kΩ. The primary application for the resistor is to maintain the minimum common mode input voltage (1.0V) required by the signal amplifier, A_2. A typical input application might utilize a strain gauge or thermistor bridge where the resistance of the sensor is 100Ω. Since only 1.0 mA may be drawn from V_{REF}, the 1.0 kΩ bridge return resistor is used to bias A_2 in its linear region as shown in Figure 3.

2

applications information (con't)

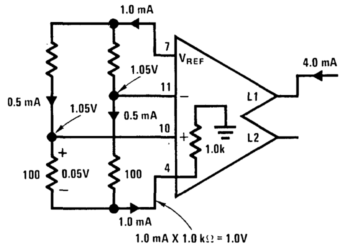


FIGURE 3. Use of Bridge Return

Over Compensation — Pin 8 (LH0045G), Pin 6 (LH0045K)

Over compensation of the signal amplifier, A_2 may be desirable in dc applications where the noise-bandwidth must be minimized. A capacitor should be placed between pin 8 (pin 6 on the LH0045K) and pin 3, common.

Typically,

$$f_{3db} = \frac{1}{2\pi R (C_1 + C_{EXT})}$$

where:

R = 400 MΩ

C1 = Internal Compensation Capacitor = 100 pF

C_{EXT} = External (over-compensation) Capacitor

Input Guard — Pins 9 and 12 (LH0045G)

Pins 9 and 12 have no internal connection whatever and thus need not be used. In some critical low current applications there may be an advantage to running a guard conductor between the inputs and the adjacent pins to intercept stray leakage currents. Pins 9 and 12 may be connected to this guard to simplify the PC board layout and allow the guard to continue under the device. (See AN-63 for further discussion of guarding techniques.)

NULL AND SPAN ADJUSTMENTS

Most applications of the LH0045 will require potentiometers to trim the initial tolerances of the sensor, the external resistors and the LH0045 itself. The preferred adjustment procedure is to stimulate the sensor, alternating between two known values, such as zero and full scale. The span and null are adjusted by monitoring the output current on a chart recorder, meter, or oscilloscope. A full scale stimulus is applied to the sensor and the span potentiometer adjusted for the desired full scale. Then, to adjust the null, apply a zero percent signal to the sensor and adjust the null potentiometer for the desired zero percent current indication.

If it is impractical to cycle the sensor during the calibration procedure, the signal may be simulated electrically with two cautions: 1) the calibration signal must be floating and 2) the calibration thus achieved does not account for sensor inaccuracies and/or errors in the signal generator.

SENSOR SELECTION

Generally it is easiest to use an insulated sensor. If it is necessary to use a grounded sensor, the power supply must be isolated from chassis ground to avoid extraneous circulating currents.

DESIGN EXAMPLE

There are numerous circuit configurations that may be utilized with the LH0045. The following is intended as a general design example which may be extended to specific cases.

Circuit Requirements

Output Characteristics

a. 0% = 4.0 mA (NULL)

b. 100% = 20 mA (SPAN = 16 mA)

c. Supply Voltage = 24V

Input (Sensor) Characteristics

a. V_{IN} = 100 mV (Full Scale)

b. V_{IN} = 0 mV (Zero Scale)

c. Source Impedance $\leq$ 1.0Ω

General Characteristics

a. $0°C \leq T_A \leq +75°C$

b. Overall Accuracy $\leq$ 0.5%

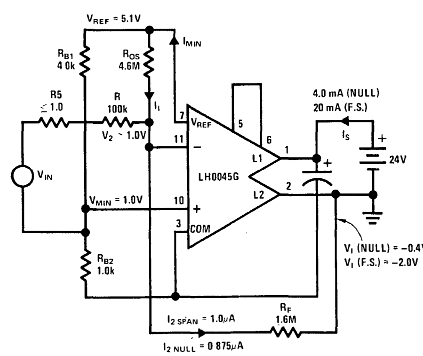


FIGURE 4. Design Example Circuit

Selection of R_F

Input bias current to the LH0045C is guaranteed less than 10 nA. Furthermore, the change in I_B over the temperature range of interest is typically under 1.0 nA. If $I_{2\ SPAN}$ is selected to be 1.0μA (1000 Δ I_B) errors due to Δ I_B/Δ T will be less than 0.1%. For SPAN = 16 mA.

$$V_{SPAN} = \Delta V_1 = -(16\,mA)(R9) = -1.6V$$

applications information (con't)

where R9 = Internal Current Set Resistor = 100Ω
For $I_{2\ SPAN}$ = 1.0μA,

$$R_F = \frac{V_{SPAN}}{I_{2\ SPAN}} = \frac{-1.6V}{1.0\mu A} = 1.6M$$

$$R_F = 1.6\ M\Omega$$

Selection of R_{B1} and R_{B2}

The minimum input common mode voltage, V_{MIN} required at the pin 10 input of A_2 is 1.0V. Furthermore, the maximum open loop supply current (I_{SOL}) drawn by the LH0045 is 3.0 mA. That leaves I_{MIN} = 4.0 mA − 3.0 mA = 1.0 mA left to bias the bridge at null. Hence:

$$R_{B2} \geqq \frac{V_{MIN}}{I_{MIN}} = \frac{1.0V}{1.0\ mA} = 1.0\ k\Omega$$

And,

$$\frac{V_{REF}\ R_{B2}}{R_{B1} + R_{B2}} = 1.0V$$

$$R_{B1} = R_{B2}\ \frac{V_{REF} - 1.0V}{1.0V}$$

$$= 1.0k\ (5.1 - 1.0)$$

$$R_{B1} \cong 4.0\ k\Omega$$

Alternatively, an LM113, 1.22V reference diode, or an op amp such as the LM108 may be used to bias the signal amplifier, A_2 as shown in Figure 5. These techniques have the advantage of lowering the impedance seen at pin 10.

Selection of R_{OS}

R_{OS} is selected to provide the null current of 4.0 mA, $V_{1\ NULL}$ = 4.0 mA x 100Ω = 0.4V. From previous calculations we know that V_{MIN} = 1.0V. The voltage pin 11, V_2 is:

$$V_2 = V_{MIN} + V_{OS} \cong V_{MIN}$$

for V_{IN} = 0V

Hence, the current required to generate the null voltage, $I_{2\ NULL}$ is:

$$I_{2\ NULL} = \frac{V_{MIN} - V_{1\ NULL}}{R_F}$$

$$= \frac{1.0V - (-0.4V)}{1.6\ M\Omega} = 0.875\mu A$$

This current must be provided by R_{OS} from V_{REF}; hence:

$$R_{OS} = \frac{V_{REF} - V_{MIN}}{I_{2\ NULL}}$$

The nominal value for V_{REF} is 5.1V, therefore the nominal value for R_{OS} is:

$$\frac{5.1V - 1.0V}{0.875\mu A} \quad \text{or}$$

$$R_{OS} = 4.6\ M\Omega$$

It should be noted however, that the variation of V_{REF} may be as high as 5.9V or as low as 4.3V. Furthermore, the tolerances of R9 (100Ω), R_{B1}, R_{B2}, and the input V_{OS} of A_2 would predict values for R_{OS} as low as 3.98M and as high as 5.43M. The implication is that in the specific case, R_{OS} should be implemented with a pot, of appropriate value, in order to accommodate the tolerances of V_{REF}, R9, V_{OS}, R_{B1}, R_{B2}, etc.

Selection of R

SPAN is required to be 16 mA. From feedback theory and the gain equation we know:

$$I_{SPAN} = V_{IN}\ \frac{R_F}{R} \times \frac{1}{R9}$$

where:

R = total impedance in signal path between pin 10 and pin 11

R9 = Current setting resistor = 100Ω

V_{IN} = Full scale input voltage = 100 mV

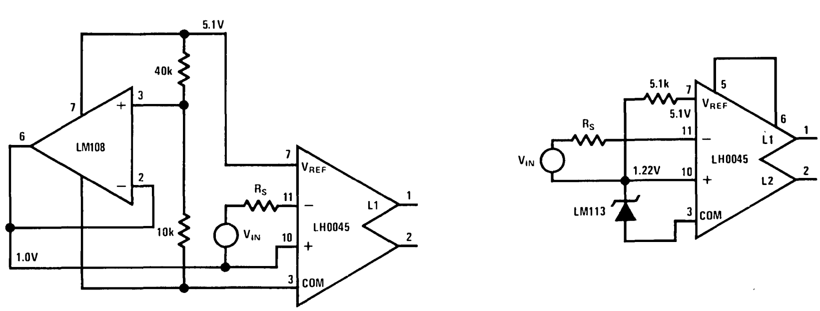


FIGURE 5. Alternate Biasing Techniques

applications information (con't)

$$\therefore R = \frac{(V_{IN})(R_F)}{(I_{SPAN})(R9)}$$

$$R = \frac{(100\ mV)(1.6\ M\Omega)}{(16\ mA)(100\Omega)}$$

$$R = 100\ k\Omega$$

As before, uncertainties in device parameters might dictate that R_F be made a pot of appropriate value.

Summary of the Steps to Determine External Resistor Values

1. Select $I_{FULL\ SCALE} = I_{NULL} + I_{SPAN}$ for the desired application. (I_{NULL} is frequently 4.0 mA and $I_{FULL\ SCALE}$ is frequently 20 mA.)

2. Select $I_{2\ SPAN}$ so that it is large compared to ΔI_B. 1000 ΔI_B is a good value.

3. Determine $V_{SPAN} = \Delta V_2 = (I_{SPAN})(R9)$.

4. Determine $R_F = (V_{SPAN}/I_{2\ SPAN})$

5. Select

$$R_{B2} \geq \frac{V_{MIN}}{I_{MIN}}$$

$$R_{B2} \geq \frac{1\ VOLT}{I_{NULL} - I_{SOL}}$$

Where:

V_{MIN} = minimum common mode input voltage

I_{MIN} = minimum available bridge current

I_{SOL} = maximum open loop supply current

6. Determine

$$R_{B1} = R_{B2}\,\frac{V_{REF} - V_{MIN}}{V_{MIN}}$$

7. Determine $V_{2\ NULL} = I_{NULL}\ R9$

8. Determine

$$I_{2\ NULL} = \frac{V_{MIN} - V_{2\ NULL}}{R_F}$$

9. Determine

$$R_{OS} = \frac{V_{REF} - V_{MIN}}{I_{2\ NULL}}$$

10. Determine

$$R = \frac{(V_{IN})(R_F)}{(I_{SPAN})(R9)}$$

Where:

V_{IN} = Sensor full scale output voltage

ERROR BUDGET ANALYSIS

Errors Due to Change in V_{REF} (ΔV_{REF})

There are several factors which could cause a change in V_{REF}. First, as the ambient temperature changes, a V_{REF} drift of ±0.2 mV/°C might be expected. Secondly, supply voltage variations could cause a 0.5 mV/V change in V_{REF}. Lastly, self-heating due to power dissipation variations can cause drift of the reference.

An overall expression for change in V_{REF} is:

$$\Delta V_{REF} = \underbrace{[(\theta)(\Delta P_{DISS}) + \Delta T_A]\,\frac{\Delta V_{REF}}{\Delta T}}_{\text{Thermal Effects}} + \underbrace{\frac{\Delta V_{REF}}{\Delta V_S}(\Delta V_S)}_{\text{Supply Voltage Effects}}$$

Where:

θ = Thermal resistance, either junction-to-ambient to junction to case

ΔP_{DISS} = Change in avg. power dissipation

ΔT_A = Change in ambient temperature

$\frac{\Delta V_{REF}}{\Delta T}$ = Reference voltage drift (in mV/°C)

$\frac{\Delta V_{REF}}{\Delta V_S}$ = Line regulation of V_{REF}

Several steps may be taken to minimize the bracketed terms in the equation above. For example, operating the LH0045G with a heat-sink reduces the thermal resistance from θ_{JA} = 83°C/W to θ_{JC} = 60°C/W. For the LH0045K (TO-3) θ_{JA} = 40°C/W may be reduced to θ_{JC} = 25°C/W by using a heat sink. The ΔP_{DISS} term may be significantly reduced using the power minimization technique described under "Thermal Considerations." For the design example, ΔP_{DISS} is reduced from 384 mW to 77 mW (R_L = 800Ω.) Evaluating the LH0045G with a heat-sink and R_L = 800Ω yields.

$$\Delta V_{REF} = \left(\frac{60^\circ C}{W}(0.077W) + 75^\circ C\right)\left(\frac{0.2\ mV}{^\circ C}\right) + \frac{0.5\ mV}{V}(16V)$$

$$\Delta V_{REF} = 24\ mV$$

The LH0045K (TO-3) under the same operating conditions would exhibit a $\Delta V_{REF} \cong 23$ mV.

applications information (con't)

An expression for error in the output current due to ΔV_{REF} is:

$$\frac{\Delta I_S}{I_{SPAN}} (\%) = 100 \frac{(K)(R_{OS})(\Delta V_{REF}) - (1-K)(\Delta V_{REF})(R_F)}{(R9)(R_{OS})(I_{SPAN})}$$

Where:

ΔV_{REF} = Total change in V_{REF}

$K = \frac{R_{B2}}{R_{B1} + R_{B2}}$

R9 = Current set resistor

I_{SPAN} = Change in output current from 0% to 100%

For example, ΔV_{REF} = 24 mV, K = 0.2, R9 = 100Ω, I_{SPAN} = 16 mA. Hence, a 0.12% worst case error might be expected in output currents due to ΔV_{REF} effects.

Error Due to V_{OS} Drift

One of the primary causes of error in I_S is caused by V_{OS} drift. Drift may be induced either by self heating of the device or ambient temperature changes. The input offset voltage drift, $\Delta V_{OS}/\Delta T$, is nominally 3.3μV/°C per millivolt of initial offset. An expression for the total temperature dependent drift is:

$$\Delta V_{OS} = [(\theta)(\Delta P_{DISS}) + \Delta T_A] \frac{\Delta V_{OS}}{\Delta T}$$

Where:

θ = Thermal resistance either junction-to-ambient or junction-to-case

ΔP_{DISS} = Change in average power dissipation

ΔT_A = Change in ambient temperature

The bracketed term may be minimized by heat sinking and using the power minimization technique described under "Thermal Considerations." For the LH0045G design example, ΔV_{OS} = 0.352 mV under ambient conditions and 0.263 mV using a heat-sink and R_L = 800Ω. Comparable V_{OS} for the LH0045K would be 0.254 mV.

The error in output current due to ΔV_{OS} is:

$$\frac{\Delta I_S}{I_{SPAN}} (\text{in }\%) = 100 \times \frac{\Delta V_{OS}}{V_{IN\ (FULL\ SCALE)}}$$

$$= 100 \times \frac{R_F}{(R)(R9)(I_{SPAN})}$$

For the design example, ΔV_{OS} = 0.263 mV, V_{IN} (Full Scale) = 100 mV. Hence, 0.26 mV ÷ 100 mV or 0.26% worst case error could be expected in output current effects.

Errors Due to Changes in R9

The temperature coefficient of R9 (TCR) will produce errors in the output current. Changes in R9 may be caused by self-heating of the device or by ambient temperature changes.

$$\frac{\Delta I_S}{I_{SPAN}} (\text{in }\%) = 100 \frac{\Delta R9}{\Delta T} (\theta\, P_{DISS} + \Delta T_A)$$

Where:

θ = Thermal resistance either from junction-to-ambient or junction-to-case

ΔP_{DISS} = Change in average power dissipation

ΔT_A = Change in ambient temperature

$\frac{\Delta R9}{\Delta T}$ = TCR of R9

Using the LH0045G design example, $\Delta R9/\Delta T$ = 0.03%/°C, hence a 3.2% worst case error in output current might be expected for operation without a heat sink over the temperature range.

Heat sinking the device and using R_L = 800Ω, reduces $\Delta I_S/I_{SPAN}$ to 2.3%. Comparable error for the LH0045K would also be about 2.3%.

The error analysis indicates that the internal current set resistor, R9 is inadequate to satisfy high accuracy design criterion. In these instances, an external 100Ω resistor should be substituted for R9.

Obviously, the TCR of the resistor should be low. Metal film or wire-wound resistors are the best choice offering TCR's less than 10 ppm/°C versus 50 ppm/°C typical drift for R9.

External Causes of Error

The components external to the LH0045 are also critical in determining errors. Specifically, the composition of resistors R_{B1}, R_{OS}, R_F, R, etc. in the design example will influence both drift and long term stability.

In particular, resistors and potentiometers of wire wound construction are recommended. Also, metal-film resistors with low TCR (≲ 10 ppm/°C) may be used for fixed resistor applications.

applications information (con't)

Error Analysis Summary

The overall errors attributable to the LH0045 may be minimized using heat sinking, and utilization of an external load resistor. Although R_L reduces the compliance of the circuit, its use is generally advisable in precision applications. External components should be selected for low TCR and long-term stability.

The design example errors, using an external 100Ω wire wound resistor for R9 equal:

$$\frac{\Delta I_S}{I_{SPAN}} = \underbrace{0.12\%}_{\Delta V_{REF}} + \underbrace{0.26\%}_{\Delta V_{OS}} + \underbrace{0.08\%}_{\Delta R9} = 0.46\%$$

SOCKETS AND HEAT SINKS

Mounting sockets, test sockets, and heat sinks are available for the G package and K package.

The following or their equivalents are recommended:

Sockets:

G – 12 lead TO-8:	Barnes Corp. #MGX-12 Textool #212-100-323
K – 8 lead TO-3:	Keystone Elec. (N.Y.) #4626 or #4627

Heat Sinks

G – 12 lead TO-8:	Thermalloy #2240A Wakefield #215-CB
K – 8 lead TO-3:	IERC #LAIC 3B4V

Operational Amplifiers

LH0053/LH0053C high speed sample and hold amplifier

general description

The LH0053/LH0053C is a high speed sample and hold circuit capable of acquiring a 20V step signal in under 5.0µs.

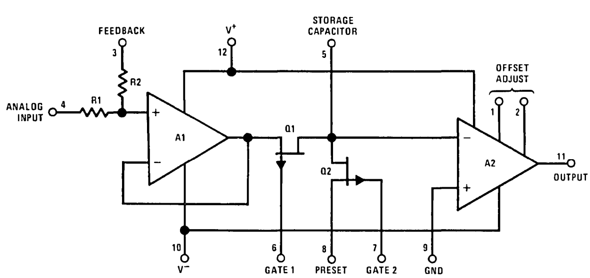
The device is ideally suited for a variety of high speed data acquisition applications including analog buffer memories for A to D conversion and synchronous demodulation.

An auxiliary switch within the device extends its usefulness in applications such as preset integrators.

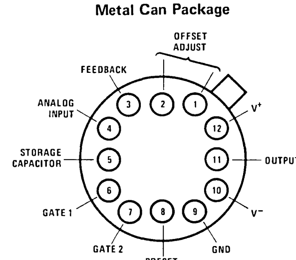
features

- Sample acquisition time 5.0µs max for 20V signal
- FET switch for preset or reset function
- Sample accuracy null
- Offset adjust to 0V
- DTL/TTL compatible FET gate
- Single storage capacitor

schematic and connection diagrams



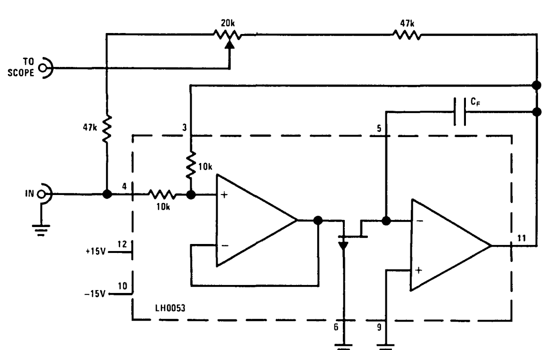
Metal Can Package



TOP VIEW

Order Number LH0053G or LH0053CG See Package 6

ac test circuit



Acquisition Time Test Circuit

absolute maximum ratings

Supply Voltage (V^+ and V^-)	±18V
Gate Input Voltage (V_6 and V_7)	±20V
Analog Input Voltage (V_4)	±15V
Input Current (I_8 and I_5)	±10 mA
Power Dissipation	1.5W
Output Short Circuit Duration	Continuous
Operating Temperature Range	
LH0053	−55°C to +125°C
LH0053C	−25°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 1)

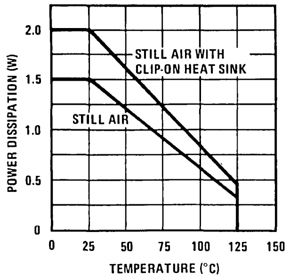
PARAMETER	CONDITIONS	LIMITS LH0053 MIN	LIMITS LH0053 TYP	LIMITS LH0053 MAX	LIMITS LH0053C MIN	LIMITS LH0053C TYP	LIMITS LH0053C MAX	UNITS
Sample (Gate "0") Input Voltage				0.5			0.5	V
Sample (Gate "0") Input Current	V_6 = 0.5V, T_A = 25°C V_6 = 0.5			−5.0 −100			−5.0 −100	µA µA
Hold (Gate "1") Input Voltage		4.5			4.5			V
Hold (Gate "1") Input Current	V_6 = 4.5V, T_A = 25°C V_6 = 4.5V			1.0 1.0			1.0 1.0	nA µA
Analog Input Voltage Range		±10	±11		±10	±11		V
Supply Current	V_4 = 0V V_6 = 0.5V		13	18		13	18	mA
Input Bias Current (I_4)	V_4 = 0V, T_A = 25°C		120	250		150	500	nA
Input Resistance		9.0	10	11	9.0	10	11	kΩ
Analog Output Voltage Range	R_L = 2.0k	±10	±12		±10	±12		V
Output Offset Voltage	V_4 = 0V, V_6 = 0.5V, T_A = 25°C V_4 = 0V, V_6 = 0.5V		5.0	7 0 10		5 0	10 15	mV mV
Sample Accuracy (Note 2)	V_4 = ±10V, V_6 = 0.5V, T_A = 25°C		0.1	0.2		0.1	0.3	%
Aperture Time	ΔV_6 = 4.5V, T_A = 25°C		10	25		10	25	ns
Sample Acquisition Time	V_4 = ±10V, T_A = 25°C, C_F = 1000 pF		5.0	10		8.0	15	µs
Sample Acquisition Time	V_4 = ±10V, T_A = 25°C, C_F = 100 pF		4.0			4.0		µs
Output Slew Rate	ΔV_{IN} = ±10V, T_A = 25°C, C_F = 1000 pF		20			20		V/µs
Large Signal Bandwidth	V_4 = ±10V, T_A = 25°C, C_F = 1000 pF		200			200		kHz
Leakage Current (Pin 5)	V_4 = ±10V, T_A = 25°C, V_4 = ±10V		6.0	30 30		10	50 3.0	pA nA
Drift Rate	V_4 = ±10V, T_A = 25°C, C_F = 1000 pF		6.0	30		10	50	mV/s
Drift Rate	V_4 = ±10V, C_F = 1000 pF			30			3.0	V/s
Q2 Switch ON Resistance	V_7 = 0.5V, I_8 = 1.0 mA, T_A = 25°C		100	300		100	300	Ω

Note 1: Unless otherwise noted, these specifications apply for V_S = ±15V, pin 9 grounded, a 1000 pF capacitor between pin 5 and pin 11, pin 3 shorted to pin 11, over the temperature range −55°C to +125°C for the LH0053 and −25°C to +85°C for the LH0053C. All typical values are for T_A = 25°C.

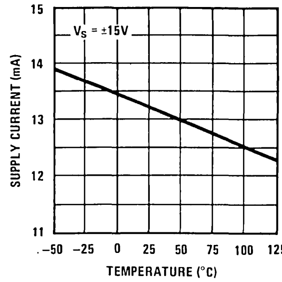
Note 2: Sample accuracy may be nulled by inserting a potentiometer in the feedback loop. This compensates for source impedance and feedback resistor tolerances.

typical performance characteristics

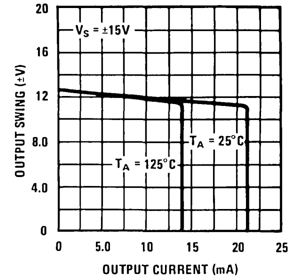
Power Dissipation



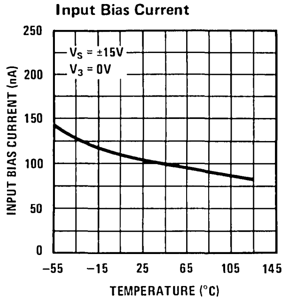
Supply Current vs Temperature



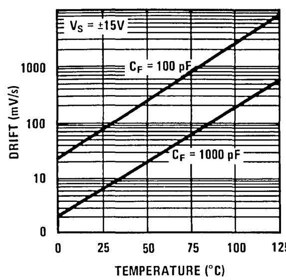
Output Current Limiting



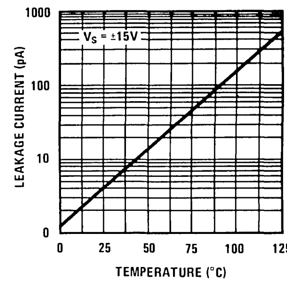
Input Bias Current



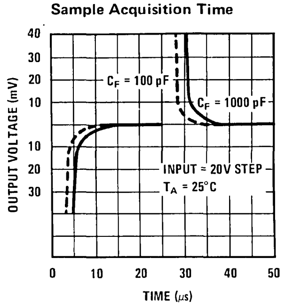
Drift



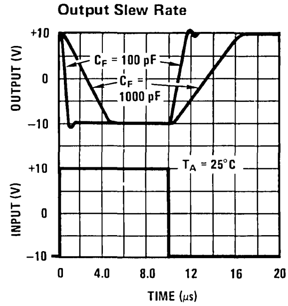
Leakage Current at Pin 5



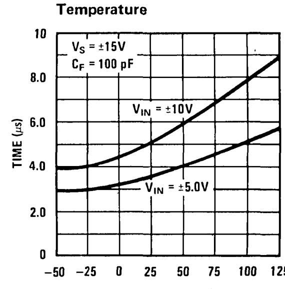
Sample Acquisition Time



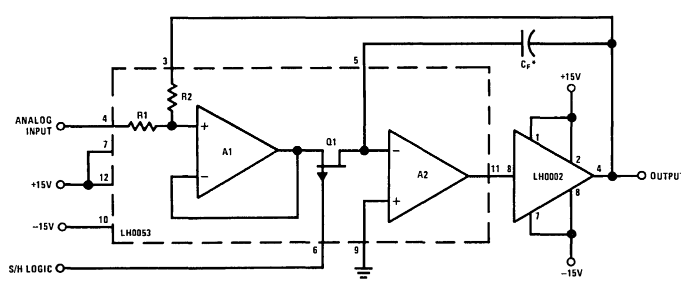
Output Slew Rate



Acquisition Time vs Temperature



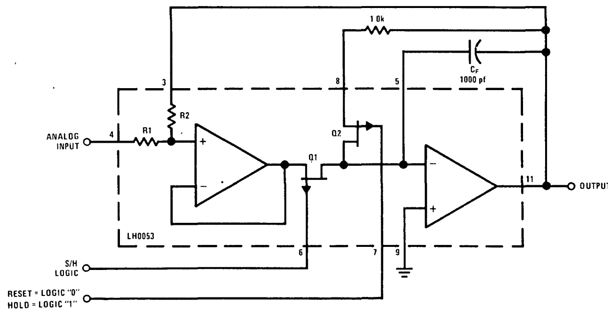
typical applications



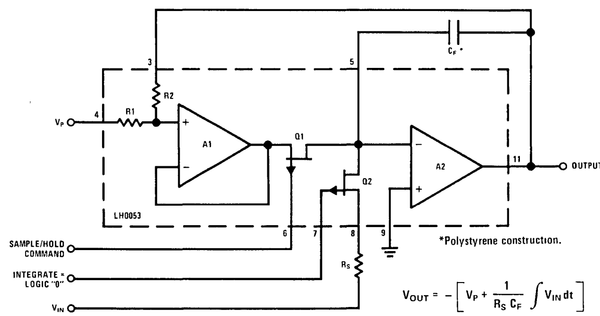
*Polystyrene construction.

Increasing Output Drive Capability

typical applications (con't)



Sample and Hold with Reset



Preset Integrator

applications information

SOURCE IMPEDANCE COMPENSATION

The gain accuracy (linearity) of the LH0053/ LH0053C is set by two internal precision resistors. Circuit applications in which the source impedance is non-zero will result in a closed loop gain error, e.g. if $R_S = 10\Omega$, a gain error of 0.1% results. Figure 1 and 2 show methods for accommodating non-zero source impedance.

DRIFT ERROR MINIMIZATION

In order to minimize drift error, care in selection C_F and layout of the printed circuit board is required. The capacitor should be of high quality teflon, polycarbonate or polystyrene construction. Board layout and clean lines are critical particularly at elevated temperature.

A ground guard (shield) surrounding pin 5 will minimize leakage currents to and from the summing junction, arising from extraneous signals. See AN-63 for detailed recommendations.

CAPACITOR SELECTION

The size of the capacitor is determined by the required drift rate usually at the expense of acquisition time.

The drift is dictated by leakage current at pin 5 and is given by:

$$\frac{dv}{dt} = \frac{I_L}{C_F}$$

Where I_L is the leakage current at pin 5 and C_F is the value of the capacitance. The room temperature leakage of the LH0053 is typical 6.0 pA, and a 1000 pF capacitor will yield a drift rate of 6.0 mV per second.

For values of C_F below 1000 pF acquisition for the LH0053 is primarily governed by the slew rate of the input amplifier (200V/μs) and the setting time of output amplifier ($\cong$ 1.0μs). For values above C_F = 1000 pF, acquisition time is given by:

$$t_a = \frac{C_F \Delta V}{I_{DSS}} + t_{S2}$$

Where:

C_F = The value of the capacitor

ΔV = The magnitude of the input step; e. g. 20V

I_{DSS} = The ON current of switch Q1 $\cong$ 5.0 mA

t_{S2} = The setting time of output amplifier $\cong$ 1.0μs

applications information (con't)

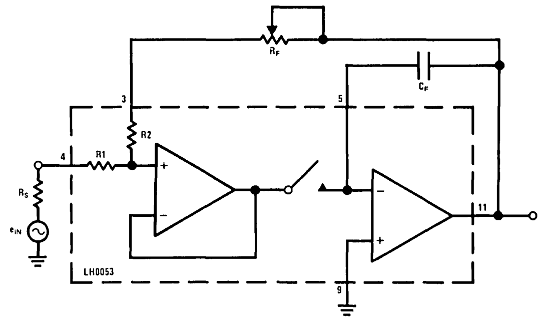


FIGURE 1. Non-Zero Source Impedance Compensation

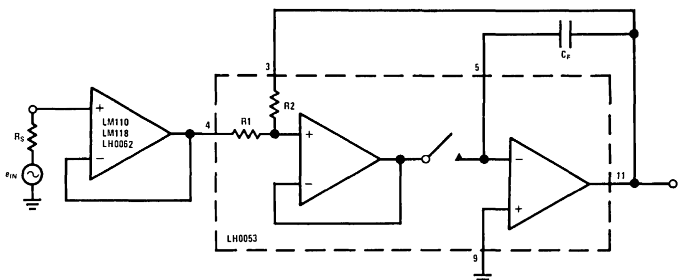


FIGURE 2. Non-Zero Source Impedance Buffering

GATE INPUT CONSIDERATIONS

5.0V TTL Applications

The LH0053 Gate inputs Gate 1 (pin 6) and Gate 2 (pin 7) will interface directly with 5.0V TTL. However, TTL gates typically pull up to 2.5V in the logic "1" state. It is therefore advisable to use a 10k pull-up resistor between the 5.0V, V_{CC}, and the output of the gate as shown in Figure 3.

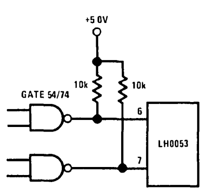


FIGURE 3. TTL Logic Compatibility

CMOS Applications

The LH0053 gate inputs may be interfaced directly with 74C, CMOS operating off of V_{CC}'s from 5.0V to 15V. However transient currents of several milliamps can flow on the rising and falling edges of the input signal. It is, therefore, advisable to parallel the outputs of two 54C/74C gates as shown in Figure 4.

It should be noted that leakage at pin 5 in the hold mode will be increased by a factor of 2 to 3 when operating into 15V logic levels.

Unused Switch, Q2

In applications when switch Q2 is not used the logic input (pin 7) should be returned to +5.0V (or +15V for HTL applications) through a 10kΩ resistor. Analog Input, preset (pin 8) should be grounded.

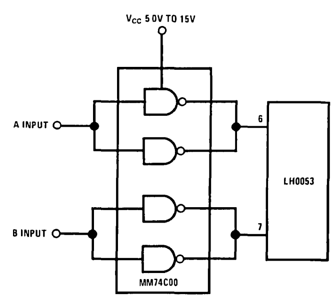


FIGURE 4. CMOS Logic Compatibility

HEAT SINKING

The LH0053 may be operated over the military temperature range, −55°C to +125°C, without incurring damage to the device. However, a clip on heat sink such as the Wakefield 215 Series or Thermolloy 2240 will reduce the internal temperature rise by about 20°C. The result is a two-fold improvement in drift rate at temperature.

applications information (con't)

Since the case of the device is electrically isolated from the circuit, the LH0053 may be mounted directly to a grounded heat sink.

POWER SUPPLY DECOUPLING

Amplifiers A1 and A2 within the LH0053 are very wide band devices and are sensitive to power supply inductance. It is advisable to bypass V^+ (pin 12) and V^- (pin 10) to ground with 0.1μF disc capacitors in order to prevent oscillation. Should this procedure prove inadequate, the disc capacitors should be parallel with 4.7μF solid tantalum electrolytic capacitors.

DC OFFSET ADJUST

Output offset error may be adjusted to zero using the circuit shown in Figure 5. Offset null should be accomplished in the sample mode ($V_6 \leq 0.5V$) and analog input (pin 4) equal to zero volts.

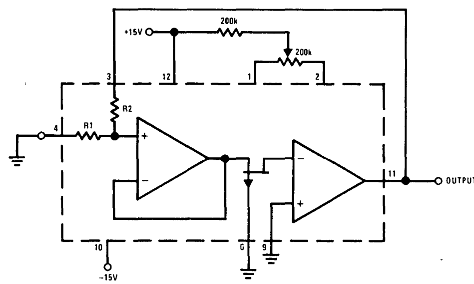


FIGURE 5. Offset Null Circuit

Operational Amplifiers

LH0061/LH0061C 0.5 amp wide band operational amplifier

general description

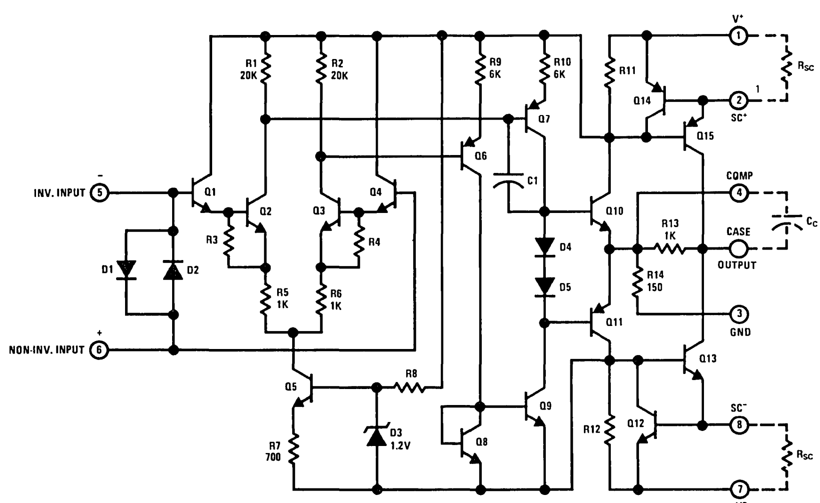
The LH0061/LH0061C is a wide band, high speed, operational amplifier capable of supplying currents in excess of 0.5 ampere at voltage levels of ±12V. Output short circuit protection is set by external resistors, and compensation is accomplished with a single external capacitor. With a suitable heat sink the device is rated at 20 Watts.

The wide bandwidth and high output power capabilities of the LH0061/LH0061C make it ideal for such applications as AC servos, deflection yoke drivers, capstan drivers, and audio amplifiers. The LH0061 is guaranteed over the temperature range −55°C to +125°C; whereas, the LH0061C is guaranteed from −25°C to +85°C.

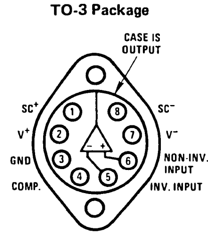
features

- Output current 0.5 Amp
- Wide large signal bandwidth 1 MHz
- High slew rate 75 V/µs
- Low standby power 240 mW
- Low input current 300 nA Max

schematic and connection diagrams



TO-3 Package



Order Numbers:

LH0061K (−55°C to +125°C)
LH0061CK (−25°C to +85°C)
See Package 19

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation	See Curve
Differential Input Current (Note 2)	±10 mA
Input Voltage (Note 3)	±15V
Peak Output Current	2A
Output Short Circuit Duration (Note 4)	Continuous
Operating Temperature Range LH0061	−55°C to +125°C
LH0061C	−25°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

dc electrical characteristics (Note 1)

PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0061			LH0061C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$R_S \leq 10\ k\Omega$, $T_C = 25°C$, $V_S = \pm 15V$		1.0	4.0		3.0	10	mV
	$R_S \leq 10\ k\Omega$, $V_S = \pm 15V$			6.0			15	mV
Voltage Drift with Temperature	$R_S \leq 10\ k\Omega$		5			5		μV/°C
Offset Voltage Change with Output Power			5			5		μV/watt
Input Offset Current	$T_C = 25°C$		30	100		50	200	nA
				300			500	nA
Offset Current Drift with Temperature			1			1		nA/°C
Input Bias Current	$T_C = 25°C$		100	300		200	500	nA
				1.0			1.0	μA
Input Resistance	$T_C = 25°C$	0.3	1.0		0.3	1.0		MΩ
Input Capacitance			3			3		pF
Common Mode Rejection Ratio	$R_S \leq 10\ k\Omega$, $\Delta V_{CM} = \pm 10V$	70	90		60	80		dB
Input Voltage Range	$V_S = \pm 15V$	±11			±11			V
Power Supply Rejection Ratio	$R_S \leq 10\ k\Omega$, $\Delta V_S = \pm 10V$	70	80		50	70		dB
Voltage Gain	$V_S = \pm 15V$, $V_O = \pm 10V$ $R_L = 1\ k\Omega$, $T_C = 25°C$	50	100		25	50		V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$ $R_L = 20\Omega$	5			2.5			V/mV
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 20\Omega$	±10	±12		±10	±12		V
Output Short Circuit Current	$V_S = \pm 15V$, $T_C = 25°C$, $R_{SC} = 1.0\Omega$		600			600		mA
Power Supply Current	$V_S = \pm 15V$, $V_{OUT} = 0$		7	10		10	15	mA
Power Consumption	$V_S = \pm 15V$, $V_{OUT} = 0$		210	300		300	450	mW

ac electrical characteristics ($T_C = 25°C$, $V_S = \pm 15V$, $C_C = 3000\ pF$)

PARAMETER	CONDITIONS	LH0061 MIN	LH0061 TYP	LH0061 MAX	LH0061C MIN	LH0061C TYP	LH0061C MAX	UNITS
Slew Rate	$A_V = +1$, $R_L = 100\Omega$	50	70		50	70		V/μs
Power Bandwidth	$R_L = 100\Omega$		1			1		MHz
Small Signal Transient Response			30			30		ns
Small Signal Overshoot			5	20		10	30	%
Settling Time (0.1%)	$\Delta V_{IN} = 10V$, $A_V = +1$		0.8			0.8		μs
Overload Recovery Time			1			1		μs
Harmonic Distortion	f = 1 kHz, $P_O = 0.5W$		0.2			0.2		%

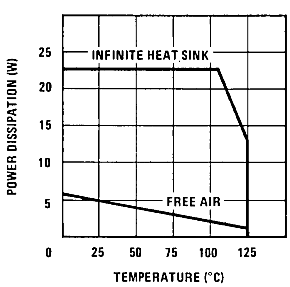
Note 1: Specifications apply for $\pm 5V \leq V_S \leq \pm 18V$, $C_C = 3000\ pF$, and $-55°C \leq T_C \leq +125°C$ for the LH0061K and $-25°C \leq T_C \leq +85°C$ for the LH0061CK. Typical values are for $T_C = 25°C$.

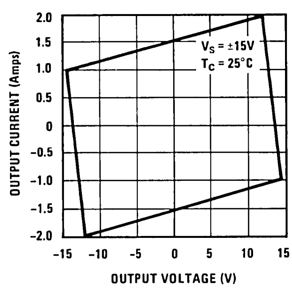
Note 2: The inputs are shunted with back-to-back diodes for overvoltage protection. Excessive current will flow if a differential voltage in excess of 1V is applied between the inputs without limiting resistors.

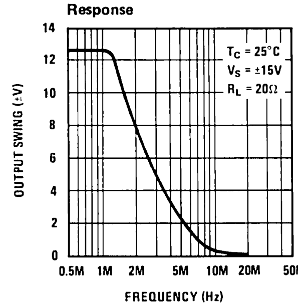
Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 4: Rating applies as long as package power rating is not exceeded.

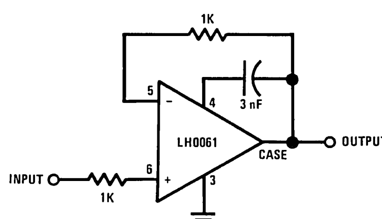
typical performance characteristics



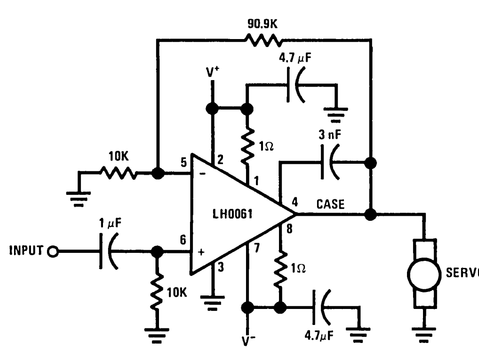




typical applications



Unity Gain Driver



AC Servo Amplifier

Operational Amplifiers

LH0062/LH0062C high speed FET op amp

general description

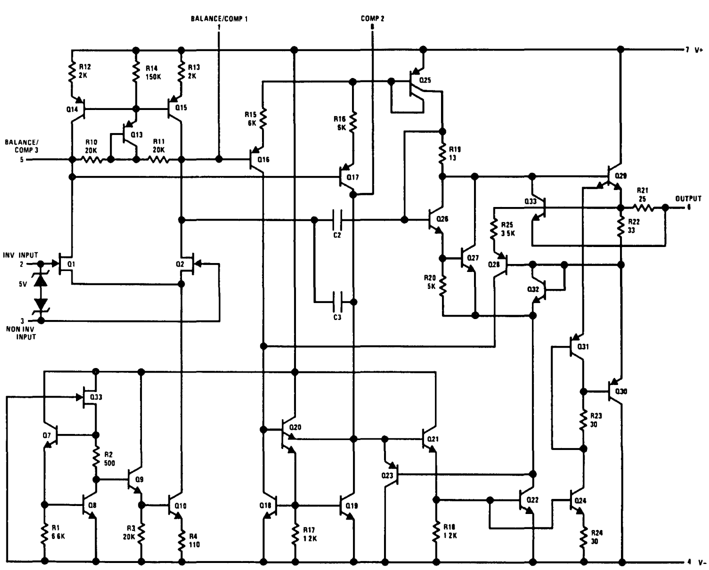
The LH0062/LH0062C is a precision, high speed FET input operational amplifier with more than an order of magnitude improvement in slew rate and bandwidth over conventional FET IC op amps. In addition it features very closely matched input characteristics, very high input impedance, and ultra low input currents with no compromise in noise, common mode rejection ratio or open loop gain. The device has internal unity gain frequency compensation, thus assuring stability in all normal applications. This considerably simplifies its 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 120 V/µs and almost double the bandwidth. (See LB-2, LB-14, and LB-17 for discussions of the application of feed-forward techniques). Over-compensation can be used with the amplifier for greater stability when maximum bandwidth is not needed. Further, a single capacitor can be added to reduce the 0.1% settling time to under 1 µs. In addition it is free of latch-up and may be simply offset nulled with negligible effect on offset drift or CMRR.

The LH0062 is designed for applications requiring wide bandwidth, high slew rate and fast settling time while at the same time demanding the high input impedance and low input currents characteristic of FET inputs. Thus it is particularly suited for such applications as video amplifiers, sample/hold circuits, high speed integrators, and buffers for A/D conversion and multiplex system. The LH0062 is specified for the full military temperature range of −55° to +125°C while the LH0062C is specified to operate over a −25°C to +85°C temperature range.

features

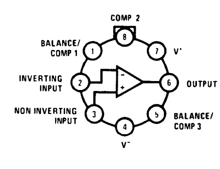
- High slew rate 70 V/µs
- Wide bandwidth 15 MHz
- Settling time (0.1%) 1µs
- Low input offset voltage 2 mV
- Low input offset current 1 pA
- Wide supply range ±5V to ±20V
- Internal 6 dB/octave frequency compensation
- Pin compatible with std IC op amps (TO-5 pkg)

schematic and connection diagrams*



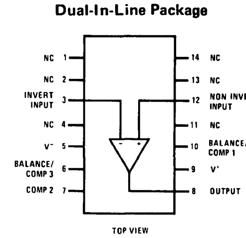
*Pin Numbers Shown for TO-5 Package

Metal Can Package



Order Number
LH0062H or LH0062CH
See Package 11

Dual-In-Line Package



Order Number
LH0062D or LH0062CD
See Package 1

absolute maximum ratings

Supply Voltage	±20V	Operating Temperature	
Power Dissipation (see graph)	500 mW	LH0062,	-55°C to +125°C
Input Voltage (Note 1)	±15V	LH0062C,	-25°C to +85°C
Differential Input Voltage (Note 2)	±30V	Storage Temperature Range	-65°C to +150°C
Short Circuit Duration	Continuous	Lead Temperature (Soldering, 10 sec)	300°C

dc electrical characteristics (Note 3)

PARAMETER	CONDITIONS	LIMITS LH0062 MIN	LH0062 TYP	LH0062 MAX	LH0062C MIN	LH0062C TYP	LH0062C MAX	UNITS
Input Offset Voltage	$R_S \leq 100\ k\Omega$; $T_A = 25°C$		2	5		10	15	mV
	$R_S \leq 100\ k\Omega$			7			20	mV
Temperature Coefficient of Input Offset Voltage	$R_S \leq 100\ k\Omega$		5	25		10	35	µV/°C
Offset Voltage Drift with Time			4			5		µV/week
Input Offset Current	$T_A = 25°C$		0.2	2		1	5	pA
				2			0.2	nA
Temperature Coefficient of Input Offset Current			Doubles every 10°C			Doubles every 10°C		
Offset Current Drift with Time			0.1			0.1		pA/week
Input Bias Current	$T_A = 25°C$		5	10		10	65	pA
				10			2	nA
Temperature Coefficient of Input Bias Current			Doubles every 10°C			Doubles every 10°C		
Differential Input Resistance			10^{12}			10^{12}		Ω
Common Mode Input Resistance			10^{12}			10^{12}		Ω
Input Capacitance			4			4		pF
Input Voltage Range	$V_S = \pm 15V$	±10	±12		±10	±12		V
Common Mode Rejection Ratio	$R_S \leq 10\ k\Omega$, $V_{IN} = \pm 10V$	80	90		70	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 10\ k\Omega$, $\pm 5V \leq V_S \leq \pm 15V$	80	90		70	90		dB
Large Signal Voltage Gain	$R_L = 2\ k\Omega$, $V_{OUT} = \pm 10V$, $T_A = 25°C$, $V_S = \pm 15V$	50	200		25	160		V/mV
	$R_L = 2\ k\Omega$, $V_{OUT} = \pm 10V$, $V_S = \pm 15V$	25			25			V/mV
Output Voltage Swing	$R_L = 2\ k\Omega$, $T_A = 25°C$, $V_S = \pm 15V$	±12	±13		±12	±13		V
	$R_L = 2\ k\Omega$, $V_S = \pm 15V$	±10			±10			V
Output Current Swing	$V_{OUT} = \pm 10V$, $T_A = 25°C$	±10	±15		±10	±15		mA
Output Resistance			75			75		Ω
Output Short Circuit Current	$T_A = 25°C$		25			25		mA
Supply Current	$V_S = \pm 15V$		5	8		7	12	mA
Power Consumption	$V_S = \pm 15V$			240			360	mW

ac electrical characteristics ($T_A = 25°C$, $V_S = \pm 15V$)

PARAMETER	CONDITIONS	LIMITS LH0062 MIN	LH0062 TYP	LH0062 MAX	LH0062C MIN	LH0062C TYP	LH0062C MAX	UNITS
Slew Rate	Voltage Follower	50	70		50	70		V/µs
Large Signal Bandwidth	Voltage Follower		2			2		MHz
Small Signal Bandwidth			15			15		MHz
Rise Time			25			25		ns
Overshoot			10			15		%
Settling Time (0.1%)	$\Delta V_{IN} = 10V$		1			1		µs
Overload Recovery			0.9			0.9		µs
Input Noise Voltage	$R_S = 10\ k\Omega$, $f_o = 10$ Hz		150			150		$nV/\sqrt{Hz}$
Input Noise Voltage	$R_S = 10\ k\Omega$, $f_o = 100$ Hz		55			55		$nV/\sqrt{Hz}$
Input Noise Voltage	$R_S = 10\ k\Omega$, $f_o = 1$ kHz		35			35		$nV/\sqrt{Hz}$
Input Noise Voltage	$R_S = 10\ k\Omega$, $f_o = 10$ kHz		30			30		$nV/\sqrt{Hz}$
Input Noise Voltage	BW = 10 Hz to 10 kHz, $R_S = 10\ k\Omega$		12			12		µVrms
Input Noise Current	BW = 10 Hz to 10 kHz		<.1			<.1		pArms

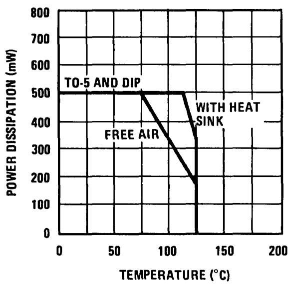
Note 1: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 2: Rating applies for minimum source resistance of 10 kΩ, for source resistances less than 10 kΩ, maximum differential input voltage is ±5V.

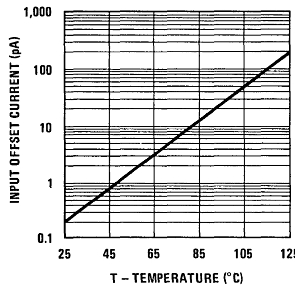
Note 3: Unless otherwise specified, these specifications apply for $\pm 5V \leq V_S \leq \pm 20V$ and $-55°C \leq T_A \leq +125°C$ for the LH0062 and $-25°C \leq T_A \leq +85°C$ for LH0062C. Typical values are given for $T_A = 25°C$. Power supplies should be bypassed with 0.1 µF ceramic capacitors.

typical performance characteristics

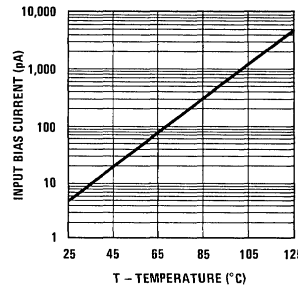
Maximum Power Dissipation



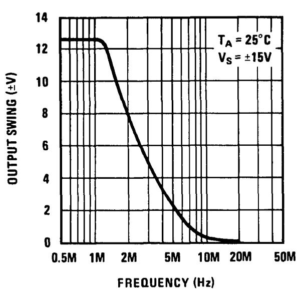
Input Offset Current vs Temperature



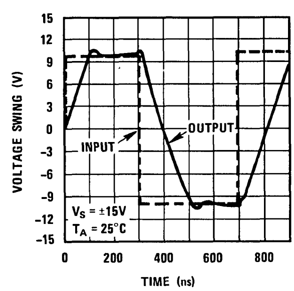
Input Bias Current vs Temperature



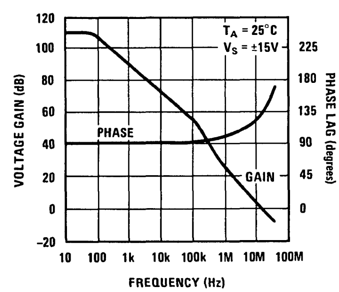
Large Signal Frequency Response



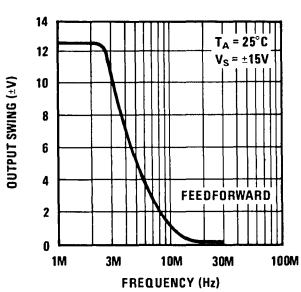
Voltage Follower Pulse Response



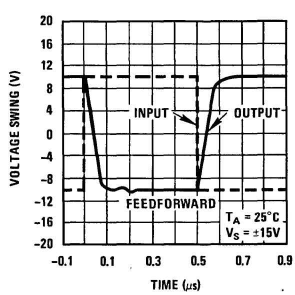
Open Loop Frequency Response



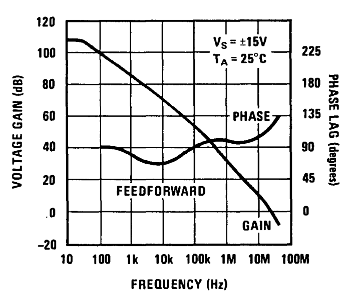
Large Signal Frequency Response



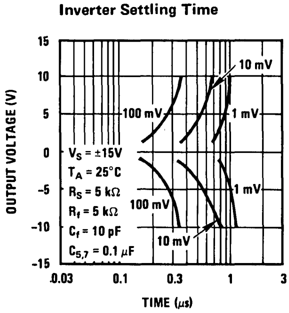
Inverter Pulse Response



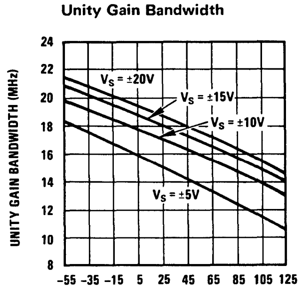
Open Loop Frequency Response



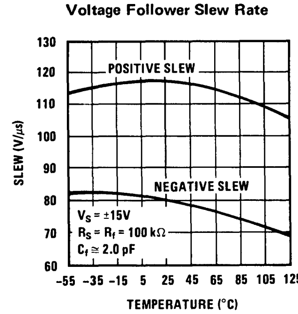
Inverter Settling Time



Unity Gain Bandwidth

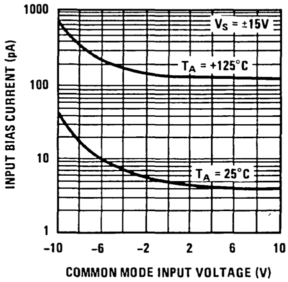


Voltage Follower Slew Rate

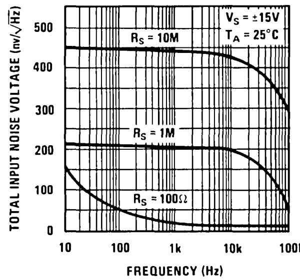


typical performance characteristics (con't)

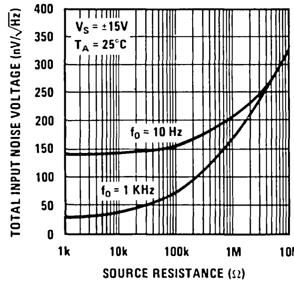
Input Bias Current vs Input Voltage



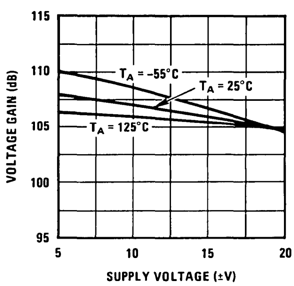
Total Input Noise Voltage* vs Frequency



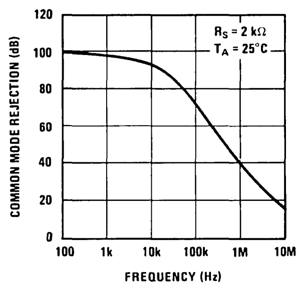
Total Input Noise Voltage* vs Source Resistance



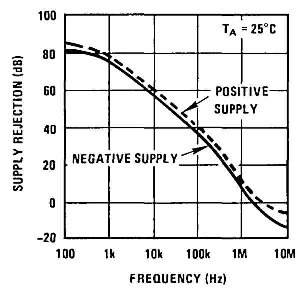
Voltage Gain



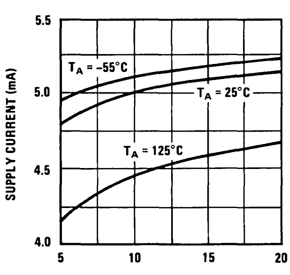
Common Mode Rejection



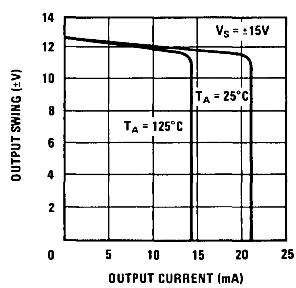
Power Supply Rejection



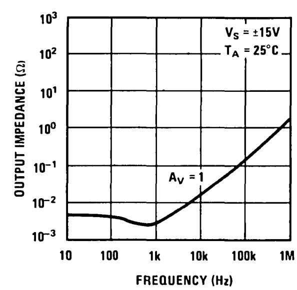
Supply Current



Current Limiting



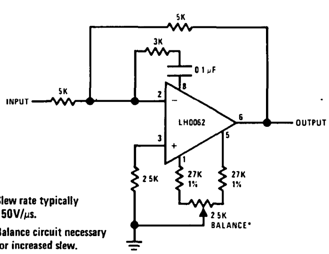
Closed Loop Output Impedance



*Noise Voltage Includes Contribution from Source Resistance

auxiliary circuits

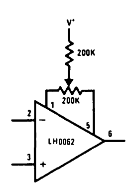
Feedforward Compensation for Greater Inverting Slew Rate†



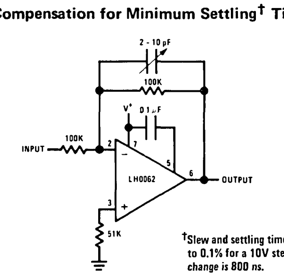
†Slew rate typically 150V/µs.

*Balance circuit necessary for increased slew.

Offset Balancing



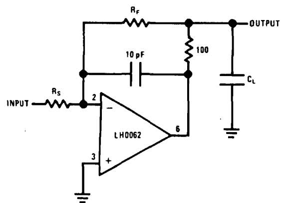
Compensation for Minimum Settling† Time



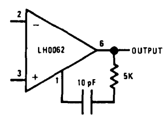
†Slew and settling time to 0.1% for a 10V step change is 800 ns.

auxiliary circuits (con't)

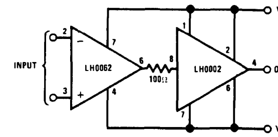
Isolating Large Capacitive Loads



Overcompensation

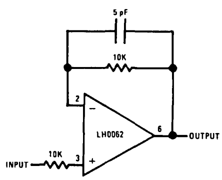


Boosting Output Drive to ±100 mA

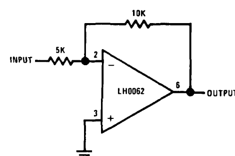


typical applications*

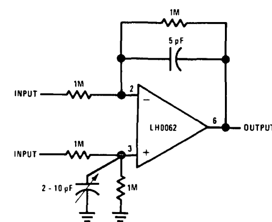
Fast Voltage Follower



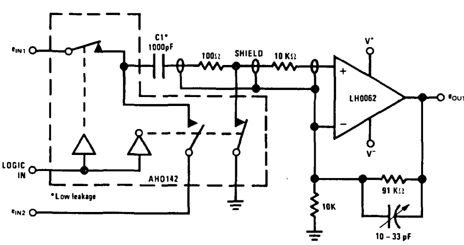
Fast Summing Amplifier



Differential Amplifier

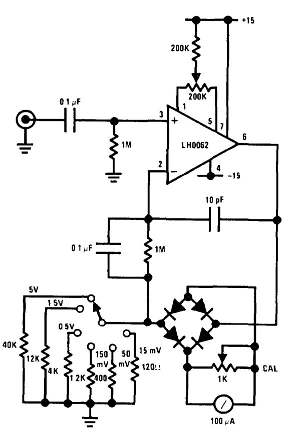


High Speed Subtractor

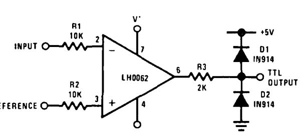


$e_{OUT} = 10 \times (e_{IN1} - e_{IN2})$

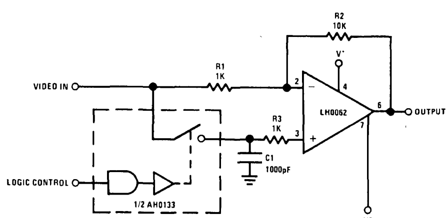
Wide Range AC Voltmeter



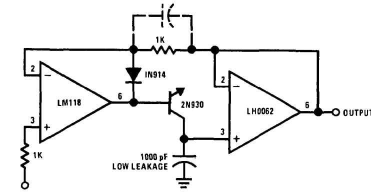
Fast Precision Voltage Comparator



Video DC Restoring Amplifier



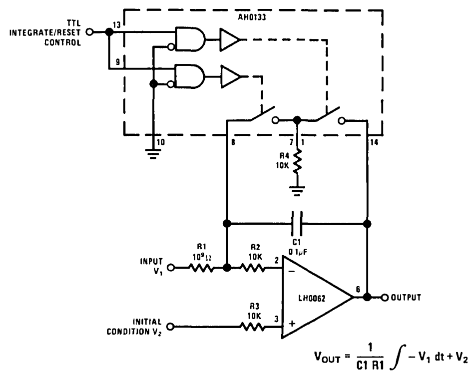
High Speed Positive Peak Detector



*Pin numbers shown for TO-5 package

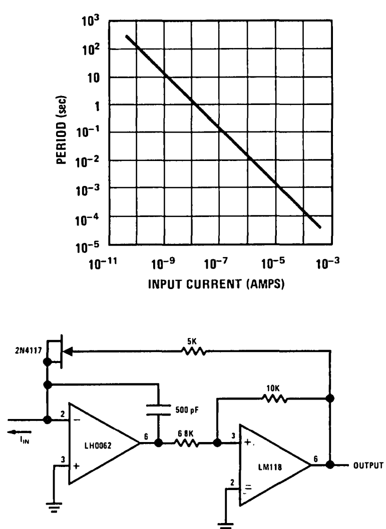
typical applications* (con't)

Precision Integrator



*Pin numbers shown for TO-5 package

Precision Wide Range Current to Period Converter



Operational Amplifiers

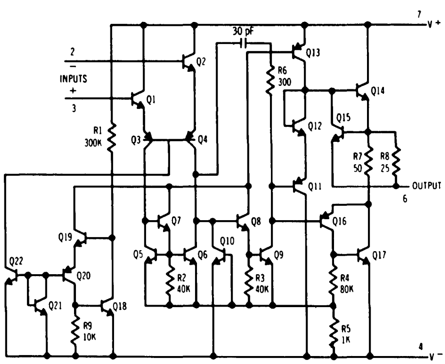
LH101 operational amplifier general description

The LH101 is a general-purpose operational amplifier which is internally compensated for unity-gain feedback. The device combines a LM101 operational amplifier and the 30 pF compensation capacitor in a single package. As such, it is a direct, plug-in replacement for both the LM101 and the LM709 in the majority of applications. Features of the amplifier include:

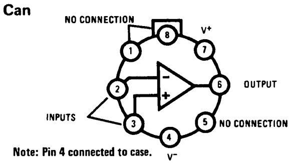
- Operation guaranteed for supply voltages from ±5V to ±20V
- Low current drain — even with the output saturated
- No latch-up when common-mode range is exceeded
- Continuous short-circuit protection
- Input transistors protected from excessive input voltage.

The LH101 is available in either an 8-lead, low-profile TO-5 header or a 1/4" x 1/4" metal flat package.

schematic** and connection diagrams



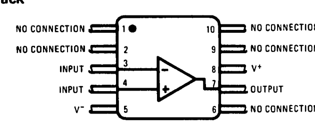
Metal Can



Note: Pin 4 connected to case.

Order Number LH101H
See Package 11

Flat Pack

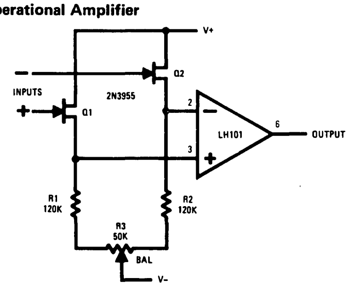


Note: Pin 5 connected to bottom of package.

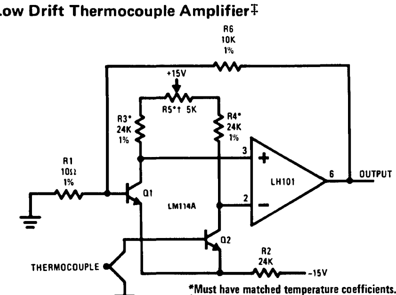
Order Number LH101F
See Package 3

typical applications **

FET Operational Amplifier

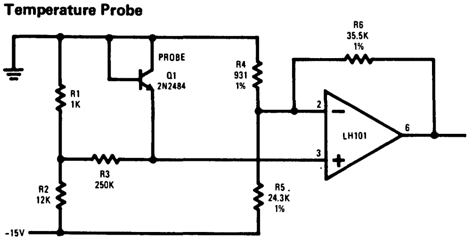


Low Drift Thermocouple Amplifier‡

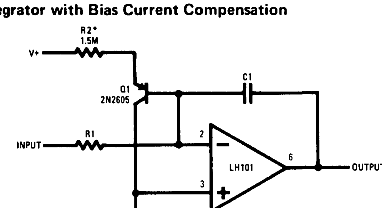


*Must have matched temperature coefficients.
†Adjust for zero input offset voltage.
‡Drifts less than 0.5μV/°C can be obtained consistently.

Temperature Probe



Integrator with Bias Current Compensation



*Select for zero integrator drift

**Pin connections shown are for metal can.

absolute maximum ratings

Supply Voltage	±22V
Power Dissipation (Note 1)	500 mW
Differential Input Voltage	±30V
Input Voltage (Note 2)	±15V
Output Short-Circuit Duration (Note 3)	Indefinite
Operating Temperature Range	−55°C to +125°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 60 sec)	300°C

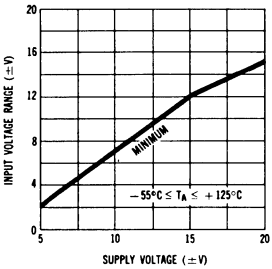
electrical characteristics (note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$, $R_S \le 10k\Omega$		1.0	5.0	mV
Input Offset Current	$T_A = 25°C$		40	200	nA
Input Bias Current	$T_A = 25°C$		120	500	nA
Input Resistance	$T_A = 25°C$	300	800		kΩ
Supply Current	$T_A = 25°C$, $V_S = \pm 20V$		1.8	3.0	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm 15V$ $V_{OUT} = \pm 10V$, $R_L \ge 2k\Omega$	50	160		V/mV
Input Offset Voltage	$R_S \le 10k\Omega$			6.0	mV
Average Temperature Coefficient of Input Offset Voltage	$R_S \le 50\Omega$ $R_S \le 10k\Omega$		3.0 6.0		μV/°C μV/°C
Input Offset Current	$T_A = +125°C$ $T_A = -55°C$		10 100	200 500	nA nA
Input Bias Current	$T_A = -55°C$		0.28	1.5	μA
Supply Current	$T_A = +125°C$, $V_S = \pm 20V$		1.2	2.5	mA
Large Signal Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \ge 2k\Omega$	25			V/mV
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10k\Omega$ $R_L = 2k\Omega$	±12 ±10	±14 ±13		V V
Input Voltage Range	$V_S = \pm 15V$	±12			V
Common Mode Rejection Ratio	$R_S \le 10k\Omega$	70	90		dB
Supply Voltage Rejection Ratio	$R_S \le 10k\Omega$	70	90		dB

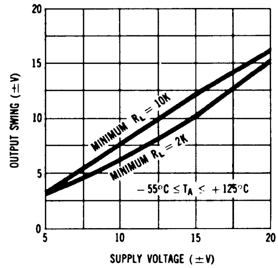
Note 1: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case for the metal-can package. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick, epoxy-glass board with ten, 0.03-inch-wide, 2-ounce copper conductors (see curve).
Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.
Note 3: Continuous short circuit is allowed for case temperatures to +125°C and ambient temperatures to +70°C.
Note 4: These specifications apply for $-55°C \le T_A \le 125°C$, $\pm 5V, \le V_S \le \pm 20V$ and C1 = 30 pF unless otherwise specified.

guaranteed performance characteristics

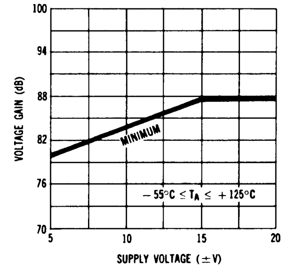
Input Voltage Range



Output Swing

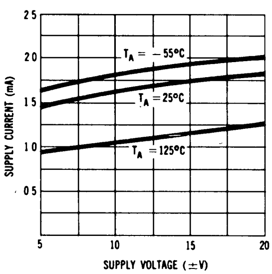


Voltage Gain

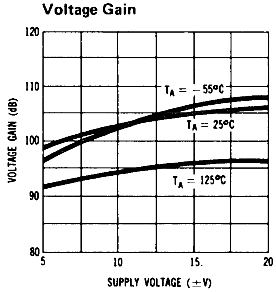


typical performance characteristics

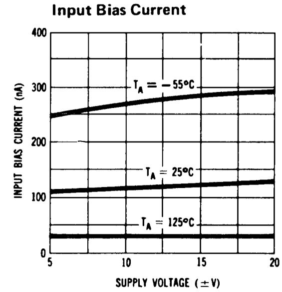
Supply Current



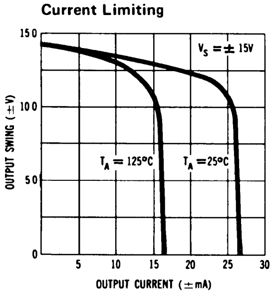
Voltage Gain



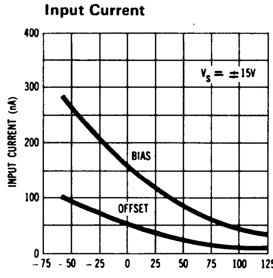
Input Bias Current



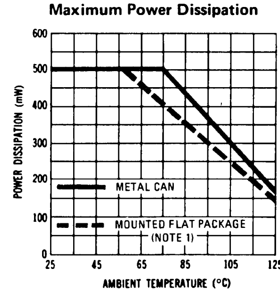
Current Limiting



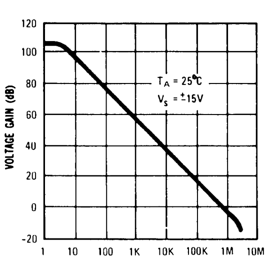
Input Current



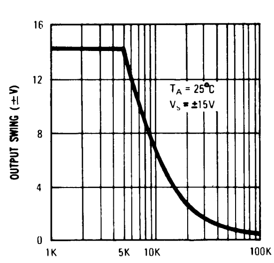
Maximum Power Dissipation



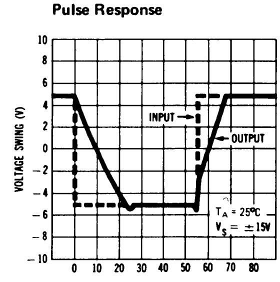
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



Operational Amplifiers

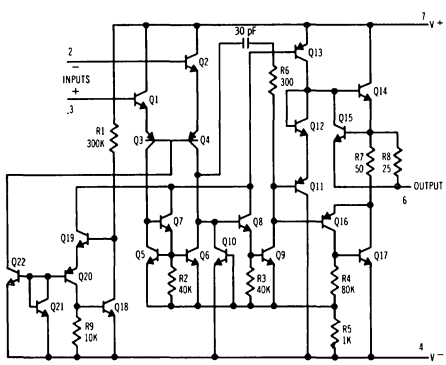
LH201 operational amplifier general description

The LH201 is a general-purpose operational amplifier which is internally compensated for unity-gain feedback. The device combines a LM201 operational amplifier and the 30 pF compensation capacitor in a single package. As such, it is a direct, plug-in replacement for both the LM201 and the LM709C in the majority of applications. It is identical to the LH101 except that operation is specified over a 0 to 70°C temperature range. Features of the amplifier include:

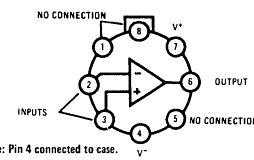
- Operation guaranteed for supply voltages from ±5V to ±20V
- Low current drain — even with the output saturated
- No latch-up when common-mode range is exceeded
- Continuous short-circuit protection
- Input transistors protected from excessive input voltage.

The LH201 is available in either an 8-lead, low-profile TO-5 header or a 1/4" x 1/4" metal flat package.

schematic** and connection diagrams



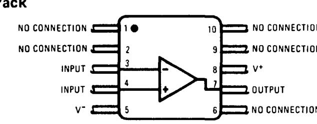
Metal Can



Note: Pin 4 connected to case.

Order Number LH201H
See Package 11

Flat Pack

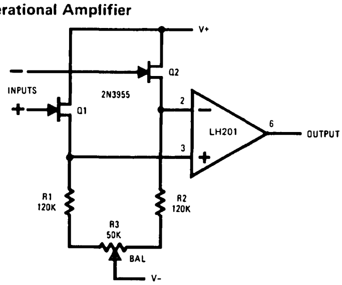


Note: Pin 5 connected to bottom of package.

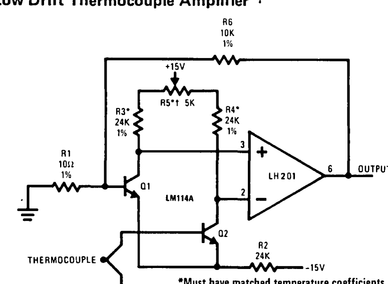
Order Number LH201F
See Package 3

typical applications**

FET Operational Amplifier

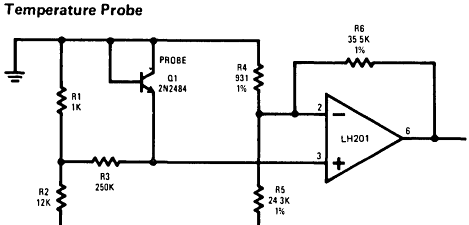


Low Drift Thermocouple Amplifier ‡

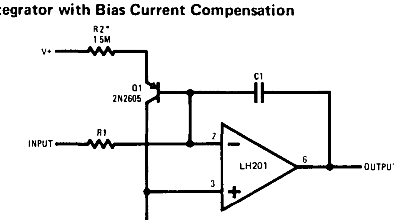


*Must have matched temperature coefficients.
†Adjust for zero input offset voltage.
‡Drifts less than 0.5μV/°C can be obtained consistently.

Temperature Probe



Integrator with Bias Current Compensation



*Select for zero integrator drift.

**Pin connections shown are for metal can.

absolute maximum ratings

Supply Voltage	±22V
Power Dissipation (Note 1)	250 mW
Differential Input Voltage	±30V
Input Voltage (Note 2)	±15V
Output Short-Circuit Duration (Note 3)	Indefinite
Operating Temperature Range	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 60 sec)	300°C

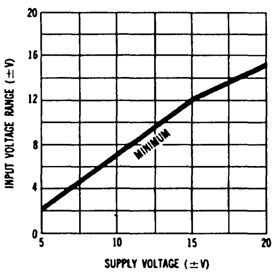
electrical characteristics (note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$, $R_S \leq 10k\Omega$		2.0	7.5	mV
Input Offset Current	$T_A = 25°C$		100	500	nA
Input Bias Current	$T_A = 25°C$		0.25	1.5	μA
Input Resistance	$T_A = 25°C$	150	400		kΩ
Supply Current	$T_A = 25°C$, $V_S = \pm 20V$		1.8	3.0	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm 15V$ $V_{OUT} = \pm 10V$, $R_L \geq 2k\Omega$	20	150		V/mV
Input Offset Voltage	$R_S \leq 10k\Omega$			10	mV
Average Temperature Coefficient of Input Offset Voltage	$R_S \leq 50\Omega$ $R_S \leq 10k\Omega$		6 10		μV/°C μV/°C
Input Offset Current	$T_A = +70°C$ $T_A = 0°C$		50 150	400 750	nA nA
Input Bias Current	$T_A = 0°C$		0.32	2.0	μA
Large Signal Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \geq 2k\Omega$	15			V/mV
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10k\Omega$ $R_L = 2k\Omega$	±12 ±10	±14 ±13		V V
Input Voltage Range	$V_S = \pm 15V$	±12			V
Common Mode Rejection Ratio	$R_S \leq 10k\Omega$	65	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 10k\Omega$	70	90		dB

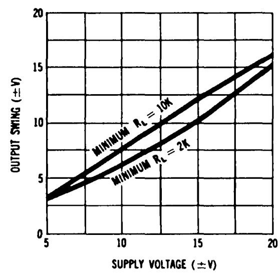
Note 1: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case for the metal-can package. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick, epoxy-glass board with ten, 0.03-inch-wide, 2-ounce copper conductors (see curve).
Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.
Note 3: Continuous short circuit is allowed for case temperatures to +125°C and ambient temperatures to +70°C.
Note 4: These specifications apply for $-55°C \leq T_A \leq 125°C$, $\pm 5V, \leq V_S \leq \pm 20V$ and C1 = 30 pF unless otherwise specified.

guaranteed performance characteristics

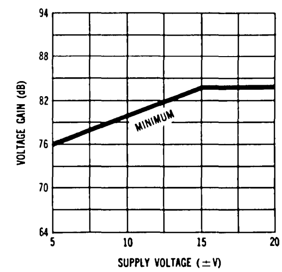
Input Voltage Range



Output Swing

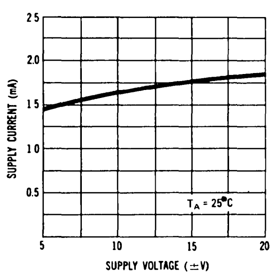


Voltage Gain

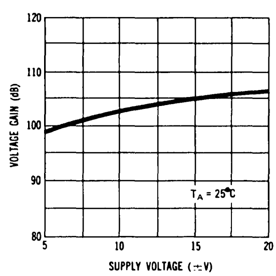


typical performance characteristics

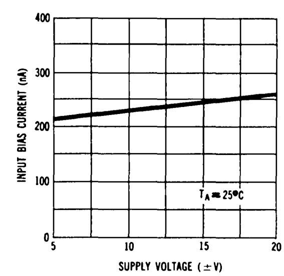
Supply Current



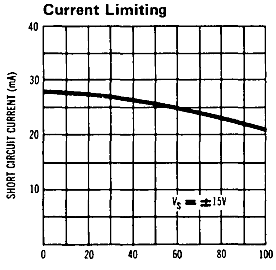
Voltage Gain



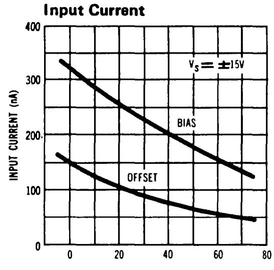
Input Bias Current



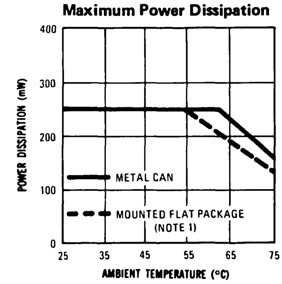
Current Limiting



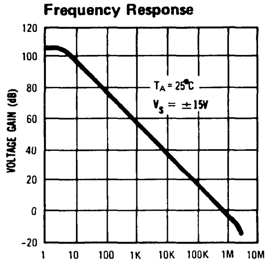
Input Current



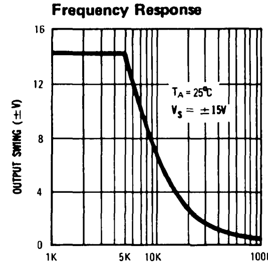
Maximum Power Dissipation



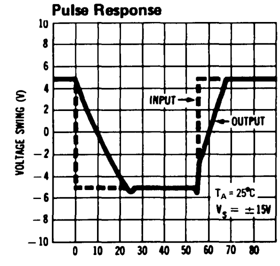
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



Operational Amplifiers

LH740A/LH740AC FET input operational amplifier

general description

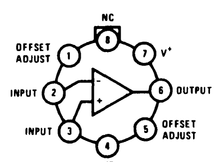
The LH740A/LH740AC is a FET input, general purpose operational amplifier with high input impedance, closely matched input characteristics, and good slew rates. Input offset voltage is typically 10.0 mV at 25°C, while input bias current is less than 100 pA at 25°C. Offset current is typically less than 40 pA at 25°C. Other important design features include:

- Internal 6 dB/octave frequency compensation
- Unity gain slew rate in excess of 6 V/μs
- Unity gain bandwidth of 1 MHz
- Input offset is adjustable with a single 10k pot
- Pin compatible with LM741, LM709, LM101A, and μA740
- Excellent offset current match over temperature, typically 100 pA
- Output is continuously short-circuit proof
- Excellent open loop gain, typically in excess of 100 dB
- Guaranteed over the full military temperature range

The LH740A/LH740AC is intended to fulfill a wide variety of applications requiring extremely low bias currents such as integrators, sample and hold amplifiers, and general purpose operational amplifier applications.

The LH740A is specified for operation over the −55°C to +125°C military temperature range. The LH740AC is specified for operation over the 0°C to +85°C temperature range.

connection diagram

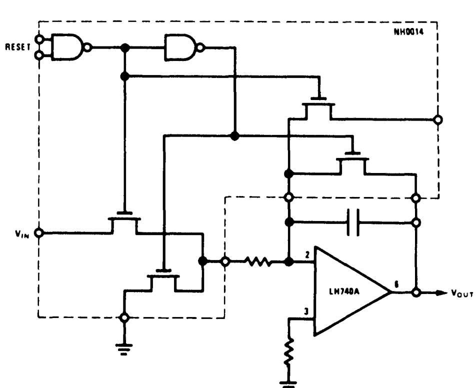


TOP VIEW

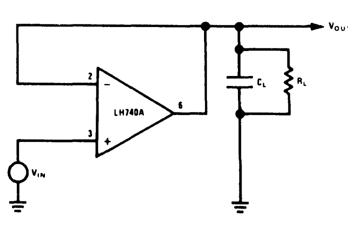
Order Number LH740AH or LH740ACH
See Package 11

typical applications

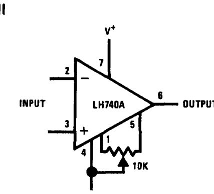
Integrator



Transient Response



Offset Null



absolute maximum ratings

Supply Voltage		±22V
Maximum Power Dissipation		500 mW
Differential Input Voltage		±5V
Input Voltage		±15V
Short Circuit Duration		Continuous
Operating Temperature Range	LH740A	−55°C to +125°C
	LH740AC	0°C to +85°C
Storage Temperature Range		−65°C to +150°C
Lead Temperature (soldering, 10 sec.)		300°C

electrical characteristics (Note 1 (V_S = ±15V, T_A = 25°C unless otherwise noted)

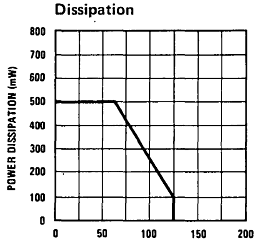
PARAMETER	CONDITIONS	LH740A MIN	LH740A TYP	LH740A MAX	LH740AC MIN	LH740AC TYP	LH740AC MAX	UNITS
Input Offset Voltage	$R_S \leq 100\ k\Omega$		10	15		10	20	mV
Input Offset Current			40	100		60	150	pA
Input Current (either input)			100	200		100	500	pA
Input Resistance			1,000,000			1,000,000		MΩ
Large Signal Voltage Gain	$R_L \geq 2\ k\Omega$, V_{OUT} = ±10V	50,000	100,000		50,000	100,000		V/V
Output Resistance			75			75		Ω
Output Short-Circuit Current			20			20		mA
Common Mode Rejection Ratio		80			80			dB
Supply Voltage Rejection Ratio		80			80			dB
Supply Current			3.0	4.0		3.0	4.0	mA
Slew Rate			6.0			6.0		V/µs
Unity Gain Bandwidth			1.0			1.0		MHz
Transient Response (Unity Gain)	$C_L \leq 100\ pF$, $R_L = 2\ k\Omega$, V_{IN} = 100 mV							
Risetime			110			300		ns
Overshoot			10	20		10		%
(These specifications apply for −55°C ≤ T_A ≤ 125°C for the LH740A and 0°C ≤ T_A ≤ 85°C for the LH740AC unless otherwise noted.)								
Input Voltage Range		±12			±12			V
Common Mode Rejection Ratio		80			80			dB
Supply Voltage Rejection Ratio		80			80			dB
Large Signal Voltage Gain		40,000			40,000			V/V
Output Voltage Swing	$R_L \geq 10\ k\Omega$	±12	±14		±12	±14		V
	$R_L \geq 2\ k\Omega$	±10	±13		±10	±13		V
Input Offset Voltage			15	20		30		mV
Input Offset Current			100	500		60	500	pA
Input Current (either input)			2.5	4.0		1.1	5.0	nA
Offset Voltage Drift	$R_S \leq 100K$		5.0			5.0		µV/°C

Note 1: For supply voltages less than ±10V, the absolute maximum input voltage is equal to the supply voltage.

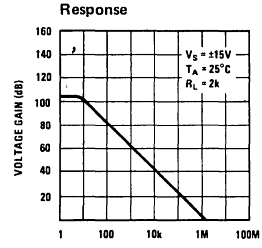
2

typical performance characteristics

Maximum Power Dissipation



Open Loop Frequency Response



Operational Amplifiers

LH2101A/LH2201A/LH2301A dual high performance op amp

general description

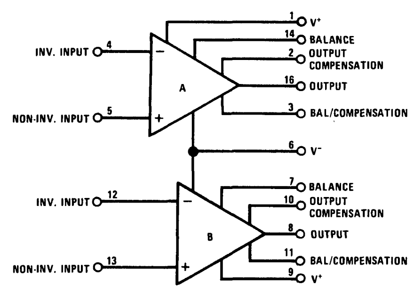
The LH2101A series of dual operational amplifiers are two LM101A type op amps in a single hermetic package. Featuring all the same performance characteristics of the single, these duals offer in addition closer thermal tracking, lower weight, reduced insertion cost, and smaller size than two singles. For additional information, see the LM101A data sheet and National's Linear Application Handbook.

The LH2101A is specified for operation over the −55°C to +125°C military temperature range. The LH2201A is specified for operation over the −25°C to +85°C temperature range. The LH2301A is specified for operation over the 0°C to +70°C temperature range.

features

- Low offset voltage
- Low offset current
- Guaranteed drift characteristics
- Offsets guaranteed over entire common mode and supply voltage ranges
- Slew rate of 10V/μs as a summing amplifier

connection diagram

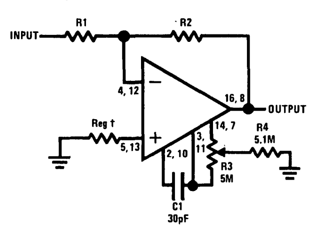


Order Number LH2101AD or LH2201AD or LH2301AD
See Package 2

Order Number LH2101AF or LH2201AF or LH2301AF
See Package 5

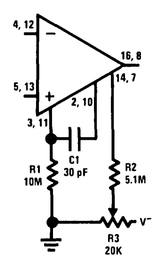
auxiliary circuits

Inverting Amplifier with Balancing Circuit

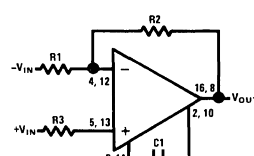


†May be zero or equal to parallel combination of R1 and R2 for minimum offset.

Alternate Balancing Circuit



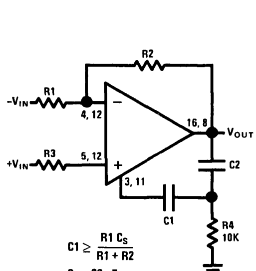
Single Pole Compensation



$C1 \geq \frac{R1\,C_S}{R1 + R2}$

$C_S = 30\ pF$

Two Pole Compensation

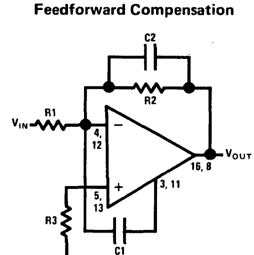


$C1 \geq \frac{R1\,C_S}{R1 + R2}$

$C_S = 30\ pF$

$C2 = 10\ C1$

Feedforward Compensation



$C2 = \frac{1}{2\pi f_O R2}$

$f_O = 3\ MHz$

absolute maximum ratings

Supply Voltage	±22V
Power Dissipation (Note 1)	500 mW
Differential Input Voltage	±30V
Input Voltage (Note 2)	±15V
Output Short-Circuit Duration	Continuous

Operating Temperature Range	LH2101A	-55°C to 125°C
	LH2201A	-25°C to 85°C
	LH2301A	0°C to 70°C
Storage Temperature Range		-65°C to 150°C
Lead Temperature (Soldering, 10 sec)		300°C

electrical characteristics each side (Note 3)

PARAMETER	CONDITIONS	LIMITS LH2101A	LH2201A	LH2301A	UNITS
Input Offset Voltage	$T_A = 25°C, R_S \le 50\ k\Omega$	2.0	2.0	7.5	mV Max
Input Offset Current	$T_A = 25°C$	10	10	50	nA Max
Input Bias Current	$T_A = 25°C$	75	75	250	nA Max
Input Resistance	$T_A = 25°C$	1.5	1.5	0.5	MΩ Min
Supply Current	$T_A = 25°C, V_S = \pm 20V$	3.0	3.3	3.0	mA Max
Large Signal Voltage Gain	$T_A = 25°C, V_S = \pm 15V$ $V_{OUT} = \pm 10V, R_L \ge 2\ k\Omega$	50	50	25	V/mV Min
Input Offset Voltage	$R_S \le 50\ k\Omega$	3.0	3.0	10	mV Max
Average Temperature Coefficient of Input Offset Voltage		15	15	30	μV/°C Max
Input Offset Current		20	20	70	nA Max
Average Temperature Coefficient of Input Offset Current	$25°C \le T_A \le 125°C$ $-55°C \le T_A \le 25°C$	0.1 0.2	0.1 0.2	0.3 0.6	nA/°C Max nA/°C Max
Input Bias Current		100	100	300	nA Max
Supply Current	$T_A = +125°C, V_S = \pm 20V$	2.5	2.5		mA Max
Large Signal Voltage Gain	$V_S = \pm 15V, V_{OUT} = \pm 10V$ $R_L \ge 2\ k\Omega$	25	25	15	V/mV Min
Output Voltage Swing	$V_S = \pm 15V, R_L = 10\ k\Omega$ $R_L = 2\ k\Omega$	±12 ±10	±12 ±10	±12 ±10	V Min V Min
Input Voltage Range	$V_S = \pm 20V$	±15	±15	±12	V Min
Common Mode Rejection Ratio	$R_S \le 50\ k\Omega$	80	80	70	dB Min
Supply Voltage Rejection Ratio	$R_S \le 50\ k\Omega$	80	80	70	dB Min

Note 1: The maximum junction temperature of the LH2101A is 150°C, while that of the LH2201A is 100°C. For operating temperatures, devices in the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: These specifications apply for $\pm 5V \le V_S \le \pm 20V$ and $-55°C \le T_A \le 125°C$, unless otherwise specified. With the LH2201A, however, all temperature specifications are limited to $-25°C \le T_A \le 85°C$. For the LH2301A these specifications apply for $0°C \le T_A \le 70°C$, ±5V and $\le V_S \le \pm 15V$. Supply current and input voltage range are specified as $V_S = \pm 15V$ for the LH2301A. $C_1 = 30\ pF$ unless otherwise specified.

2

Operational Amplifiers

LH2108/LH2208/LH2308, LH2108A/LH2208A/LH2308A dual super beta op amp

general description

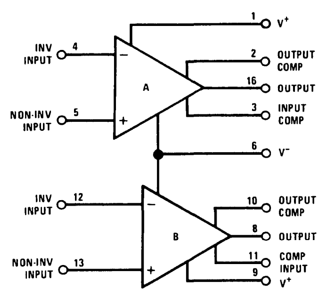
The LH2108A/LH2208A/LH2308A and LH2108/LH2208/LH2308 series of dual operational amplifiers are two LM108A or LM108 type op amps in a single hermetic package. Featuring all the same performance characteristics of the single device, these duals also offer closer thermal tracking, lower weight, reduced insertion cost, and smaller size than two single devices. For additional information see the LM108A or LM108 data sheet and National's Linear Application Handbook.

The LH2108A/LH2108 is specified for operation over the -55°C to +125°C military temperature range. The LH2208A/LH2208 is specified for operation over the -25°C to +85°C temperature range. The LH2308A/LH2308 is specified for operation over the 0°C to +70°C temperature range.

features

- Low offset current — 50 pA
- Low offset voltage — 0.7 mV
- Low offset voltage — LH2108A 0.3 mV; LH2108 0.7 mV
- Wide input voltage range — ±15V
- Wide operating supply range — ±3V to ±20V

connection diagram

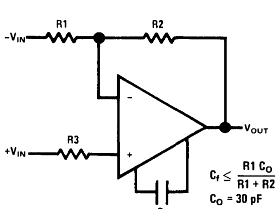


Order Number LH2108AD, LH2208AD, LH2308AD, or LH2108D, LH2208D, or LH2308D
See Package 2

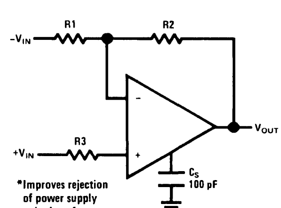
Order Number LH2108F, LH2208F, or LH2308F
See Package 5

auxiliary circuits

Standard Compensation Circuit

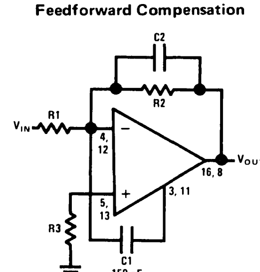


Alternate * Frequency Compensation



*Improves rejection of power supply noise by a factor of ten.

Feedforward Compensation



$$C2 = \frac{1}{2\pi f_O R2}$$

f_O = 3 MHz

absolute maximum ratings

Supply Voltage	±20V	Operating Temperature Range	
Power Dissipation (Note 1)	500 mW	LH2108A/LH2108	−55°C to +125°C
Differential Input Current (Note 2)	±10 mA	LH2208A/LH2208	−25°C to +85°C
Input Voltage (Note 3)	±15V	LH2308A/LH2308	0°C to +70°C
Output Short Circuit Duration	Continuous	Storage Temperature Range	−65°C to +150°C
		Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics each side (Note 4)

PARAMETER	CONDITIONS	LIMITS			UNITS
		LH2108	LH2208	LH2308	
Input Offset Voltage	$T_A = 25°C$	2.0	2.0	7.5	mV Max
Input Offset Current	$T_A = 25°C$	0.2	0.2	1.0	nA Max
Input Bias Current	$T_A = 25°C$	2.0	2.0	7.0	nA Max
Input Resistance	$T_A = 25°C$	30	30	10	MΩ Min
Supply Current	$T_A = 25°C$	0.6	0.6	0.8	mA Max
Large Signal Voltage Gain	$T_A = 25°C$ $V_S = ±15V$ $V_{OUT} = ±10V$, $R_L \geq 10$ kΩ	50	50	25	V/mV Min
Input Offset Voltage		3.0	3.0	10	mV Max
Average Temperature Coefficient of Input Offset Voltage		15	15	30	μV/°C Max
Input Offset Current		0.4	0.4	1.5	nA Max
Average Temperature Coefficient of Input Offset Current		2.5	2.5	10	pA/°C Max
Input Bias Current		3.0	3.0	10	nA Max
Supply Current	$T_A = +125°C$	0 4	0.4	–	mA Max
Large Signal Voltage Gain	$V_S = ±15V$, $V_{OUT} = ±10V$ $R_L \geq 10$ kΩ	25	25	15	V/mV Min
Output Voltage Swing	$V_S = ±15V$, $R_L = 10$ kΩ	±13	±13	±13	V Min
Input Voltage Range	$V_S = ±15V$	±13.5	±13.5	±14	V Min
Common Mode Rejection Ratio		85	85	80	dB Min
Supply Voltage Rejection Ratio		80	80	80	dB Min

electrical characteristics each side (Note 4)

PARAMETER	CONDITIONS	LIMITS			UNITS
		LH2108A	LH2208A	LH2308A	
Input Offset Voltage	$T_A = 25°C$	0.5	0 5	0.5	mV Max
Input Offset Current	$T_A = 25°C$	0 2	0.2	1.0	nA Max
Input Bias Current	$T_A = 25°C$	2.0	2 0	7.0	nA Max
Input Resistance	$T_A = 25°C$	30	30	10	MΩ Min
Supply Current	$T_A = 25°C$	0.6	0.6	0.8	mA Max
Large Signal Voltage Gain	$T_A = 25°C$ $V_S = ±15V$ $V_{OUT} = ±10V$, $R_L > 10$ kΩ	80	80	80	V/mV Min
Input Offset Voltage		1.0	1.0	0.73	mV Max
Average Temperature Coefficient of Input Offset Voltage		5	5	5	μV/°C Max
Input Offset Current		0.4	0.4	1.5	nA Max
Average Temperature Coefficient of Input Offset Current		2.5	2.5	10	pA/°C Max
Input Bias Current		3.0	3.0	10	nA Max
Supply Current	$T_A = +125°C$	0 4	0.4	–	mA Max
Large Signal Voltage Gain	$V_S = ±15V$, $V_{OUT} = ±10V$ $R_L \geq 10$ kΩ	40	40	60	V/mV Min
Output Voltage Swing	$V_S = ±15V$, $R_L = 10$ kΩ	±13	±13	±13	V Min
Input Voltage Range	$V_S = ±15V$	±13.5	±13.5	±14	V Min
Common Mode Rejection Ratio		96	96	96	dB Min
Supply Voltage Rejection Ratio		96	96	96	dB Min

Note 1: The maximum junction temperature of the LH2108A/LH2108 is 150°C, while that of the LH2208A/LH2208 is 100°C and the LH2308A/LH2308 is 85°C. For operating at elevated temperatures, devices in the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with 0.03-inch-wide, 2-ounce cooper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

Note 2: The inputs are shunted with back-to-back diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 4: These specifications apply for $±5V \leq V_S \leq ±20V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise specified. With the LH2208A/LH2208, however, all temperature specifications are limited to $-25°C \leq T_A \leq 85°C$ and with the LH2308A/LH2308 for $±5V \leq V_S \leq 15V$ and $0°C \leq T_A \leq 70°C$.

Operational Amplifiers

LH2110/LH2210/LH2310 dual voltage follower

general description

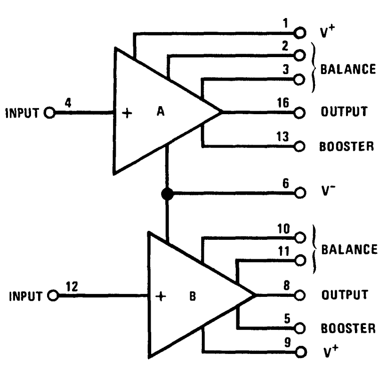
The LH2110 series of dual voltage followers are two LM110 type followers in a single hermetic package. Featuring all the same performance characteristics of the single, these duals offer in addition closer thermal tracking, lower weight, reduced insertion cost and smaller size than two singles. For additional information, see the LM110 data sheet and National's Linear Application Notebook.

The LH2110 is specified for operation over the −55°C to +125°C military temperature range. The LH2210 is specified for operation over the −25°C to +85°C temperature range. The LH2310 is specified for operation over the 0°C to +70°C temperature range.

features

- Low input current — 1 nA
- High input resistance — 10^{10} ohms
- High slew rate — 30V/µs
- Wide bandwidth — 20 MHz
- Wide operating supply range — ±5V to ±18V
- Output short circuit proof

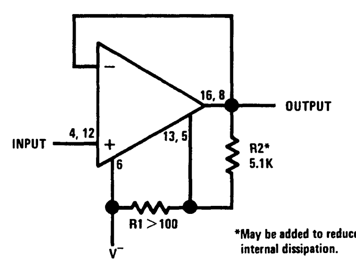
connection diagram



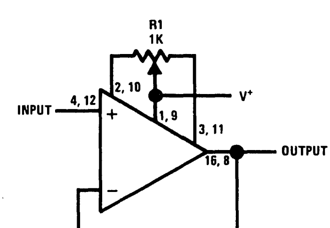
Order Number LH2110D or LH2210D or LH2310D
See Package 2

Order Number LH2110F or LH2210F or LH2310F
See Package 5

auxiliary circuits



Increasing Negative Swing Under Load



Offset Balancing Circuit

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Input Voltage (Note 2)	±15V
Output Short Circuit Duration (Note 3)	Continuous

Operating Temperature Range	LH2110	−55°C to 125°C
	LH2210	−25°C to 85°C
	LH2310	0°C to 70°C
Storage Temperature Range		−65°C to 150°C
Lead Temperature (Soldering, 10 sec)		300°C

electrical characteristics Each side (Note 4)

PARAMETER	CONDITIONS	LIMITS			UNITS
		LH2110	LH2210	LH2310	
Input Offset Voltage	$T_A = 25°C$	4.0	4.0	7.5	mV Max
Input Bias Current	$T_A = 25°C$	3.0	3.0	7.0	nA Max
Input Resistance	$T_A = 25°C$	10^{10}	10^{10}	10^{10}	Ω Min
Input Capacitance		1.5	1.5	1.5	pF Typ
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm15V$ $V_{OUT} = \pm10V$, $R_L = 8\ k\Omega$	.999	.999	.999	V/V Min
Output Resistance	$T_A = 25°C$	2.5	2.5	2.5	Ω Max
Supply Current (Each Amplifier)	$T_A = 25°C$	5.5	5.5	5.5	mA Max
Input Offset Voltage		6.0	6.0	10	mV Max
Offset Voltage Temperature Drift	$-55°C \leq T_A \leq 85°C$ $T_A = 125°C$	6 12	6 12	10 –	μV/°C Typ μV/°C Typ
Input Bias Current		10	10	10	nA Max
Large Signal Voltage Gain	$V_S = \pm15V$, $V_{OUT} = \pm10V$ $R_L = 10\ k\Omega$	.999	.999	.999	V/V Min
Output Voltage Swing (Note 5)	$V_S = \pm15V$, $R_L = 10\ k\Omega$	±10	±10	±10	V Min
Supply Current (Each Amplifier)	$T_A = 125°C$	4.0	4.0	–	mA Max
Supply Voltage Rejection Ratio	$\pm5V \leq V_S \leq \pm18V$	70	70	70	dB Min

Note 1: The maximum junction temperature of the LH2110 is 150°C, while that of the LH2210 is 100°C and the LH2310 is 85°C. For operating at elevated temperatures, devices in the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: Continuous short circuit is allowed for case temperatures to 125°C and ambient temperatures to 70°C. It is necessary to insert a resistor greater than 2 kΩ in series with the input when the amplifier is driven from low impedance sources to prevent damage when the output is shorted.

Note 4: These specifications apply for $\pm5V \leq V_S \leq \pm18V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise specified. With the LM210, however, all temperature specifications are limited to $-25°C \leq T_A \leq 85°C$ and for the LH2310, all temperature specifications are limited to $0°C \leq T_A \leq 70°C$.

Note 5: Increased output swing under load can be obtained by connecting an external resistor between the booster and V^- terminals.

Operational Amplifiers

LH24250/LH24250C dual programmable micropower op amp

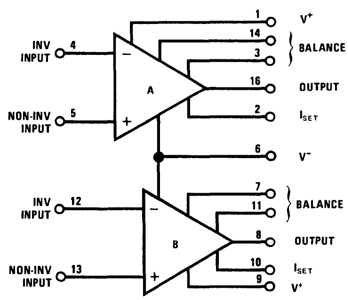
general description

The LH24250/LH24250C series of dual programmable micropower operational amplifiers are two LM4250 type op amps in a single hermetic package. Featuring all the same performance characteristics of the LM4250, the LH24250/LH24250C duals also offer closer thermal tracking, lower weight, reduced insertion cost and smaller size than two single devices. For additional information, see the LM4250 data sheet and National's Linear Application Handbook.

features

- ±1V to ±18V power supply operation
- Standby power consumption as low as 20 μW
- Offset current programmable from less than 0.5 nA to 30 nA
- Programmable slew rate
- May be shut-down using standard open collector TTL
- Internally compensated and short circuit proof

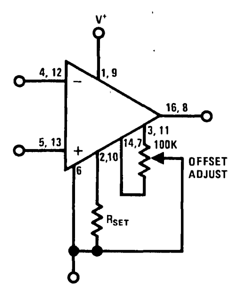
connection diagram and auxiliary circuit



Order Number LH24250F or LH24250CF
See Package 5

Order Number LH24250D or LH24250CD
See Package 2

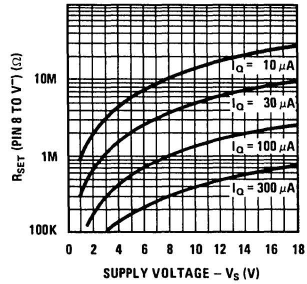
Offset Null Circuit



typical quiescent current setting resistor

(Pin 8 to V-)

V_S	10 μA	30 μA	100 μA	300 μA
±1.5	1.5 MΩ	470 kΩ	150 kΩ	
±3	3.3 MΩ	1.1 MΩ	330 kΩ	100 kΩ
±6	7.5 MΩ	2.7 MΩ	750 kΩ	220 kΩ
±9	13 MΩ	4 MΩ	1.3 MΩ	350 kΩ
±12	18 MΩ	5.6 MΩ	1.5 MΩ	510 kΩ
±15	22 MΩ	7.5 MΩ	2.2 MΩ	620 kΩ



absolute maximum ratings

Supply Voltage	±18V	Operating Temperature Range	
Power Dissipation (Note 1)	500 mW	LH24250	−55°C to +125°C
Differential Input Voltage (Note 2)	±15V	LH24250C	0°C to +70°C
Input Voltage (Note 3)	±15V	Storage Temperature Range	−65°C to +150°C
Output Short Circuit Duration	Continuous	Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics – each side (Note 4)

PARAMETER	CONDITIONS	LIMITS		UNITS
		LH24250	LH24250C	
Input Offset Voltage	$T_A = 25°C$, $R_S \leq 100\ k\Omega$	3.0	6.0	mV Max
Input Offset Current	$T_A = 25°C$	5	10	nA Max
Input Bias Current	$T_A = 25°C$	15	30	nA Max
Input Resistance	$T_A = 25°C$	3	3	MΩ Min
Power Consumption	$T_A = 25°C$, $V_O = 0$, $R_{SET} = 2.7\ M\Omega$	480	600	μW Max
Large Signal Voltage Gain	$T_A = 25°C$, $R_L \geq 10\ k\Omega$	100	75	V/mV Min
Input Offset Voltage	$R_S \geq 10\ k\Omega$	4.0	7.5	mV Max
Input Offset Current		5	15	nA Max
Input Bias Current		15	50	nA Max
Large Signal Voltage Gain	$R_L \geq 10\ k\Omega$	50	50	V/mV Min
Output Voltage Swing	$R_L \geq 10\ k\Omega$, $V_S = \pm15V$	±10	±10	V Min
Input Voltage Range	$T_A = 25°C$, $V_S = \pm15V$	±12	±12	V Min
Common Mode Rejection Ratio	$T_A = 25°C$, $R_S \leq 10\ k\Omega$	70	70	dB Min
Supply Voltage Rejection Ratio	$T_A = 25°C$, $R_S \leq 10\ k\Omega$	76	76	dB Min

Note 1: Derate linearly 2 mW/°C case temperature above 25°C.

Note 2: This rating applies to maximum voltage differential between input terminals. The maximum input voltage on either input terminal is limited to $\pm V_S$ up to ±15V.

Note 3: This rating limited to ± supply voltage to a maximum of ±15V.

Note 4: These specifications apply for $V_S = \pm6V$, $I_q = 30\ \mu A$, and $-55°C \leq T_A \leq +125°C$ unless otherwise specified. With the LH24250C, however, all temperature specifications are limited to $0°C \leq T_A \leq 70°C$.

Operational Amplifiers

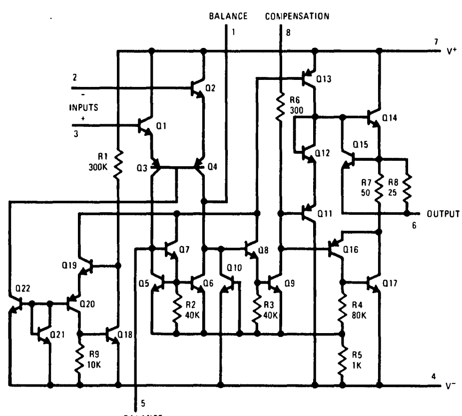
LM101 operational amplifier general description

The LM101 is a general-purpose operational amplifier built on a single silicon chip. The resulting close match and tight thermal coupling gives low offsets and temperature drift as well as fast recovery from thermal transients. In addition, the device features:

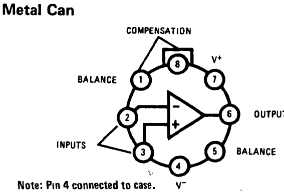
- Frequency compensation with a single 30 pF capacitor
- Operation from ±5V to ±20V
- Low current drain: 1.8 mA at ±20V
- Continuous short-circuit protection
- Operation as a comparator with differential inputs as high as ±30V
- No latch-up when common mode range is exceeded
- Same pin configuration as the LM709.

The unity-gain compensation specified makes the circuit stable for all feedback configurations, even with capacitive loads. However, it is possible to optimize compensation for best high frequency performance at any gain. As a comparator, the output can be clamped at any desired level to make it compatible with logic circuits. Further, the low power dissipation permits high-voltage operation and simplifies packaging in full-temperature-range systems.

schematic** and connection diagrams

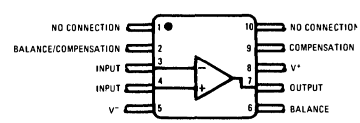


Metal Can



Order Number LM101H
See Package 11

Flat Package

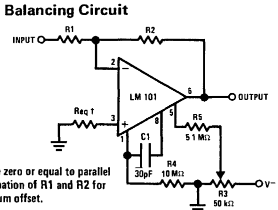


Note: Pin 5 connected to bottom of package.

Order Number LM101F
See Package 3

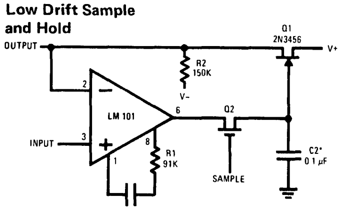
typical applications **

Inverting Amplifier with Balancing Circuit



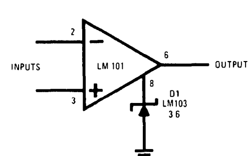
†May be zero or equal to parallel combination of R1 and R2 for minimum offset.

Low Drift Sample and Hold

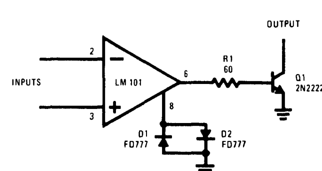


*Polycarbonate-dielectric capacitor.

Voltage Comparator for Driving DTL or TTL Integrated Circuits



Voltage Comparator for Driving RTL Logic or High Current Driver



**Pin connections shown are for metal can.

absolute maximum ratings

Supply Voltage	±22V
Power Dissipation (Note 1)	500 mW
Differential Input Voltage	±30V
Input Voltage (Note 2)	±15V
Output Short-Circuit Duration (Note 3)	Indefinite
Operating Temperature Range	−55°C to +125°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 60 sec)	300°C

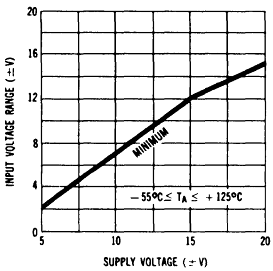
electrical characteristics (note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$, $R_S \leq 10k\Omega$		1.0	5.0	mV
Input Offset Current	$T_A = 25°C$		40	200	nA
Input Bias Current	$T_A = 25°C$		120	500	nA
Input Resistance	$T_A = 25°C$	300	800		kΩ
Supply Current	$T_A = 25°C$, $V_S = \pm20V$		1.8	3.0	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm15V$ $V_{OUT} = \pm10V$, $R_L \geq 2k\Omega$	50	160		V/mV
Input Offset Voltage	$R_S \leq 10k\Omega$			6.0	mV
Average Temperature Coefficient of Input Offset Voltage	$R_S \leq 50\Omega$ $R_S \leq 10k\Omega$		3.0 6.0		μV/°C μV/°C
Input Offset Current	$T_A = +125°C$ $T_A = -55°C$		10 100	200 500	nA nA
Input Bias Current	$T_A = -55°C$		0.28	1.5	μA
Supply Current	$T_A = +125°C$, $V_S = \pm20V$		1.2	2.5	mA
Large Signal Voltage Gain	$V_S = \pm15V$, $V_{OUT} = \pm10V$ $R_L \geq 2k\Omega$	25			V/mV
Output Voltage Swing	$V_S = \pm15V$, $R_L = 10k\Omega$ $R_L = 2k\Omega$	±12 ±10	±14 ±13		V V
Input Voltage Range	$V_S = \pm15V$	±12			V
Common Mode Rejection Ratio	$R_S \leq 10k\Omega$	70	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 10k\Omega$	70	90		dB

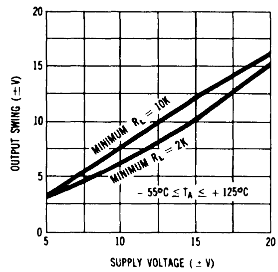
Note 1: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case for the metal-can package. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick, epoxy-glass board with ten, 0.03-inch-wide, 2-ounce copper conductors (see curve).
Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.
Note 3: Continuous short circuit is allowed for case temperatures to +125°C and ambient temperatures to +70°C.
Note 4: These specifications apply for $-55°C \leq T_A \leq 125°C$, $\pm5V, \leq V_S \leq \pm20V$ and C1 = 30 pF unless otherwise specified.

guaranteed performance characteristics

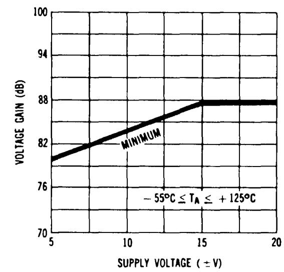
Input Voltage Range



Output Swing

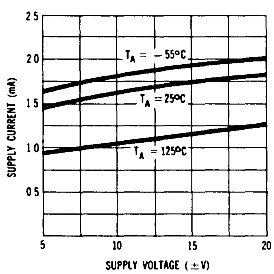


Voltage Gain

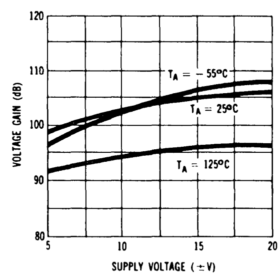


typical performance characteristics

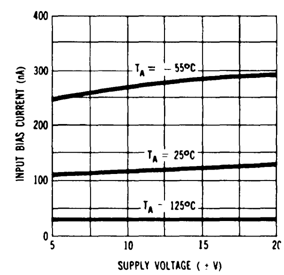
Supply Current



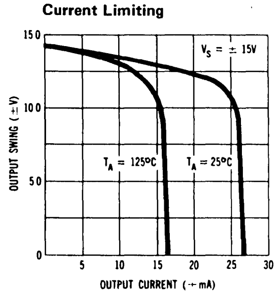
Voltage Gain



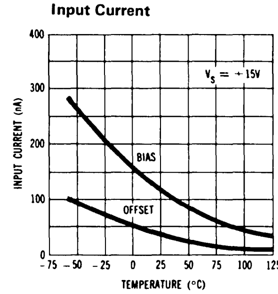
Input Bias Current



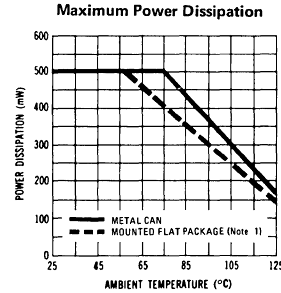
Current Limiting



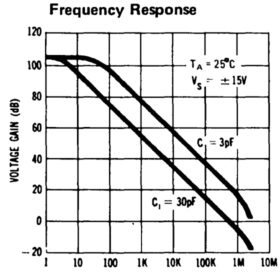
Input Current



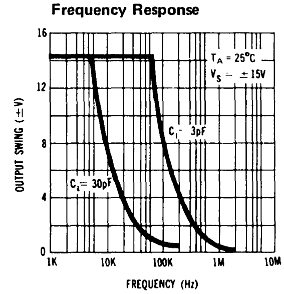
Maximum Power Dissipation



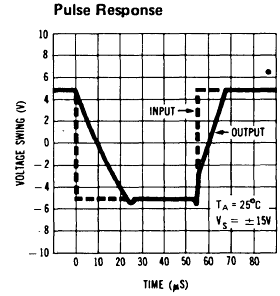
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



Operational Amplifiers

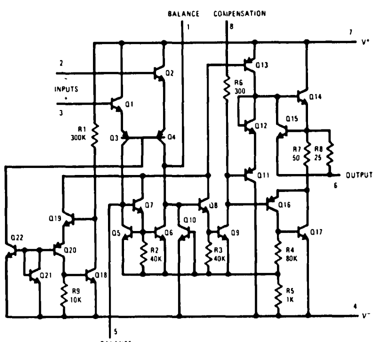
LM201 operational amplifier general description

The LM201 is a general-purpose operational amplifier built on a single silicon chip. It is identical to the LM101 except that operation is specified over a 0 to 70°C temperature range. The device features:

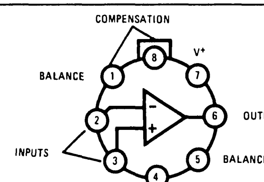
- Frequency compensation with a single 30 pF capacitor
- Operation from ±5V to ±20V
- Low current drain: 1.8 mA at ±20V
- Continuous short-circuit protection
- Operation as a comparator with differential inputs as high as ±30V
- No latch-up when common mode range is exceeded
- LM709 lead configuration in metal cans and flat-packages.

The unity-gain compensation specified makes the circuit stable for all feedback configurations, even with capacitive loads. However, it is possible to optimize compensation for best high frequency performance at any gain. As a comparator, the output can be clamped at any desired level to make it compatible with logic circuits. Further, the low power dissipation permits high-voltage operation and simplifies packaging.

schematic** and connection diagrams



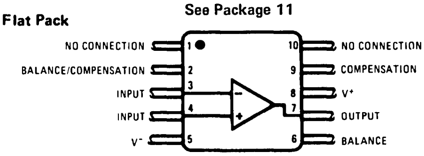
Metal Can



Note: Pin 4 connected to case.

Order Number LM201H
See Package 11

Flat Pack

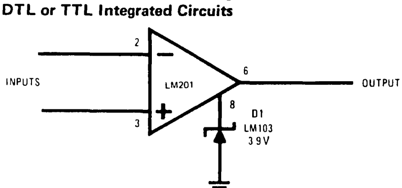


Note: Pin 5 connected to bottom of package.

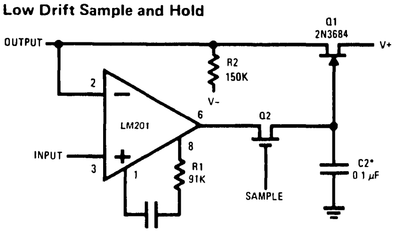
Order Number LM201F
See Package 3

typical applications**

Voltage Comparator for Driving DTL or TTL Integrated Circuits

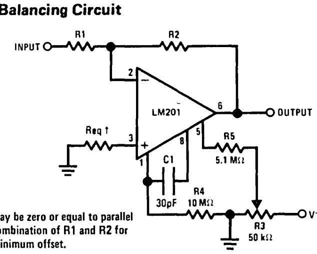


Low Drift Sample and Hold



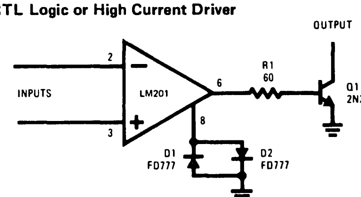
*Polycarbonate-dielectric capacitor.

Inverting Amplifier with Balancing Circuit



†May be zero or equal to parallel combination of R1 and R2 for minimum offset.

Voltage Comparator for Driving RTL Logic or High Current Driver



**Pin connections shown are for metal can.

absolute maximum ratings

Supply Voltage	±22V
Power Dissipation (Note 1)	250 mW
Differential Input Voltage	±30V
Input Voltage (Note 2)	±15V
Output Short-Circuit Duration (Note 3)	Indefinite
Operating Temperature Range	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

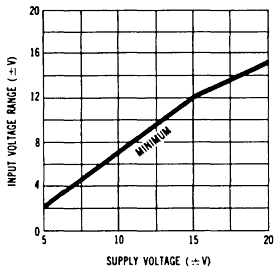
electrical characteristics (note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$, $R_S \leq 10k\Omega$		2.0	7.5	mV
Input Offset Current	$T_A = 25°C$		100	500	nA
Input Bias Current	$T_A = 25°C$		0.25	1.5	μA
Input Resistance	$T_A = 25°C$	100	400		kΩ
Supply Current	$T_A = 25°C$, $V_S = \pm 20V$		1.8	3.0	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm 15V$ $V_{OUT} = \pm 10V$, $R_L \geq 2k\Omega$	20	150		V/mV
Input Offset Voltage	$R_S \leq 10k\Omega$			10	mV
Average Temperature Coefficient of Input Offset Voltage	$R_S \leq 50\Omega$ $R_S \leq 10k\Omega$		6 10		μV/°C μV/°C
Input Offset Current	$T_A = +70°C$ $T_A = 0°C$		50 150	400 750	nA nA
Input Bias Current	$T_A = 0°C$		0.32	2.0	μA
Large Signal Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \geq 2k\Omega$	15			V/mV
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10k\Omega$ $R_L = 2k\Omega$	±12 ±10	±14 ±13		V V
Input Voltage Range	$V_S = \pm 15V$	±12			V
Common Mode Rejection Ratio	$R_S \leq 10k\Omega$	65	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 10k\Omega$	70	90		dB

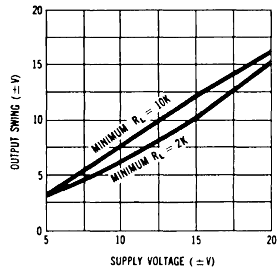
Note 1: For operating at elevated temperatures, the device must be derated based on a 100°C maximum junction temperature and a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case for the metal-can package. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick, epoxy-glass board with ten, 0.03-inch-wide, 2-ounce copper conductors (see curve).
Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.
Note 3: Continuous short circuit is allowed for case temperatures to 70°C and ambient temperatures to 55°C.
Note 4: These specifications apply for $0°C \leq T_A \leq 70°C$, $\pm 5V \leq V_S \leq \pm 20V$ and C1 = 30 pF unless otherwise specified.

guaranteed performance characteristics

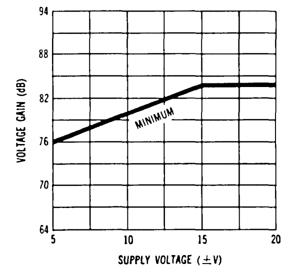
Input Voltage Range



Output Swing

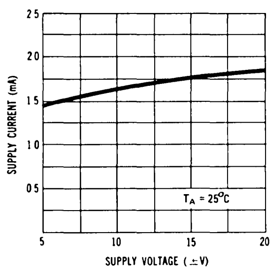


Voltage Gain

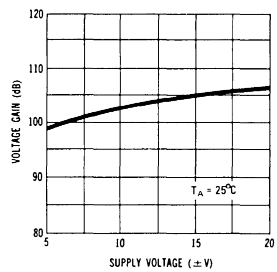


typical performance characteristics

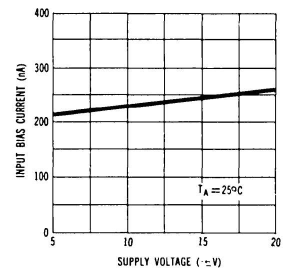
Supply Current



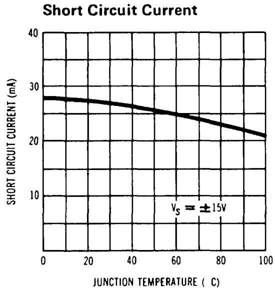
Voltage Gain



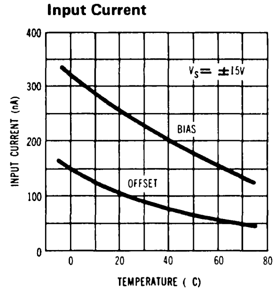
Input Bias Current



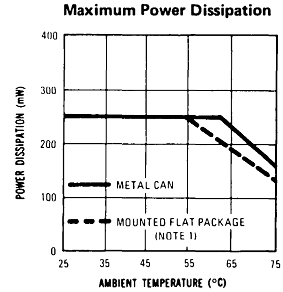
Short Circuit Current



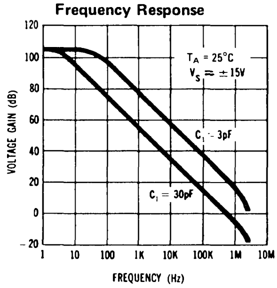
Input Current



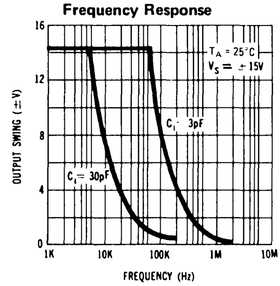
Maximum Power Dissipation



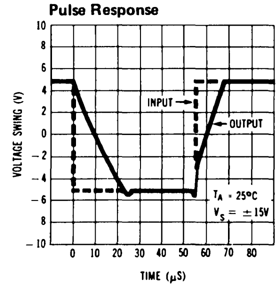
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



2

Operational Amplifiers

LM101A/LM201A operational amplifier general description

The LM101A and LM201A are general purpose operational amplifiers which feature improved performance over industry standards like the LM101 and the 709. Advanced processing techniques make possible an order of magnitude reduction in input currents, and a redesign of the biasing circuitry reduces the temperature drift of input current. Improved specifications include:

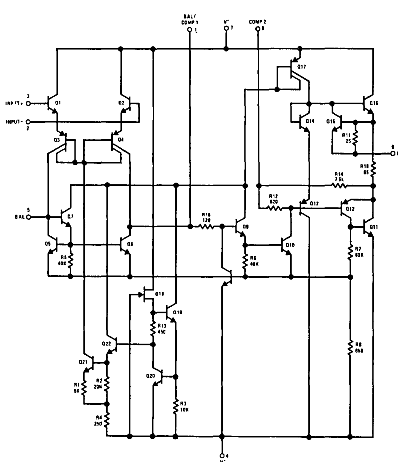
- Offset voltage 3 mV maximum over temperature
- Input current 100 nA maximum over temperature
- Offset current 20 nA maximum over temperature
- Guaranteed drift characteristics
- Offsets guaranteed over entire common mode and supply voltage ranges
- Slew rate of 10V/μs as a summing amplifier

This amplifier offers many features which make its application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, freedom from oscillations and compensation with a single 30 pF capacitor. It has advantages over internally compensated amplifiers in that the frequency compensation can be tailored to the particular application. For example, in low frequency circuits it can be overcompensated for increased stability margin. Or the compensation can be optimized to give more than a factor of ten improvement in high frequency performance for most applications.

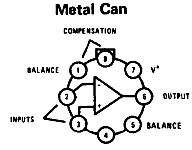
The LM101A series offers the features of the LM101, which makes its application nearly foolproof. In addition, the device provides better accuracy and lower noise in high impedance circuitry. The low input currents also make it particularly well suited for long interval integrators or timers, sample and hold circuits and low frequency waveform generators. Further, replacing circuits where matched transistor pairs buffer the inputs of conventional IC op amps, it can give lower offset voltage and drift at a lower cost.

The LM201A is identical to the LM101A, except that the LM201A has its performance guaranteed over a –25°C to 85°C temperature range, instead of –55°C to 125°C.

schematic** and connection diagrams



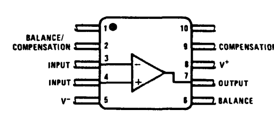
Metal Can



Note: Pin 4 connected to case.
TOP VIEW

Order Number LM101AH or LM201AH
See Package 11

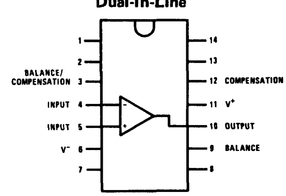
Flat Package



Note: Pin 5 connected to bottom of package.
TOP VIEW

Order Number LM101AF or LM201AF
See Package 3

Dual-In-Line

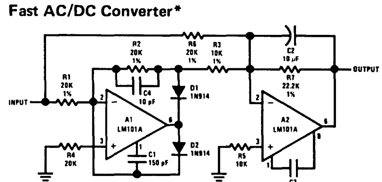


Note: Pin 6 connected to bottom of package.
TOP VIEW

Order Number LM101AD or LM201AD
See Package 1

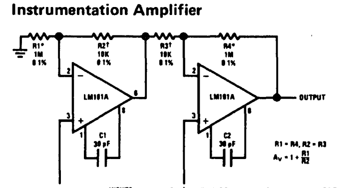
typical applications**

Fast AC/DC Converter*



* LESS THAN 1% ERROR TO 100 kHz

Instrumentation Amplifier



*, † Matching determines CMRR.

**Pin connections shown are for metal can.

absolute maximum ratings

Supply Voltage		±22V
Power Dissipation (Note 1)		500 mW
Differential Input Voltage		±30V
Input Voltage (Note 2)		±15V
Output Short-Circuit Duration (Note 3)		Indefinite
Operating Temperature Range	LM101A	−55°C to 125°C
	LM201A	−25°C to 85°C
Storage Temperature Range		−65°C to 150°C
Lead Temperature (Soldering, 10 sec)		300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$, $R_S \le 50\ k\Omega$		0.7	2.0	mV
Input Offset Current	$T_A = 25°C$		1.5	10	nA
Input Bias Current	$T_A = 25°C$		30	75	nA
Input Resistance	$T_A = 25°C$	1.5	4		MΩ
Supply Current	$T_A = 25°C$, $V_S = \pm20V$		1.8	3.0	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm15V$ $V_{OUT} = \pm10V$, $R_L \ge 2\ k\Omega$	50	160		V/mV
Input Offset Voltage	$R_S \le 50\ k\Omega$			3.0	mV
Average Temperature Coefficient of Input Offset Voltage			3.0	15	μV/°C
Input Offset Current				20	nA
Average Temperature Coefficient of Input Offset Current	$25°C \le T_A \le 125°C$ $-55°C \le T_A \le 25°C$		0.01 0.02	0.1 0.2	nA/°C nA/°C
Input Bias Current				100	nA
Supply Current	$T_A = +125°C$, $V_S = \pm20V$		1.2	2.5	mA
Large Signal Voltage Gain	$V_S = \pm15V$, $V_{OUT} = \pm10V$ $R_L \ge 2\ k\Omega$	25			V/mV
Output Voltage Swing	$V_S = \pm15V$, $R_L = 10\ k\Omega$ $R_L = 2\ k\Omega$	±12 ±10	±14 ±13		V V
Input Voltage Range	$V_S = \pm20V$	±15			V
Common Mode Rejection Ratio	$R_S \le 50\ k\Omega$	80	96		dB
Supply Voltage Rejection Ratio	$R_S \le 50\ k\Omega$	80	96		dB

Note 1: The maximum junction temperature of the LM101A is 150°C, while that of the LM201A is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line apckage is 100°C/W, junction to ambient.

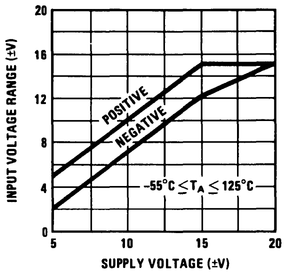
Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: Continuous short circuit is allowed for case temperatures to +125°C and ambient temperatures to +75°C.

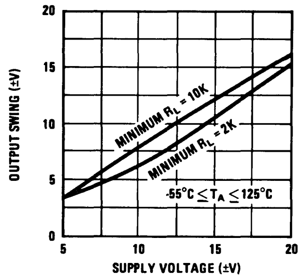
Note 4: These specifications apply for $\pm5V \le V_S \le \pm20V$ and $-55°C \le T_A \le 125°C$, unless otherwise specified. With the LM201A, however, all temperature specifications are limited to $-25°C \le T_A \le 85°C$.

guaranteed performance characteristics

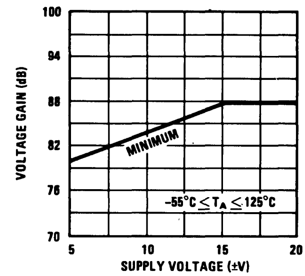
Input Voltage Range



Output Swing

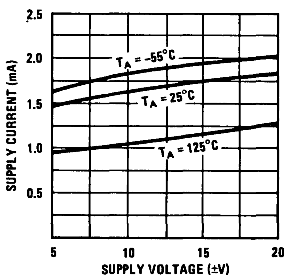


Voltage Gain

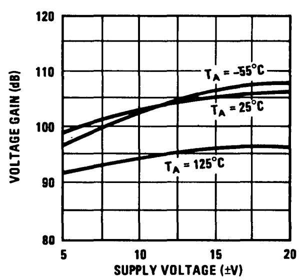


typical performance characteristics

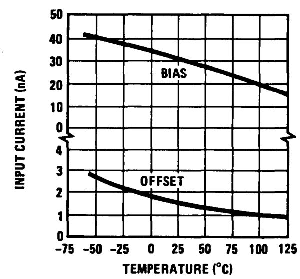
Supply Current



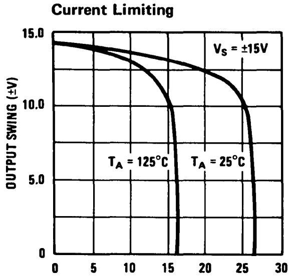
Voltage Gain



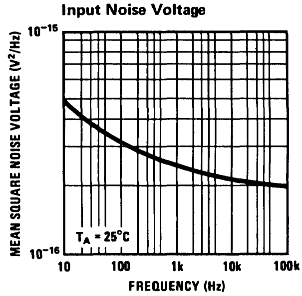
Input Current



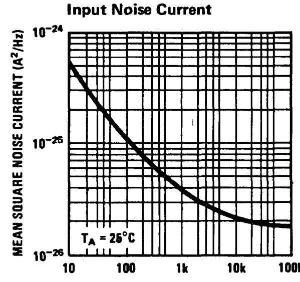
Current Limiting



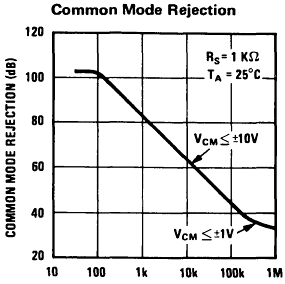
Input Noise Voltage



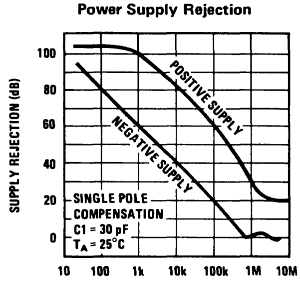
Input Noise Current



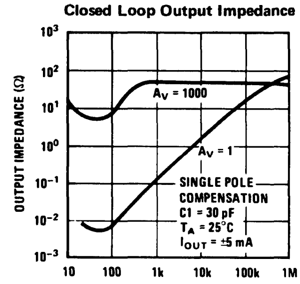
Common Mode Rejection



Power Supply Rejection

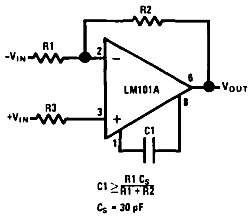


Closed Loop Output Impedance

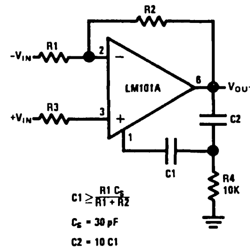


compensation circuits**

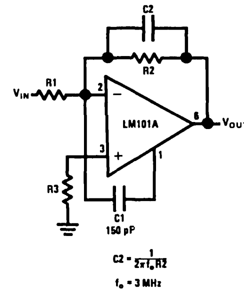
Single Pole Compensation



Two Pole Compensation



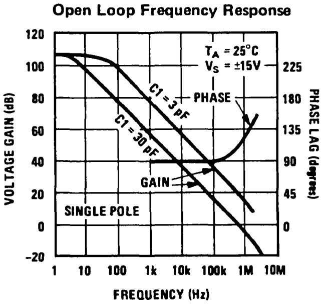
Feedforward Compensation



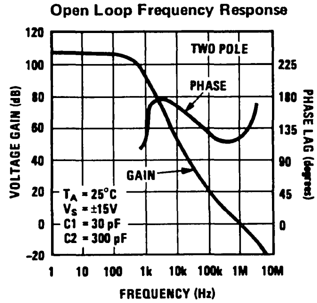
**Pin connections shown are for metal can.

typical performance characteristics (con't)

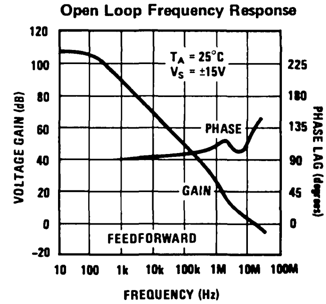
Open Loop Frequency Response



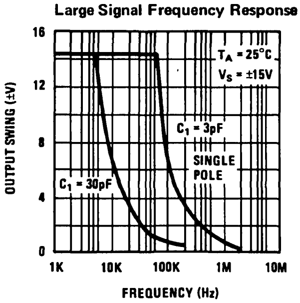
Open Loop Frequency Response



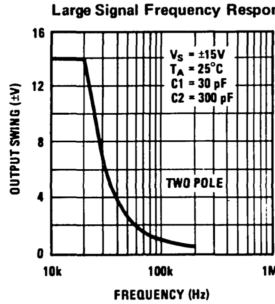
Open Loop Frequency Response



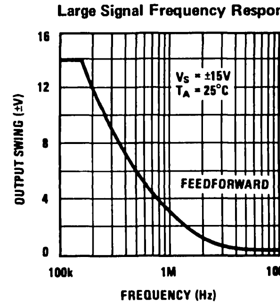
Large Signal Frequency Response



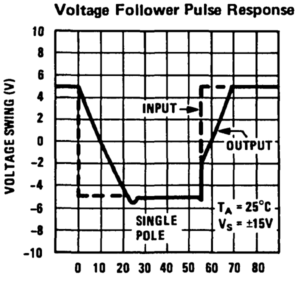
Large Signal Frequency Response



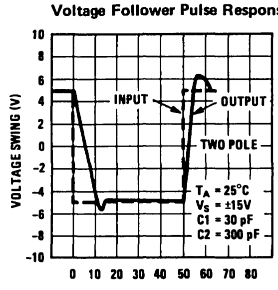
Large Signal Frequency Response



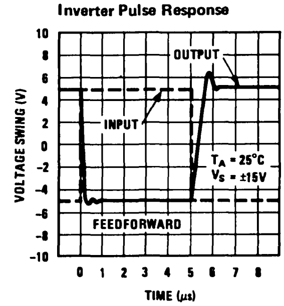
Voltage Follower Pulse Response



Voltage Follower Pulse Response

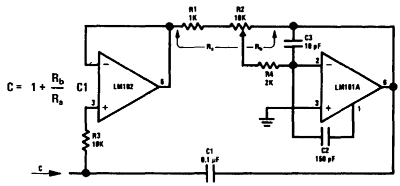


Inverter Pulse Response

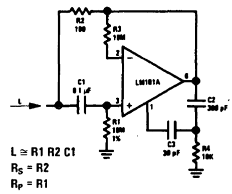


typical applications ** (con't)

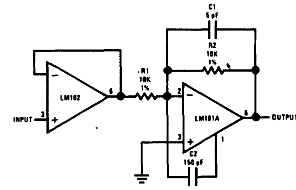
Variable Capacitance Multiplier



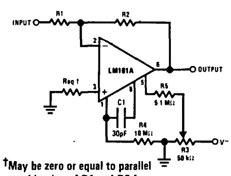
Simulated Inductor



Fast Inverting Amplifier With High Input Impedance

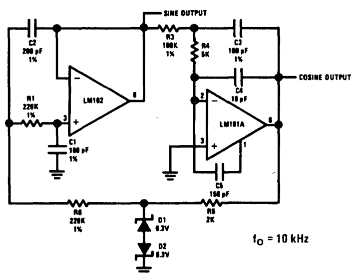


Inverting Amplifier with Balancing Circuit



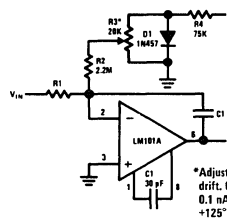
†May be zero or equal to parallel combination of R1 and R2 for minimum offset.

Sine Wave Oscillator



f_O = 10 kHz

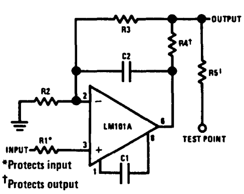
Integrator with Bias Current Compensation



*Adjust for zero integrator drift. Current drift typically 0.1 nA/°C over −55°C to +125°C temperature range.

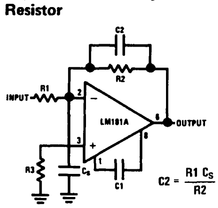
application hints**

Protecting Against Gross Fault Conditions

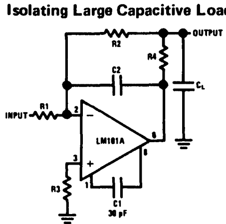


*Protects input
†Protects output
‡Protects output—not needed when R4 is used.

Compensating For Stray Input Capacitances Or Large Feedback Resistor



Isolating Large Capacitive Loads



Although the LM101A is designed for trouble free operation, experience has indicated that it is wise to observe certain precautions given below to protect the devices from abnormal operating conditions. It might be pointed out that the advice given here is applicable to practically any IC op amp, although the exact reason why may differ with different devices.

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 instantaneous output current of the source to something less than 100 mA. This is especially important when the inputs go outside a piece of equipment where they could accidentally be connected to high voltage sources. Large capacitors on the input (greater than 0.1 μF) should be treated as a low source impedance and isolated with a resistor. Low impedance sources do not cause a problem unless their output voltage exceeds the supply voltage. However, the supplies go to zero when they are turned off, so the isolation is usually needed.

The output circuitry is protected against damage from shorts to ground. However, when the amplifier output is connected to a test point, it should be isolated by a limiting resistor, as test points frequently get shorted to bad places. Further, when the amplifier drives a load external to the equipment, it is also advisable to use some sort of limiting resistance to preclude mishaps.

Precautions should be taken to insure that the power supplies for the integrated circuit never become reversed—even under transient conditions. With reverse voltages greater than 1V, the IC will conduct excessive current, fuzing internal aluminum interconnects. If there is a possibility of this happening, clamp diodes with a high peak current rating should be installed on the supply lines. Reversal of the voltage between V^+ and V^- will always cause a problem, although reversals with respect to ground may also give difficulties in many circuits.

The minimum values given for the frequency compensation capacitor are stable only for source resistances less than 10 kΩ, stray capacitances on the summing junction less than 5 pF and capacitive loads smaller than 100 pF. If any of these conditions are not met, it becomes necessary to overcompensate the amplifier with a larger compensation capacitor. Alternately, lead capacitors can be used in the feedback network to negate the effect of stray capacitance and large feedback resistors or an RC network can be added to isolate capacitive loads.

Although the LM101A is relatively unaffected by supply bypassing, this cannot be ignored altogether. Generally it is necessary to bypass the supplies to ground at least once on every circuit card, and more bypass points may be required if more than five amplifiers are used. When feed-forward compensation is employed, however, it is advisable to bypass the supply leads of each amplifier with low inductance capacitors because of the higher frequencies involved.

**Pin connections shown are for metal can.

Operational Amplifiers

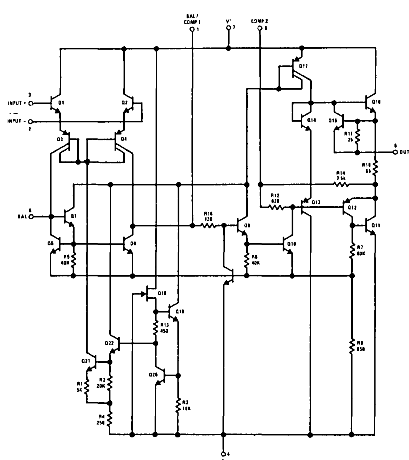
LM301A operational amplifier general description

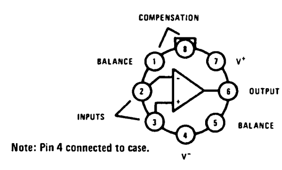
The LM301A is a general-purpose operational amplifier which features improved performance over the 709C and other popular amplifiers. Advanced processing techniques make possible an order of magnitude reduction in input currents, and a redesign of the biasing circuitry reduces the temperature drift of input current.

This amplifier offers many features which make its application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, freedom from oscillations and compensation with a single 30 pF capacitor. It has advantages over internally compensated amplifiers in that the compensation can be tailored to the particular application. For example, as a summing amplifier, slew rates of 10 V/μs and bandwidths of 10 MHz can be realized. In addition, the circuit can be used as a comparator with differential inputs up to ±30V; and the output can be clamped at any desired level to make it compatible with logic circuits.

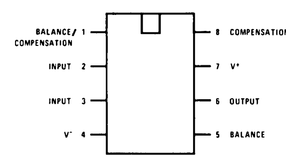
The LM301A provides better accuracy and lower noise than its predecessors in high impedance circuitry. The low input currents also make it particularly well suited for long interval integrators or timers, sample and hold circuits and low frequency waveform generators. Further, replacing circuits where matched transistor pairs buffer the inputs of conventional IC op amps, it can give lower offset voltage and drift at reduced cost.

schematic** and connection diagrams





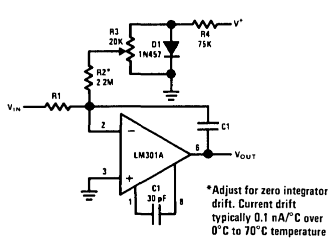
Order Number LM301AH
See Package 11



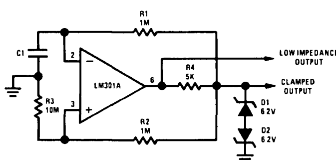
Order Number LM301AN
See Package 20

typical applications **

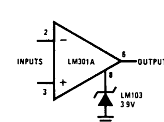
Integrator with Bias Current Compensation



Low Frequency Square Wave Generator



Voltage Comparator for Driving DTL or TTL Integrated Circuits



**Pin connections shown are for metal can.

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Differential Input Voltage	±30V
Input Voltage (Note 2)	±15V
Output Short-Circuit Duration (Note 3)	Indefinite
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$, $R_S \leq 50\ k\Omega$		2.0	7.5	mV
Input Offset Current	$T_A = 25°C$		3	50	nA
Input Bias Current	$T_A = 25°C$		70	250	nA
Input Resistance	$T_A = 25°C$	0.5	2		MΩ
Supply Current	$T_A = 25°C$, $V_S = \pm15V$		1.8	3.0	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm15V$ $V_{OUT} = \pm10V$, $R_L \geq 2\ k\Omega$	25	160		V/mV
Input Offset Voltage	$R_S \leq 50\ k\Omega$			10	mV
Average Temperature Coefficient of Input Offset Voltage			6.0	30	μV/°C
Input Offset Current				70	nA
Average Temperature Coefficient of Input Offset Current	$25°C \leq T_A \leq 70°C$ $0°C \leq T_A \leq 25°C$		0.01 0.02	0.3 0.6	nA/°C nA/°C
Input Bias Current				300	nA
Large Signal Voltage Gain	$V_S = \pm15V$, $V_{OUT} = \pm10V$ $R_L \geq 2\ k\Omega$	15			V/mV
Output Voltage Swing	$V_S = \pm15V$, $R_L = 10\ k\Omega$ $R_L = 2\ k\Omega$	±12 ±10	±14 ±13		V V
Input Voltage Range	$V_S = \pm15V$	±12			V
Common Mode Rejection Ratio	$R_S \leq 50\ k\Omega$	70	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 50\ k\Omega$	70	96		dB

Note 1: For operating at elevated temperatures, the device must be derated based on a 100°C maximum junction temperature and a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case.

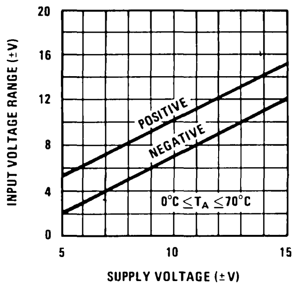
Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: Continuous short circuit is allowed for case temperatures to 70°C and ambient temperatures to 55°C.

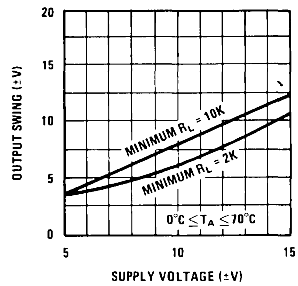
Note 4: These specifications apply for $0°C \leq T_A < 70°C$, $\pm5V, \leq V_S \leq \pm15V$ and C1 = 30 pF unless otherwise specified.

guaranteed performance characteristics

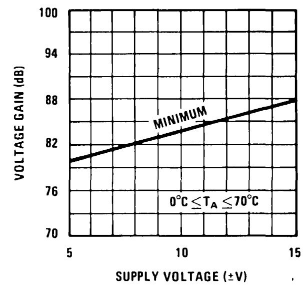
Input Voltage Range



Output Swing

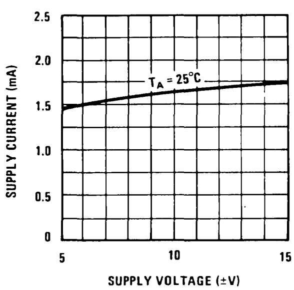


Voltage Gain

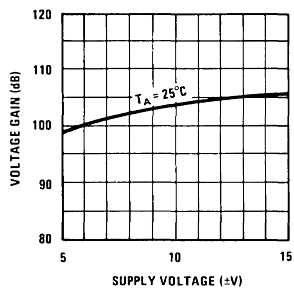


typical performance characteristics

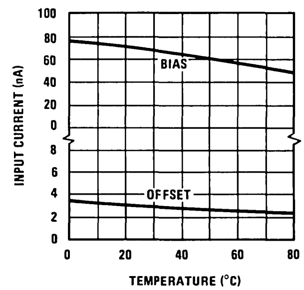
Supply Current



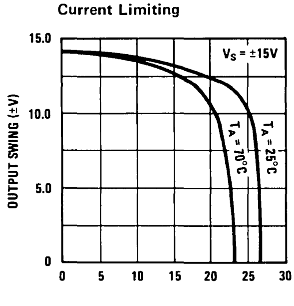
Voltage Gain



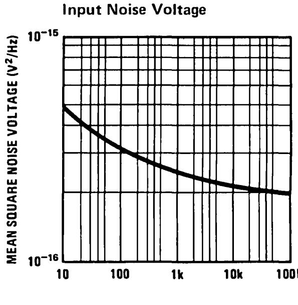
Input Current



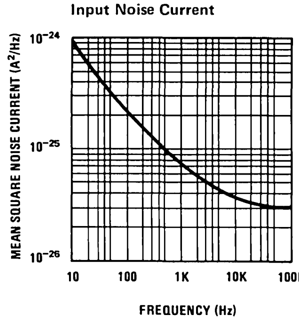
Current Limiting



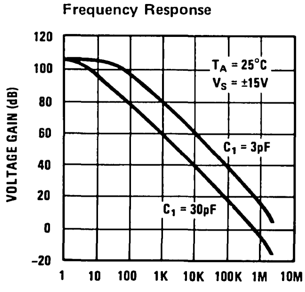
Input Noise Voltage



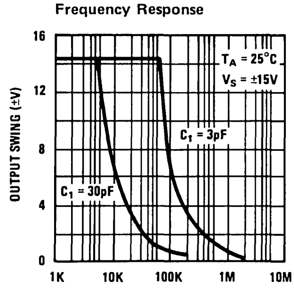
Input Noise Current



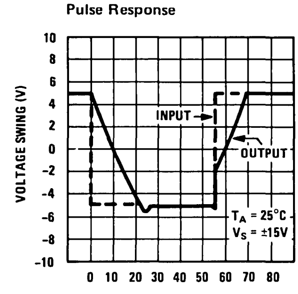
Open Loop
Frequency Response



Large Signal
Frequency Response



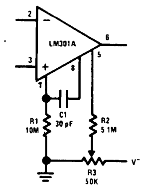
Voltage Follower
Pulse Response



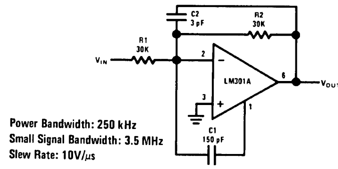
2

typical applications ** (con't)

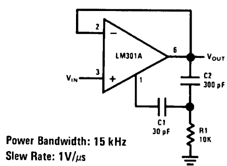
Standard Compensation and Offset Balancing Circuit



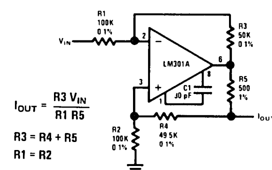
Fast Summing Amplifier



Fast Voltage Follower



Bilateral Current Source



$$I_{OUT} = \frac{R3\ V_{IN}}{R1\ R5}$$

R3 = R4 + R5

R1 = R2

**Pin connections shown are for metal can.

Operational Amplifiers

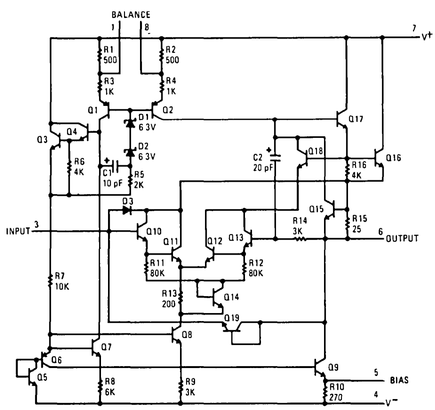
LM102 voltage follower general description

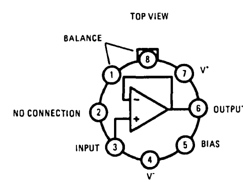
The LM102 is a high-gain operational amplifier designed specifically for unity-gain voltage follower applications. Built on a single silicon chip, the device incorporates advanced processing techniques to obtain very low input current and high input impedance. Further, the input transistors are operated at zero collector-base voltage to virtually eliminate high temperature leakage currents. It can therefore be operated in a temperature stabilized component oven to get extremely low input currents and low offset voltage drift. Other outstanding characteristics of the device include:

- Fast slewing — 10V/μs
- Low input current — 10 nA (max)
- High input resistance — 10,000 MΩ
- No external frequency compensation required
- Simple offset balancing with optional 1K potentiometer
- Plug-in replacement for both the LM101 and LM709 in voltage follower applications.

The LM102, which is designed to operate with supply voltages between ±12V and ±15V, also features low input capacitance as well as excellent small signal and large signal frequency response — all of which minimize high frequency gain error. Because of the low wiring capacitances inherent in monolithic construction, this fast operation can be realized without increasing power consumption.

schematic** and connection diagrams



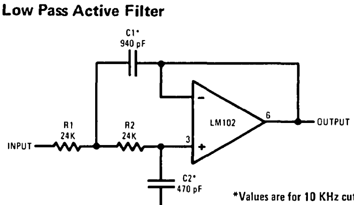


Note: Pin 4 connected to case.

Order Number LM102H
See Package 11

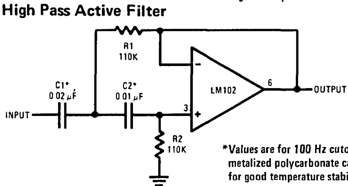
typical applications **

Low Pass Active Filter



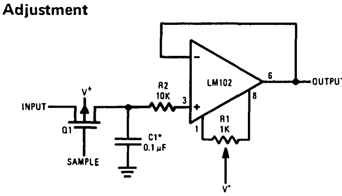
*Values are for 10 KHz cutoff. Use silvered mica capacitors for good temperature stability.

High Pass Active Filter



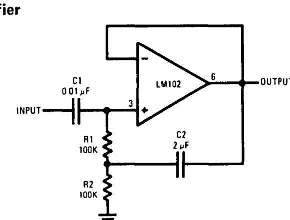
*Values are for 100 Hz cutoff. Use metalized polycarbonate capacitors for good temperature stability

Sample and Hold With Offset Adjustment



*Polycarbonate-dielectric capacitor.

High Input Impedance AC Amplifier



**Pin connections shown are for metal can.

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Input Voltage (Note 2)	±15V
Output Short-Circuit Duration (Note 3)	Indefinite
Operating Temperature Range	−55°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (soldering, 10 sec)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
Offset Voltage			2	5	mV
Average Temperature Coefficient of Offset Voltage			6		μV/°C
Input Current			3	10	nA
Input Resistance		10^{10}	10^{12}		Ω
Voltage Gain	$R_L \geq 10\ k\Omega$	0.999	0.9996		
Output Resistance			0.8	2.5	Ω
Output Voltage Swing (Note 5)	$R_L \geq 8\ k\Omega$	±10	±13		V
Supply Current			3.5	5.5	mA
Positive Supply Rejection		60			dB
Negative Supply Rejection		70			dB
Input Capacitance				3.0	pF
Offset Voltage	$-55°C \leq T_A \leq 125°C$			7.5	mV
Input Current	$T_A = 125°C$		3	10	nA
	$T_A = -55°C$		30	100	nA
Voltage Gain	$-55°C \leq T_A \leq 125°C$, $R_L \geq 10\ k\Omega$	0.999			
Output Voltage Swing (Note 5)	$R_L \geq 10\ k\Omega$	±10			V
Supply Current	$T_A = 125°C$		2.6	4.0	mA

Note 1: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 45°C/W junction to case or 150°C/W junction to ambient (see curve).

Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

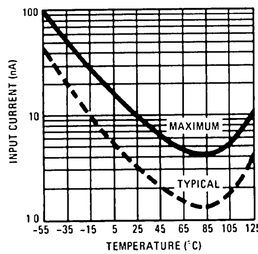
Note 3: Continuous short circuit is allowed for case temperatures to 125°C and ambient temperatures to 70°C. It is necessary to insert a resistor greater than 2 kΩ in series with the input when the amplifier is driven from low impedance sources to prevent damage when the output is shorted.

Note 4: These specifications apply for $T_A = 25°C$, $V_S = \pm15V$ and $C_L \leq 100\ pF$ unless otherwise noted

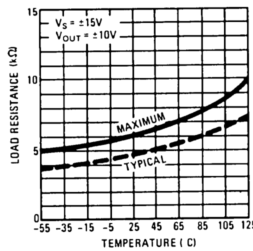
Note 5: Increased output swing under load can be obtained by connecting an external resistor between the booster and V^- terminals.See curve.

guaranteed performance characteristics

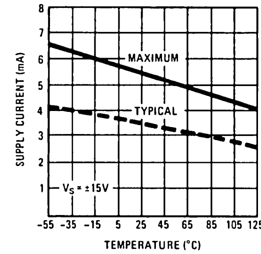
Input Current



Output Swing

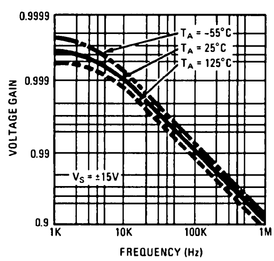


Supply Current

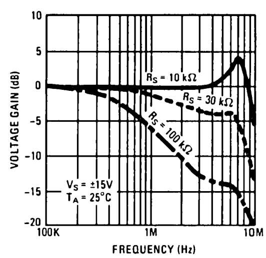


typical performance characteristics

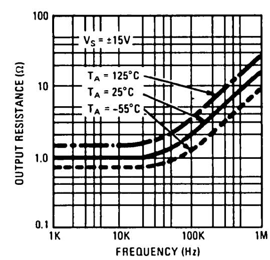
Voltage Gain



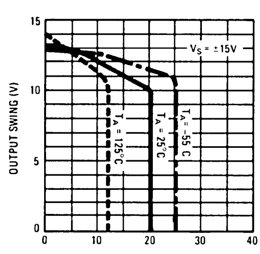
Voltage Gain



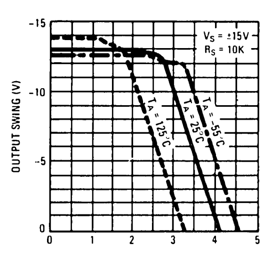
Output Resistance



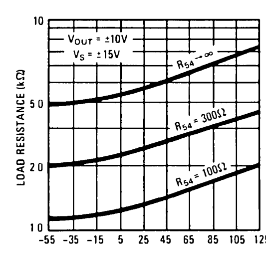
Positive Output Swing



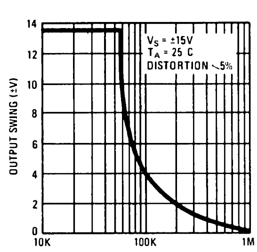
Negative Output Swing



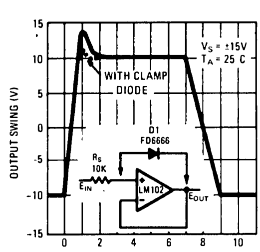
Output Swing



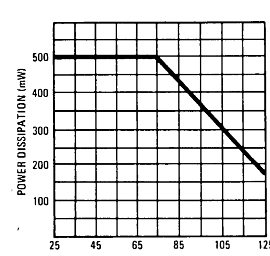
Large Signal Frequency Response



Large Signal Pulse Response



Maximum Power Dissipation



2

Operational Amplifiers

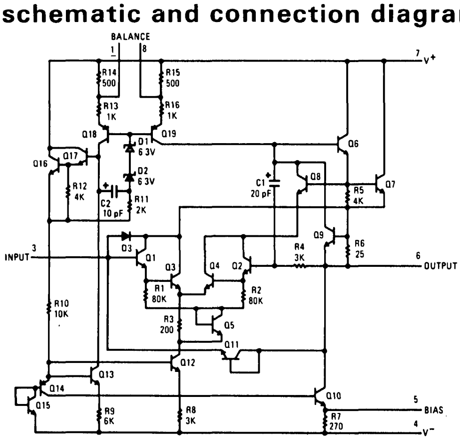
LM202 voltage follower general description

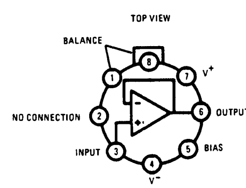
The LM202, a limited temperature range version of the LM102, is a high-gain operational amplifier designed specifically for unity-gain voltage follower applications. Built on a single silicon chip, the device incorporates advanced processing techniques to obtain very low input current and high input impedance. Further, the input transistors are operated at zero collector-base voltage to virtually eliminate high temperature leakage currents. It can therefore be operated in a temperature stabilized component oven to get extremely low input currents and low offset voltage drift. Other outstanding characteristics of the device include:

- Fast slewing: 10V/μs
- Low input current: 15 nA (max)
- High input resistance: 10,000 MΩ
- No external frequency compensation required
- Simple offset balancing with optional 1K potentiometer
- Specified for operation from −25°C to 85°C
- Plug-in replacement for both the LM201 and LM709C voltage follower applications.

The LM202, which is designed to operate with supply voltages between ±12V and ±15V, also features low input capacitance as well as excellent small signal and large signal frequency response — all of which minimize high frequency gain error. Because of the low wiring capacitances inherent in monolithic construction, this fast operation can be realized without increasing power consumption.

schematic and connection diagrams



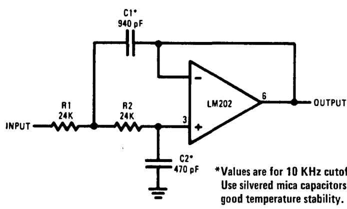


Note: Pin 4 connected to case.

Order Number LM202H
See Package 11

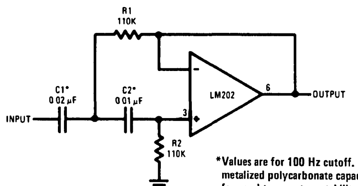
typical applications

Low Pass Active Filter



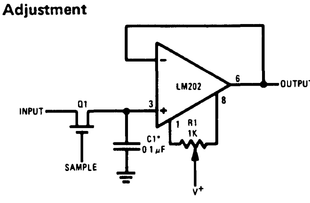
*Values are for 10 KHz cutoff. Use silvered mica capacitors for good temperature stability.

High Pass Active Filter



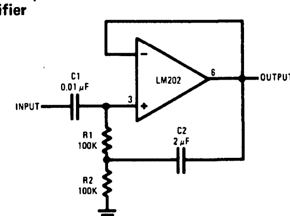
*Values are for 100 Hz cutoff. Use metalized polycarbonate capacitors for good temperature stability.

Sample and Hold With Offset Adjustment



*Polycarbonate-dielectric capacitor.

High Input Impedance AC Amplifier



absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Input Voltage (Note 2)	±15V
Output Short Circuit Duration (Note 3)	Indefinite
Operating Temperature Range	−25°C to 85°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (soldering, 10 sec)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Offset Voltage			3	10	mV
Average Temperature Coefficient of Offset Voltage			15		μV/°C
Input Current			7	15	nA
Input Resistance		10^{10}	10^{12}		Ω
Voltage Gain	$R_L \geq 8\ K\Omega$	.999	0.9995	1.000	
Output Resistance			0.8	2.5	Ω
Output Voltage Swing	$R_L \geq 8\ K\Omega$	±10			V
Supply Current			3.5	5.5	mA
Positive Supply Rejection		60			
Negative Supply Rejection		70			
Input Capacitance			3.0		pF
Offset Voltage	$-25°C \leq T_A \leq 85°C$			15	mV
Input Current	$T_A = 85°C$		1.5	5.0	nA
	$T_A = -25°C$		30	50	nA

Note 1: For operating at elevated temperatures, the device must be derated based on a 100°C maximum junction temperature and a thermal resistance of 45°C/W junction to case or 150°C/W junction to ambient (see curve).

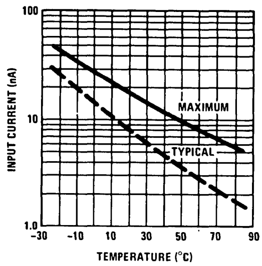
Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: Continuous short circuit is allowed for case temperatures to 85°C and ambient temperatures to 55°C. It is necessary to insert a resistor greater than 2 kΩ in series with the input when the amplifier is driven from low impedance sources to prevent damage when the output is shorted.

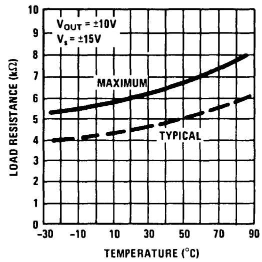
Note 4: These specifications apply for T_A = 25°C, V_S = ±15V and $C_L \leq$ 100 pF unless otherwise noted.

guaranteed performance characteristics

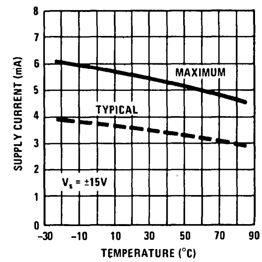
Input Current



Output Swing

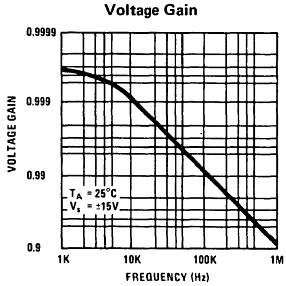


Supply Current

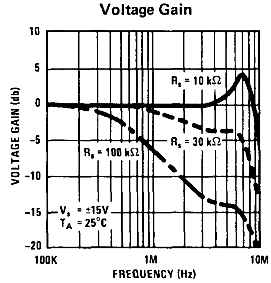


typical performance characteristics

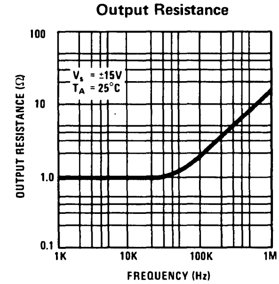
Voltage Gain



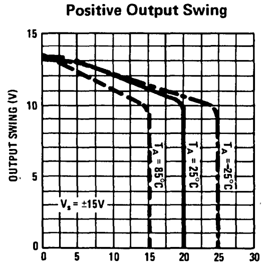
Voltage Gain



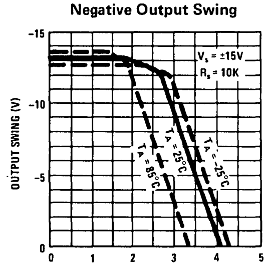
Output Resistance



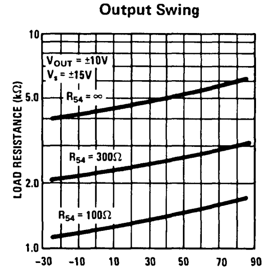
Positive Output Swing



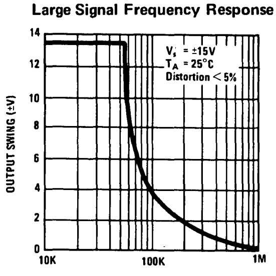
Negative Output Swing



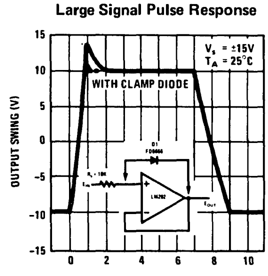
Output Swing



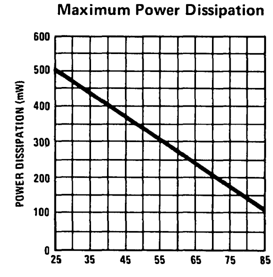
Large Signal Frequency Response



Large Signal Pulse Response



Maximum Power Dissipation



Operational Amplifiers

LM302 voltage follower

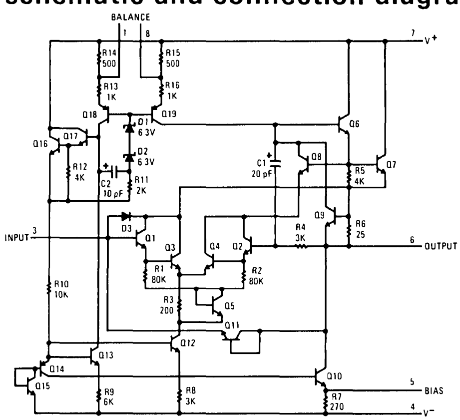
general description

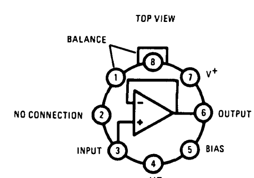
The LM302 is a high gain operational amplifier designed specifically for unity-gain voltage follower applications. Built on a single silicon chip, the device incorporates advanced processing techniques to obtain very low input current and high input impedance. Further, the input transistors are operated at zero collector-base voltage to virtually eliminate high temperature leakage currents. It can therefore be operated in a temperature stabilized component over to get extremely low input currents and low offset voltage drift. Other outstanding characteristics of the device include:

- Fast Slewing – 10V/μs
- Low input current – 30 nA (max)
- High input resistance – 1,000 MΩ
- No external frequency compensation required
- Simple offset balancing with optional 1K potentiometer
- Specified for operation from 0°C to 70°C
- Plug-in replacement for both the LM201 and LM709C in voltage follower applications.

The LM302, which is designed to operate with supply voltages between ±12V and ±15V, also features low input capacitance as well as excellent small signal and large signal frequency response – all of which minimize high frequency gain error. Because of the low wiring capacitances inherent in monolithic construction, this fast operation can be realized without increasing power consumption.

schematic and connection diagrams



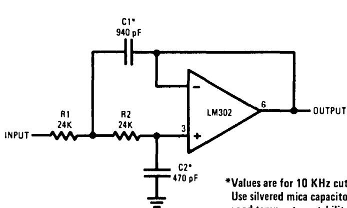


Note: Pin 4 connected to case.

Order Number LM302H
See Package 11

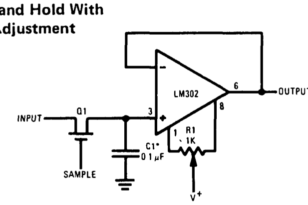
typical applications

Low Pass Active Filter



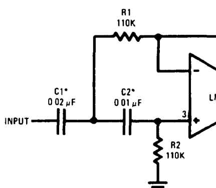
*Values are for 10 KHz cutoff. Use silvered mica capacitors for good temperature stability.

Sample and Hold With Offset Adjustment



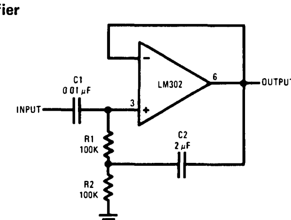
*Polycarbonate-dielectric capacitor.

High Pass Active Filter



*Values are for 100 Hz cutoff. Use metalized polycarbonate capacitors for good temperature stability

High Input Impedance AC Amplifier



absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	400 mW
Input Voltage (Note 2)	±15V
Output Short Circuit Duration (Note 3)	Indefinite
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	-65°C to 150°C
Lead Temperature (soldering, 10 sec)	300°C

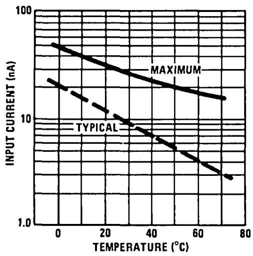
electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Offset Voltage			5	15	mV
Average Temperature Coefficient of Offset Voltage			20		μV/°C
Input Current			10	30	nA
Input Resistance		10^9	10^{12}		Ω
Voltage Gain	$R_L > 8$ KΩ	0.9985	0.9995	1.000	
Output Resistance			0.8	2.5	Ω
Output Voltage Swing	$R_L \geq 8$ KΩ	±10			V
Supply Current			3.5	5.5	mA
Positive Supply Rejection		60			dB
Negative Supply Rejection		70			dB
Input Capacitance			3.0		pF
Offset Voltage	$0°C \leq T_A \leq 70°C$			20	mV
Input Current	$T_A = 70°C$ $T_A = 0°C$		3.0 20	15 50	nA nA

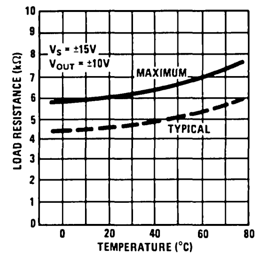
Note 1: For operating at elevated temperatures, the device must be derated based on a 85°C maximum junction temperature and a thermal resistance of 45°C/W junction to case or 150°C/W junction to ambient (see curve).
Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.
Note 3: Continuous short circuit is allowed for case temperatures to 70°C and ambient temperatures to 55°C. It is necessary to insert a resistor greater than 2 KΩ in series with the input when the amplifier is driven from low impedance sources to prevent damage when the output is shorted.
Note 4: These specifications apply for T_A = 25°C, V_S = ±15V and $C_L \leq$ 100 pF unless otherwise noted.

guaranteed performance characteristics

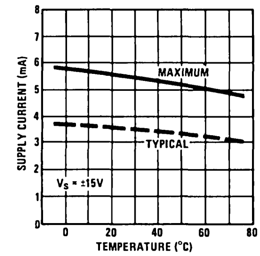
Input Current



Output Swing

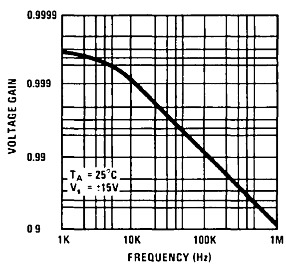


Supply Current

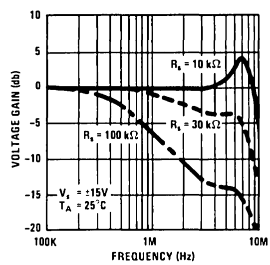


typical performance characteristics

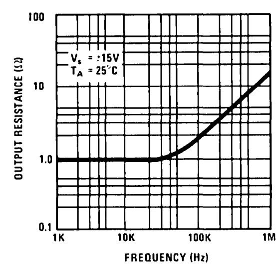
Voltage Gain



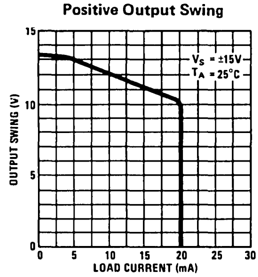
Voltage Gain



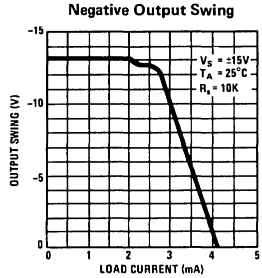
Output Resistance



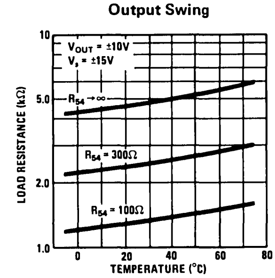
Positive Output Swing



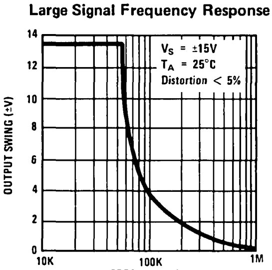
Negative Output Swing



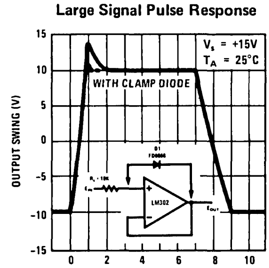
Output Swing



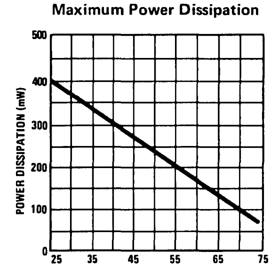
Large Signal Frequency Response



Large Signal Pulse Response



Maximum Power Dissipation



2

Operational Amplifiers

LM107/LM207 operational amplifier

general description

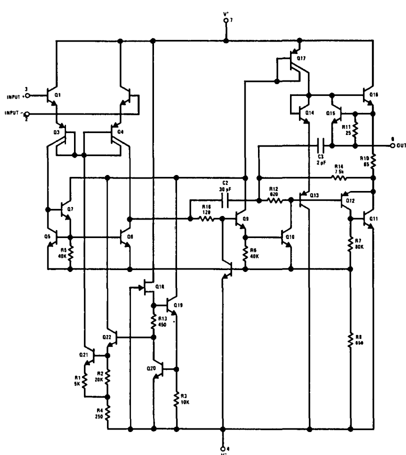
The LM107 and LM207 are complete, general purpose operational amplifiers, with the necessary frequency compensation built into the chip. Advanced processing techniques make the input currents a factor of ten lower than industry standards like the 709. Yet, they are a direct, plug-in replacement for the 709, LM101, LM101A and 741. Specifications which have been improved include:

- Offset voltage 3 mV maximum over temperature
- Input current 100 nA maximum over temperature
- Offset current 20 nA maximum over temperature
- Guaranteed drift characteristics
- Offsets guaranteed over entire common mode range

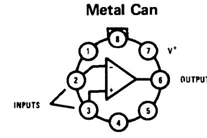
The LM107 series offers the features of the LM101, which makes its application nearly foolproof. In addition, the device provides better accuracy and lower noise in high impedance circuitry. The low input currents also make it particularly well suited for long interval integrators or timers, sample and hold circuits and low frequency waveform generators. Further, replacing circuits where matched transistor pairs buffer the inputs of conventional IC op amps, it can give lower offset voltage and drift at a lower cost.

The LM207 is identical to the LM107, except that the LM207 has its performance guaranteed over a –25°C to 85°C temperature range, instead of –55°C to 125°C.

schematic** and connection diagrams



Metal Can

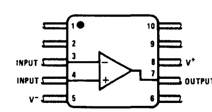


Note: Pin 4 connected to case.

TOP VIEW

Order Number
LM107H or LM207H
See Package 11

Flat Package

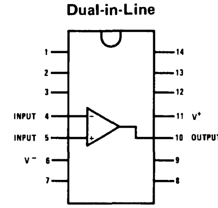


Note: Pin 5 connected to bottom of package.

TOP VIEW

Order Number
LM107F or LM207F
See Package 3

Dual-in-Line



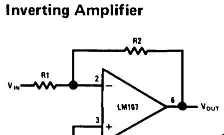
Note: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM107D or LM207D
See Package 1

typical applications **

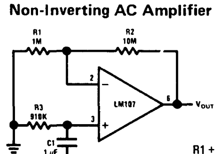
Inverting Amplifier



$V_{OUT} = -\frac{R2}{R1} V_{IN}$

$R_{IN} = R1$

Non-Inverting AC Amplifier

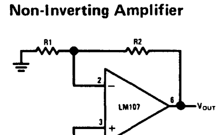


$V_{OUT} = \frac{R1 + R2}{R1} V_{IN}$

$R_{IN} = R3$

$R3 = R1/R2$

Non-Inverting Amplifier



$V_{OUT} = \frac{R1 + R2}{R1} V_{IN}$

**Pin connections shown are for metal can.

absolute maximum ratings

Supply Voltage		±22V
Power Dissipation (Note 1)		500 mW
Differential Input Voltage		±30V
Input Voltage (Note 2)		±15V
Output Short-Circuit Duration		Indefinite
Operating Temperature Range	LM107	-55°C to 125°C
	LM207	-25°C to 85°C
Storage Temperature Range		-65°C to 150°C
Lead Temperature (Soldering, 10 sec)		300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$, $R_S \leq 50\ k\Omega$		0.7	2.0	mV
Input Offset Current	$T_A = 25°C$		1.5	10	nA
Input Bias Current	$T_A = 25°C$		30	75	nA
Input Resistance	$T_A = 25°C$	1.5	4		MΩ
Supply Current	$T_A = 25°C$, $V_S = \pm 20V$		1.8	3.0	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm 15V$ $V_{OUT} = \pm 10V$, $R_L \geq 2\ k\Omega$	50	160		V/mV
Input Offset Voltage	$R_S \leq 50\ k\Omega$			3.0	mV
Average Temperature Coefficient of Input Offset Voltage			3.0	15	μV/°C
Input Offset Current				20	nA
Average Temperature Coefficient of Input Offset Current	$25°C \leq T_A \leq 125°C$		0.01	0.1	nA/°C
	$-55°C \leq T_A \leq 25°C$		0.02	0.2	nA/°C
Input Bias Current				100	nA
Supply Current	$T_A = +125°C$, $V_S = \pm 20V$		1.2	2.5	mA
Large Signal Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \geq 2\ k\Omega$	25			V/mV
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10\ k\Omega$	±12	±14		V
	$R_L = 2\ k\Omega$	±10	±13		V
Input Voltage Range	$V_S = \pm 20V$	±15			V
Common Mode Rejection Ratio	$R_S \leq 50\ k\Omega$	80	96		dB
Supply Voltage Rejection Ratio	$R_S \leq 50\ k\Omega$	80	96		dB

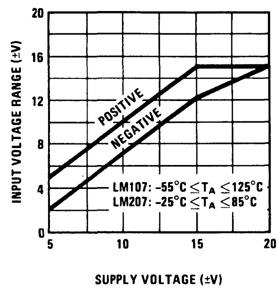
Note 1: The maximum junction temperature of the LM107 is 150°C, while that of the LM207 is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

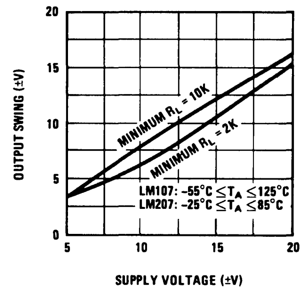
Note 3: These specifications apply for $\pm 5V \leq V_S \leq \pm 20V$ and $-55°C \leq T_A \leq 125°C$ for the LM107 or $-25°C \leq T_A$ 85°C for the LM207, unless otherwise specified.

guaranteed performance characteristics

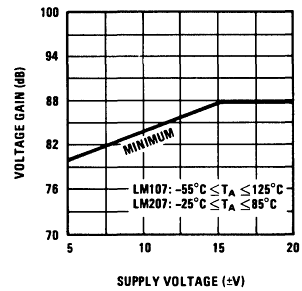
Input Voltage Range



Output Swing

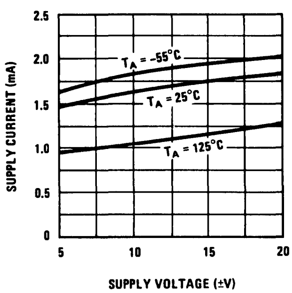


Voltage Gain

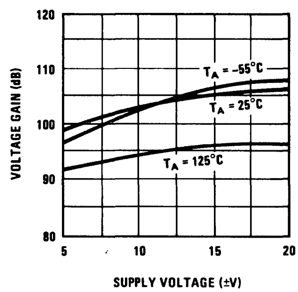


typical performance characteristics

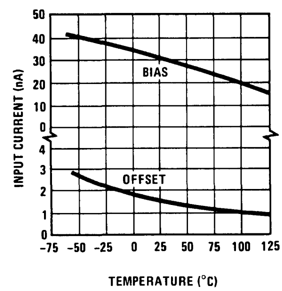
Supply Current



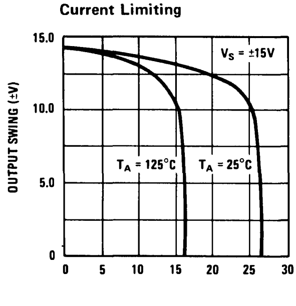
Voltage Gain



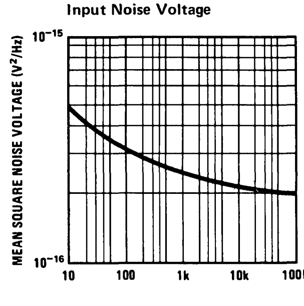
Input Current



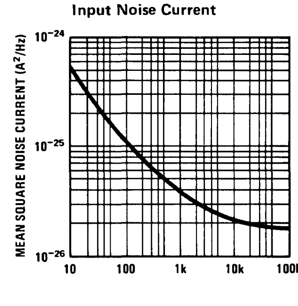
Current Limiting



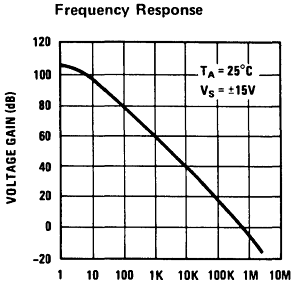
Input Noise Voltage



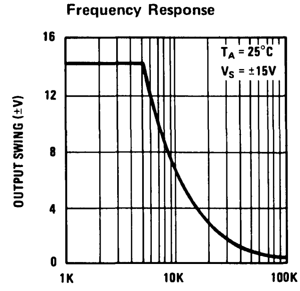
Input Noise Current



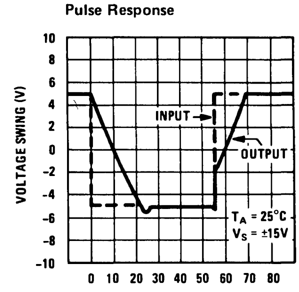
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



Operational Amplifiers

LM307 operational amplifier

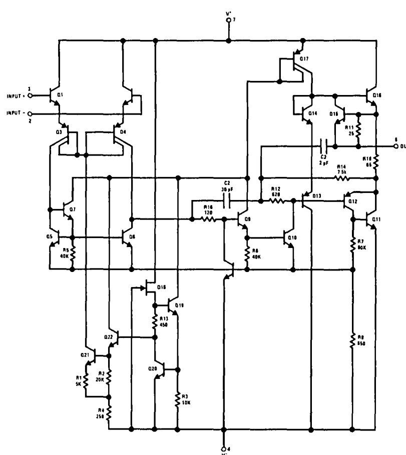
general description

The LM307 is a complete, general purpose operational amplifier, with the necessary frequency compensation built into the chip. Advanced processing techniques make the input currents a factor of ten lower than industry standards like the 709C. Yet, it is a direct, plug-in replacement for the 709C, LM201, MC1439 and 741 in most applications.

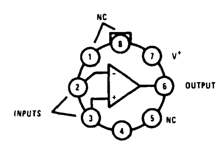
In addition to reduced input current, the offset voltage and offset current are guaranteed over the entire common mode range and maximum drift specifications are given. The amplifier also offers many features which make its application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

The LM307 provides better accuracy and lower noise than its predecessors in high impedance circuitry. The low input currents also make it particularly well suited for long interval integrators or timers, sample and hold circuits and low frequency waveform generators. Further, replacing circuits where matched transistor pairs buffer the inputs of conventional IC op amps, it can give lower offset voltage and drift at reduced cost.

schematic** and connection diagrams



Metal Can

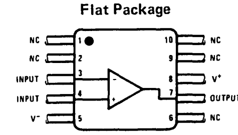


Note: Pin 4 connected to case.

TOP VIEW

Order Number LM307H
See Package 11

Flat Package

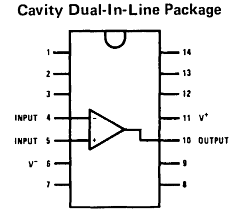


Note: Pin 5 connected to bottom of package.

TOP VIEW

Order Number LM307F
See Package 3

Cavity Dual-In-Line Package

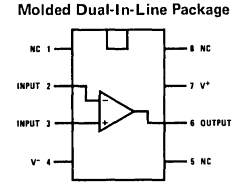


Note: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM307D
See Package 1

Molded Dual-In-Line Package



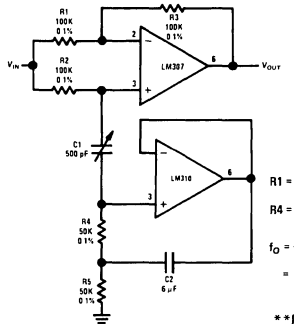
Note: Pin 4 connected to bottom of package.

TOP VIEW

Order Number LM307N
See Package 20

typical applications**

Tunable Notch Filter



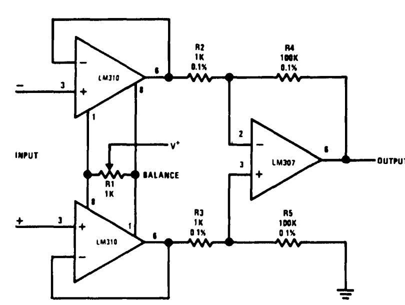
$R1 = R2 = R3$

$R4 = R5 = \frac{R1}{2}$

$f_o = \frac{1}{2\pi\sqrt{C1\ C2\ (R2)^2}}$

$= 60\ Hz$

Differential Input Instrumentation Amplifier



**Pin connections shown are for metal can.

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Differential Input Voltage	±30V
Input Voltage (Note 2)	±15V
Output Short-Circuit Duration (Note 3)	Indefinite
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$, $R_S \leq 50\ k\Omega$		2.0	7.5	mV
Input Offset Current	$T_A = 25°C$		3	50	nA
Input Bias Current	$T_A = 25°C$		70	250	nA
Input Resistance	$T_A = 25°C$	0.5	2		MΩ
Supply Current	$T_A = 25°C$, $V_S = \pm15V$		1.8	3.0	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm15V$ $V_{OUT} = \pm10V$, $R_L \geq 2\ k\Omega$	25	160		V/mV
Input Offset Voltage	$R_S \leq 50\ k\Omega$			10	mV
Average Temperature Coefficient of Input Offset Voltage			6.0	30	μV/°C
Input Offset Current				70	nA
Average Temperature Coefficient of Input Offset Current	$25°C \leq T_A \leq 70°C$ $0°C \leq T_A \leq 25°C$		0.01 0.02	0.3 0.6	nA/°C nA/°C
Input Bias Current				300	nA
Large Signal Voltage Gain	$V_S = \pm15V$, $V_{OUT} = \pm10V$ $R_L \geq 2\ k\Omega$	15			V/mV
Output Voltage Swing	$V_S = \pm15V$, $R_L = 10\ k\Omega$ $R_L = 2\ k\Omega$	±12 ±10	±14 ±13		V V
Input Voltage Range	$V_S = \pm15V$	±12			V
Common Mode Rejection Ratio	$R_S \leq 50\ k\Omega$	70	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 50\ k\Omega$	70	96		dB

Note 1: For operating at elevated temperatures, the device must be derated based on a 100°C maximum junction temperature and a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case.

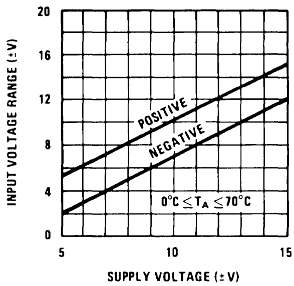
Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: Continuous short circuit is allowed for case temperatures to 70°C and ambient temperatures to 55°C.

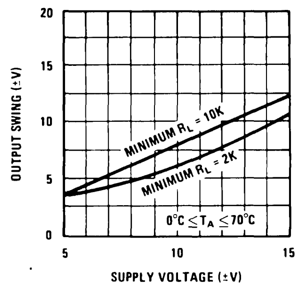
Note 4: The specifications apply for $0°C \leq T_A \leq 70°C$ and $\pm5V \leq V_S \leq \pm15V$, unless otherwise specified.

guaranteed performance characteristics

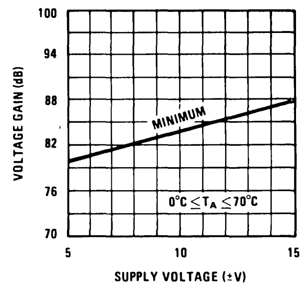
Input Voltage Range



Output Swing

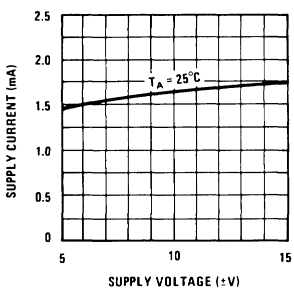


Voltage Gain

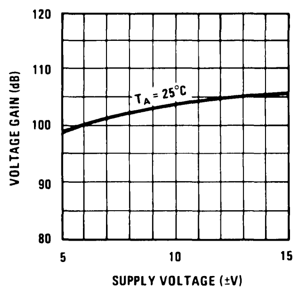


typical performance characteristics

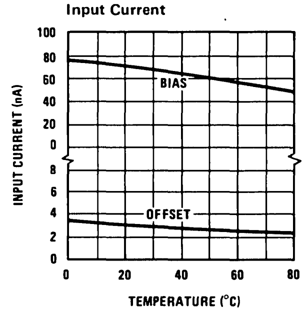
Supply Current



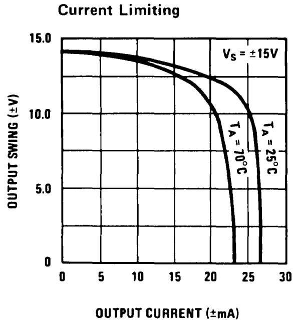
Voltage Gain



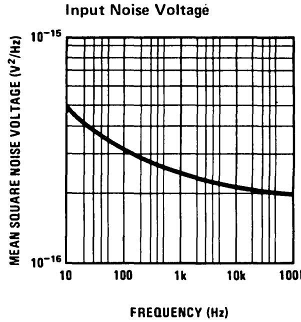
Input Current



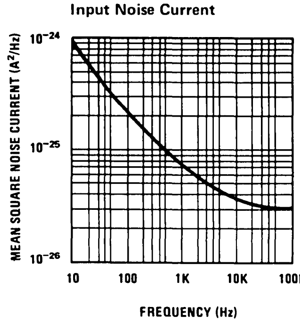
Current Limiting



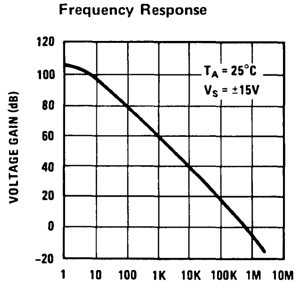
Input Noise Voltage



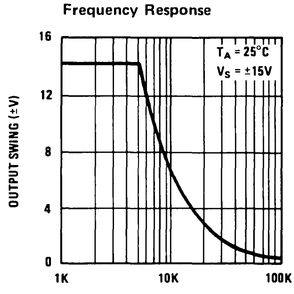
Input Noise Current



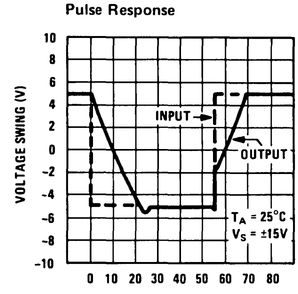
Open Loop
Frequency Response



Large Signal
Frequency Response



Voltage Follower
Pulse Response



2

Operational Amplifiers

LM108/LM208 operational amplifier

general description

The LM108 and LM208 are precision operational amplifiers having specifications a factor of ten better than FET amplifiers over a −55°C to 125°C temperature range. Selected units are available with offset voltages less than 1.0 mV and drifts less than 5 μV/°C, again over the military temperature range. This makes it possible to eliminate offset adjustments, in most cases, and obtain performance approaching chopper stabilized amplifiers.

The devices operate with supply voltages from ±2V to ±20V and have sufficient supply rejection to use unregulated supplies. Although the circuit is interchangeable with and uses the same compensation as the LM101A, an alternate compensation scheme can be used to make it particularly insensitive to power supply noise and to make supply bypass capacitors unnecessary. Outstanding characteristics include:

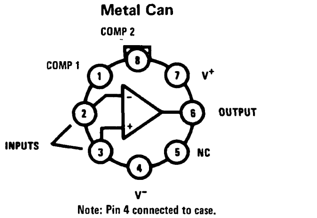
- Maximum input bias current of 3.0 nA over temperature
- Offset current less than 400 pA over temperature
- Supply current of only 300 μA, even in saturation
- Guaranteed drift characteristics

The low current error of the LM108 series makes possible many designs that are not practical with conventional amplifiers. In fact, it operates from 10 MΩ source resistances, introducing less error than devices like the 709 with 10 kΩ sources. Integrators with drifts less than 500 μV/sec and analog time delays in excess of one hour can be made using capacitors no larger than 1 μF.

The LM208 is identical to the LM108, except that the LM208 has its performance guaranteed over a −25°C to 85°C temperature range, instead of −55°C to 125°C.

connection diagrams *

Metal Can



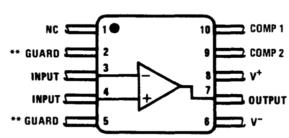
Note: Pin 4 connected to case.

*Pin connections shown on schematic diagram are for TO-5 package.

**Unused pin (no internal connection) to allow for input anti-leakage guard ring on printed circuit board layout.

Order Number LM108H or LM208H
See Package 11

Flat Package

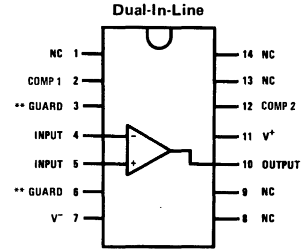


Note: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM108F or LM208F
See Package 3

Dual-In-Line

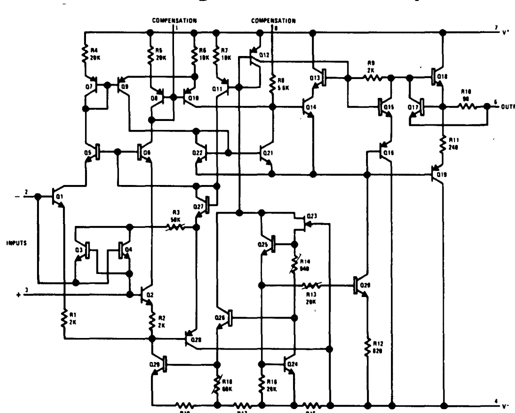


Note: Pin 7 connected to bottom of package.

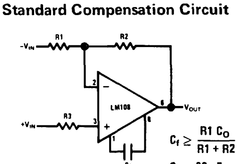
TOP VIEW

Order Number LM108D or LM208D
See Package 1

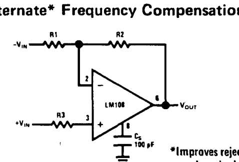
schematic diagram* and compensation circuits



Standard Compensation Circuit



Alternate* Frequency Compensation



*Improves rejection of power supply noise by a factor of ten.

absolute maximum ratings

Supply Voltage		±20V
Power Dissipation (Note 1)		500 mW
Differential Input Current (Note 2)		±10 mA
Input Voltage (Note 3)		±15V
Output Short-Circuit Duration		Indefinite
Operating Temperature Range	LM108	-55°C to 125°C
	LM208	-25°C to 85°C
Storage Temperature Range		-65°C to 150°C
Lead Temperature (Soldering, 10 sec)		300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage (Note 5)	$T_A = 25°C$		0.7	2.0	mV
Input Offset Current	$T_A = 25°C$		0.05	0.2	nA
Input Bias Current	$T_A = 25°C$		0.8	2.0	nA
Input Resistance	$T_A = 25°C$	30	70		MΩ
Supply Current	$T_A = 25°C$		0.3	0.6	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = ±15V$ $V_{OUT} = ±10V$, $R_L \geq 10$ kΩ	50	300		V/mV
Input Offset Voltage (Note 5)				3.0	mV
Average Temperature Coefficient of Input Offset Voltage (Note 5)			3.0	15	μV/°C
Input Offset Current				0.4	nA
Average Temperature Coefficient of Input Offset Current			0.5	2.5	pA/°C
Input Bias Current				3.0	nA
Supply Current	$T_A = +125°C$		0.15	0.4	mA
Large Signal Voltage Gain	$V_S = ±15V$, $V_{OUT} = ±10V$ $R_L \geq 10$ kΩ	25			V/mV
Output Voltage Swing	$V_S = ±15V$, $R_L = 10$ kΩ	±13	±14		V
Input Voltage Range	$V_S = ±15V$	±13.5			V
Common Mode Rejection Ratio		85	100		dB
Supply Voltage Rejection Ratio		80	96		dB

Note 1: The maximum junction temperature of the LM108 is 150°C, while that of the LM208 is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

Note 2: The inputs are shunted with back-to-back diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

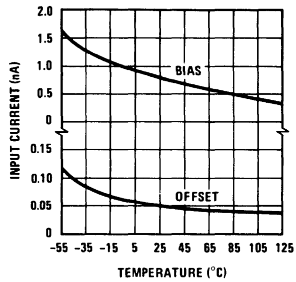
Note 4: These specifications apply for $±5V \leq V_S \leq ±20V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise specified. With the LM208, however, all temperature specifications are limited to $-25°C \leq T_A \leq 85°C$.

Note 5: The LM108A has a guaranteed offset voltage less than 0.5 mV at 25°C and 1.0 mV for $-55°C \leq T_A \leq 125°C$ and $V_S = ±15V$. The average temperature coefficient of input offset voltage is guaranteed to be less than 5 μV/°C for these same conditions.

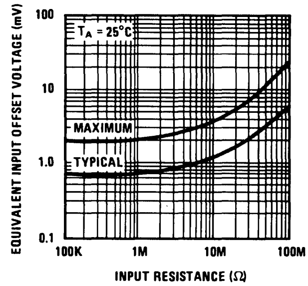
2

typical performance characteristics

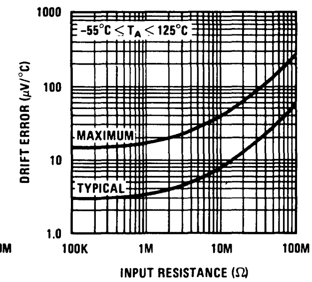
Input Currents



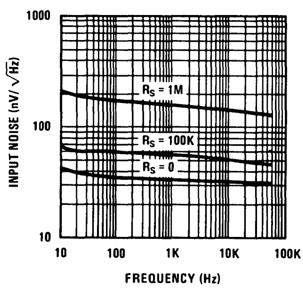
Offset Error



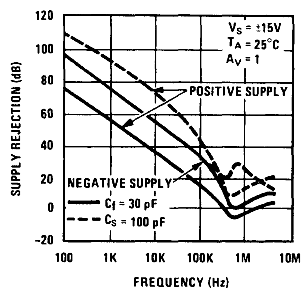
Drift Error



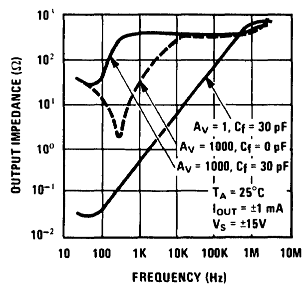
Input Noise Voltage



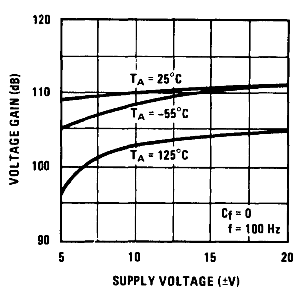
Power Supply Rejection



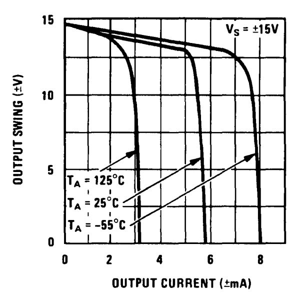
Closed Loop Output Impedance



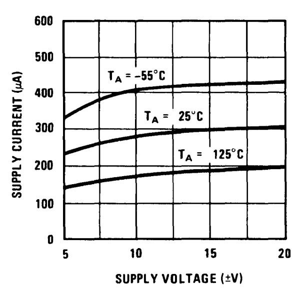
Voltage Gain



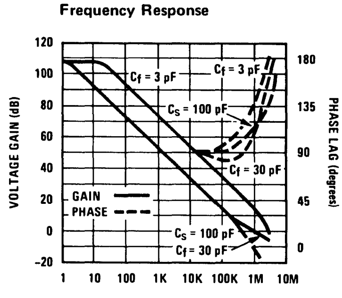
Output Swing



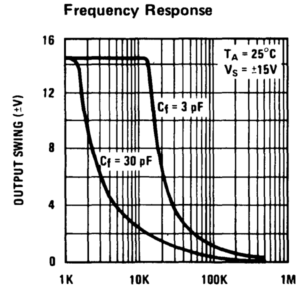
Supply Current



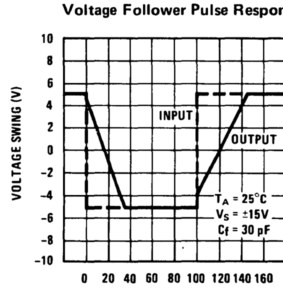
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



Operational Amplifiers

LM308 operational amplifier

general description

The LM308 is a precision operational amplifier featuring input currents nearly a thousand times lower than industry standards like the LM709C. In fact, its performance approaches that of high quality FET amplifiers. The circuit is directly interchangeable with the LM301A in low frequency circuits and incorporates the same protective features which make its application nearly foolproof.

The device operates with supply voltages from ±2V to ±15V and has sufficient supply rejection to use unregulated supplies. Although the circuit is designed to work with the standard compensation for the LM301A, an alternate compensation scheme can be used to make it particularly insensitive to power supply noise and to make supply bypass capacitors unnecessary. Power consumption is extremely low, so the amplifiers are ideally suited for battery powered applications. Outstanding characteristics include:

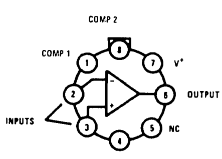
- Maximum input bias current of 7.0 nA
- Offset current less than 1.0 nA
- Supply current of only 300 μA, even in saturation
- Guaranteed drift characteristics

The low current error of the LM308 makes possible many designs that are not practical with conventional amplifiers. In fact, it operates from 10 MΩ source resistances, introducing less error than devices like the 709C with 10 kΩ sources. Integrators with worst case drifts less than 1 mV/sec and analog time delays in excess of one hour can be made using capacitors no larger than 1 μF. The device is well suited for use with piezoelectric, electrostatic or other capacitive transducers, in addition to low frequency active filters with small capacitor values.

2

connection diagrams *

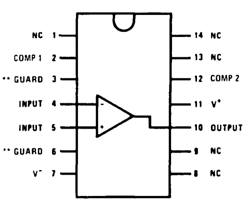
Metal Can Package



Note: Pin 4 connected to case.

Order Number LM308H
See Package 11

Dual-In-Line Package

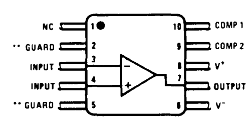


Note: Pin 7 connected to bottom of package.

TOP VIEW

Order Number LM308D
See Package 1

Flat Package

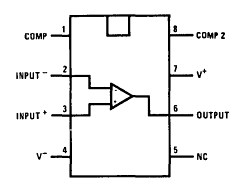


Note: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM308F
See Package 3

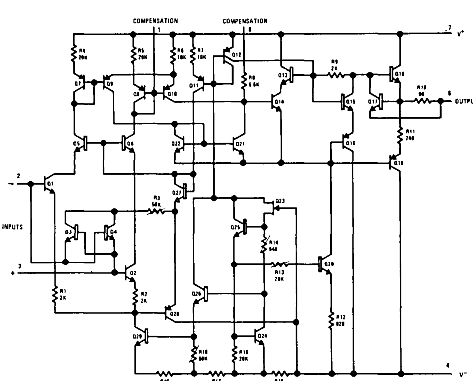
Dual-In-Line Package



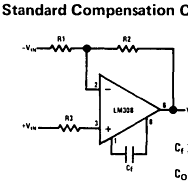
TOP VIEW

Order Number LM308N
See Package 20.

schematic diagram* and compensation circuits



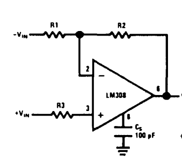
Standard Compensation Circuit



$C_f \geq \frac{R1\ C_O}{R1 + R2}$

$C_O = 30\ pF$

Alternate* Frequency Compensation



*Improves rejection of power supply noise by a factor of ten.

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Differential Input Current (Note 2)	±10 mA
Input Voltage (Note 3)	±15V
Output Short-Circuit Duration	Indefinite
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	-65°C to 150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	T_A = 25°C		2.0	7.5	mV
Input Offset Current	T_A = 25°C		0.2	1	nA
Input Bias Current	T_A = 25°C		1.5	7	nA
Input Resistance	T_A = 25°C	10	40		MΩ
Supply Current	T_A = 25°C, V_S = ±15V		0.3	0.8	mA
Large Signal Voltage Gain	T_A = 25°C, V_S = ±15V V_{OUT} = ±10V, $R_L \geq 10$ kΩ	25	300		V/mV
Input Offset Voltage				10	mV
Average Temperature Coefficient of Input Offset Voltage			6.0	30	μV/°C
Input Offset Current				1.5	nA
Average Temperature Coefficient of Input Offset Current			2.0	10	pA/°C
Input Bias Current				10	nA
Large Signal Voltage Gain	V_S = ±15V, V_{OUT} = ±10V $R_L \geq 10$ kΩ	15			V/mV
Output Voltage Swing	V_S = ±15V, R_L = 10 kΩ	±13	±14		V
Input Voltage Range	V_S = ±15V	±14			V
Common Mode Rejection Ratio		80	100		dB
Supply Voltage Rejection Ratio		80	96		dB

Note 1: The maximum junction temperature of the LM308 is 85°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

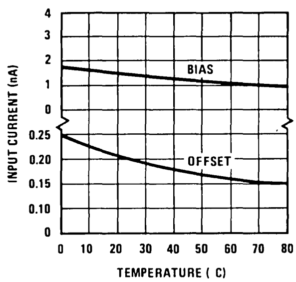
Note 2: The inputs are shunted with back-to-back diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

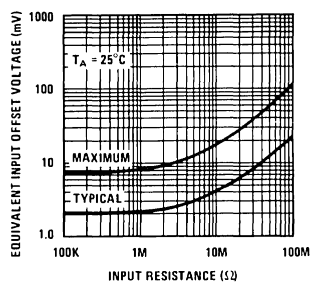
Note 4: These specifications apply for ±5V $\leq V_S \leq$ ±15V and 0°C $\leq T_A \leq$ 70°C, unless otherwise specified.

typical performance characteristics

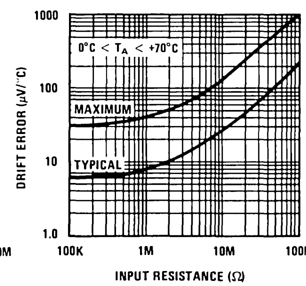
Input Currents



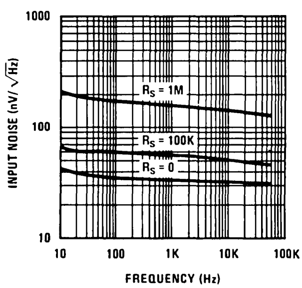
Offset Error



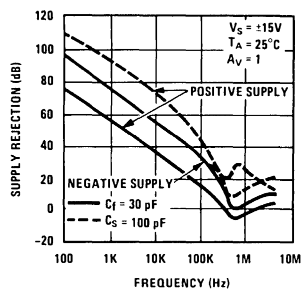
Drift Error



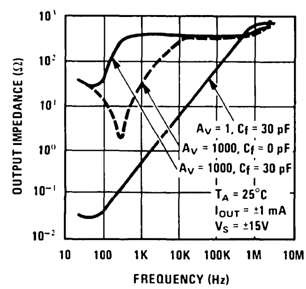
Input Noise Voltage



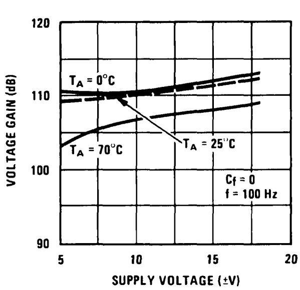
Power Supply Rejection



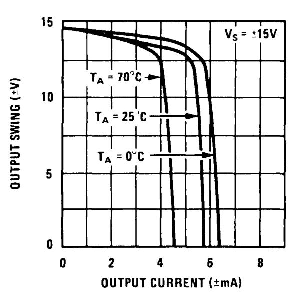
Closed Loop Output Impedance



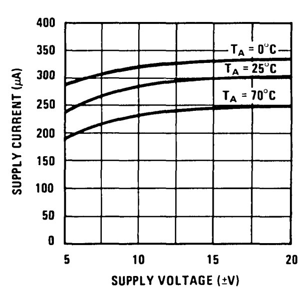
Voltage Gain



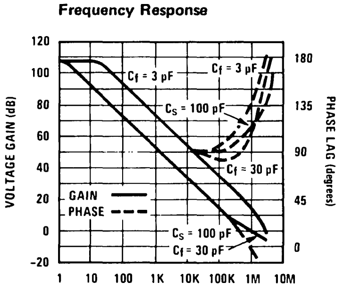
Output Swing



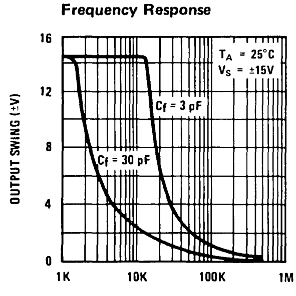
Supply Current



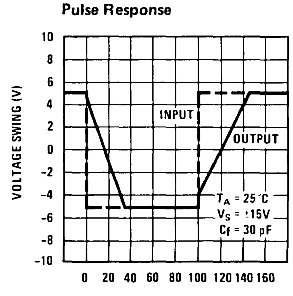
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



2

Operational Amplifiers

LM108A/LM208A/LM308A operational amplifier

general description

The LM108A, LM208A and LM308A are precision operational amplifiers having specifications about a factor of ten better than FET amplifiers over their operating temperature range. In addition to low input currents, these devices have extremely low offset voltage, making it possible to eliminate offset adjustments, in most cases, and obtain performance approaching chopper stabilized amplifiers.

The devices operate with supply voltages from ±2V to ±20V and have sufficient supply rejection to use unregulated supplies. Although the circuit is interchangeable with and uses the same compensation as the LM101A, an alternate compensation scheme can be used to make it particularly insensitive to power supply noise and to make supply bypass capacitors unnecessary. Outstanding characteristics include:

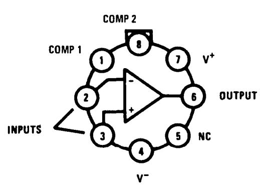
- Offset voltage guaranteed less than 0.5 mV
- Maximum input bias current of 3.0 nA over temperature
- Offset current less than 400 pA over temperature
- Supply current of only 300 μA, even in saturation
- Guaranteed 5 μV/°C drift.

The low current error of the LM108A series makes possible many designs that are not practical with conventional amplifiers. In fact, it operates from 10 MΩ source resistances, introducing less error than devices like the 709 with 10 kΩ sources. Integrators with drifts less than 500 μV/sec and analog time delays in excess of one hour can be made using capacitors no larger than 1 μF.

The LM208A is identical to the LM108A, except that the LM208A has its performance guaranteed over a −25°C to 85°C temperature range, instead of −55°C to 125°C. The LM308A has slightly-relaxed specifications and has its performance guaranteed over a 0°C to 70°C temperature range.

connection diagrams *

Metal Can



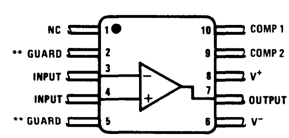
Note: Pin 4 connected to case.

*Pin connections shown on schematic diagram are for TO-5 package.

**Unused pin (no internal connection) to allow for input anti-leakage guard ring on printed circuit board layout.

Order Number LM108AH or LM208AH or LM308AH
See Package 11

Flat Package

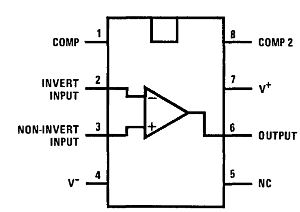


Note: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM108AF or LM208AF or LM308AF
See Package 3

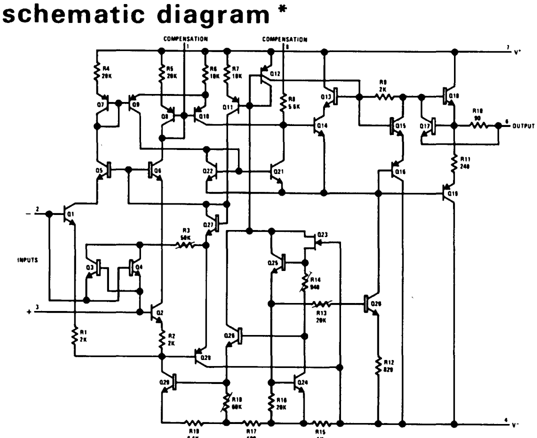
Dual-In-Line



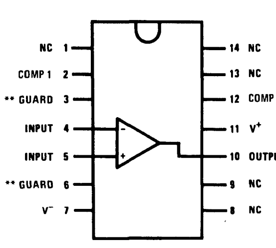
TOP VIEW

Order Number LM308AN
See Package 20

schematic diagram *



Dual-In-Line



Note: Pin 7 connected to bottom of package.

TOP VIEW

Order Number LM108AD or LM208AD or LM308AD
See Package 1

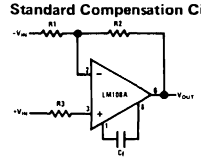
LM108A/LM208A

absolute maximum ratings

Supply Voltage		±20V
Power Dissipation (Note 1)		500 mW
Differential Input Current (Note 2)		±10 mA
Input Voltage (Note 3)		±15V
Output Short-Circuit Duration		Indefinite
Operating Temperature Range	LM108A	-55°C to 125°C
	LM208A	-25°C to 85°C
Storage Temperature Range		-65°C to 150°C
Lead Temperature (Soldering, 10 sec)		300°C

compensation circuits

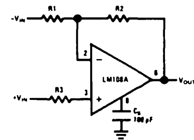
Standard Compensation Circuit



$C_f \geq \frac{R1\,C_O}{R1 + R2}$

C_O = 30 pF

Alternate* Frequency Compensation



*Improves rejection of power supply noise by a factor of ten.

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$		0.3	0.5	mV
Input Offset Current	$T_A = 25°C$		0.05	0.2	nA
Input Bias Current	$T_A = 25°C$		0.8	2.0	nA
Input Resistance	$T_A = 25°C$	30	70		MΩ
Supply Current	$T_A = 25°C$		0.3	0.6	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm15V$ $V_{OUT} = \pm10V$, $R_L \geq 10\ k\Omega$	80	300		V/mV
Input Offset Voltage				1.0	mV
Average Temperature Coefficient of Input Offset Voltage			1.0	5.0	μV/°C
Input Offset Current				0.4	nA
Average Temperature Coefficient of Input Offset Current			0.5	2.5	pA/°C
Input Bias Current				3.0	nA
Supply Current	$T_A = +125°C$		0.15	0.4	mA
Large Signal Voltage Gain	$V_S = \pm15V$, $V_{OUT} = \pm10V$ $R_L \geq 10\ k\Omega$	40			V/mV
Output Voltage Swing	$V_S = \pm15V$, $R_L = 10\ k\Omega$	±13	±14		V
Input Voltage Range	$V_S = \pm15V$	±13.5			V
Common Mode Rejection Ratio		96	110		dB
Supply Voltage Rejection Ratio		96	110		dB

Note 1: The maximum junction temperature of the LM108A is 150°C, while that of the LM208A is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

Note 2: The inputs are shunted with back-to-back diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 4: These specifications apply for $\pm5V \leq V_S \leq \pm20V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise specified. With the LM208A, however, all temperature specifications are limited to $-25°C \leq T_A \leq 85°C$.

LM308A

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Differential Input Current (Note 2)	±10 mA
Input Voltage (Note 3)	±15V
Output Short-Circuit Duration	Indefinite
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	-65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$		0.3	0.5	mV
Input Offset Current	$T_A = 25°C$		0.2	1	nA
Input Bias Current	$T_A = 25°C$		1.5	7	nA
Input Resistance	$T_A = 25°C$	10	40		MΩ
Supply Current	$T_A = 25°C$, $V_S = \pm15V$		0.3	0.8	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm15V$ $V_{OUT} = \pm10V$, $R_L \geq 10\,k\Omega$	80	300		V/mV
Input Offset Voltage				0.73	mV
Average Temperature Coefficient of Input Offset Voltage			1.0	5.0	μV/°C
Input Offset Current				1.5	nA
Average Temperature Coefficient of Input Offset Current			2.0	10	pA/°C
Input Bias Current				10	nA
Large Signal Voltage Gain	$V_S = \pm15V$, $V_{OUT} = \pm10V$ $R_L \geq 10\,k\Omega$	60			V/mV
Output Voltage Swing	$V_S = \pm15V$, $R_L = 10\,k\Omega$	±13	±14		V
Input Voltage Range	$V_S = \pm15V$	±14			V
Common Mode Rejection Ratio		96	110		dB
Supply Voltage Rejection Ratio		96	110		dB

Note 1: The maximum junction temperature of the LM308A is 85°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

Note 2: The inputs are shunted with back-to-back diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 4: These specifications apply for $\pm5V \leq V_S \leq \pm15V$ and $0°C \leq T_A \leq 70°C$, unless otherwise specified.

Operational Amplifiers

LM110/LM210 voltage follower

general description

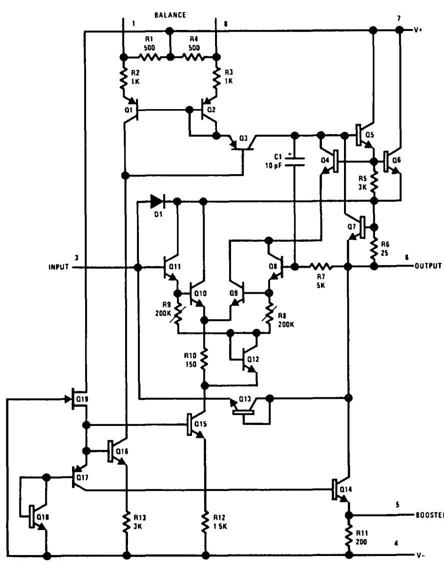
The LM110 and LM210 are monolithic operational amplifiers internally connected as unity-gain non-inverting amplifiers. They use super-gain transistors in the input stage to get low bias current without sacrificing speed. Directly interchangeable with 101, 741 and 709 in voltage follower applications, these devices have internal frequency compensation and provision for offset balancing. Outstanding characteristics include:

- Input current: 10 nA max. over temperature
- Small signal bandwidth: 20 MHz
- Slew rate: 30V/μs
- Supply voltage range: ±5V to ±18V

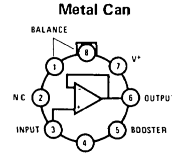
The LM110 and LM210 are useful in fast sample and hold circuits, active filters or as general-purpose buffers. Further, the frequency response is enough better than standard IC amplifiers that the followers can be included in the feedback loop without introducing instability. They are plug-in replacements for the LM102 or LM202 voltage followers, offering lower offset voltage, drift, bias current and noise in addition to higher speed and wider operating voltage range.

The LM210 is identical to the LM110, except that its performance is specified over a −25°C to 85°C temperature range instead of −55°C to 125°C.

schematic** and connection diagrams



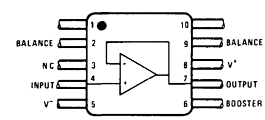
Metal Can



Note: Pin 4 connected to case.
TOP VIEW

Order Number LM110H or LM210H
See Package 11

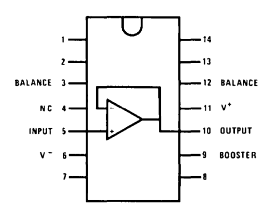
Flat Package



Note: Pin 5 connected to bottom of package.
TOP VIEW

Order Number LM110F or LM210F
See Package 3

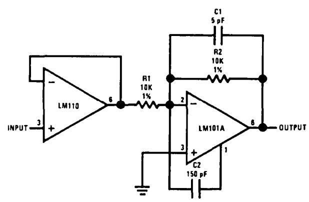
Dual-In-Line



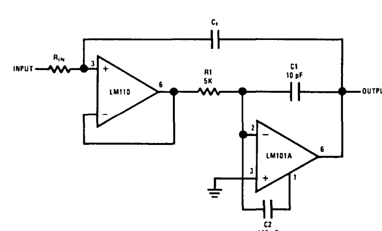
Note: Pin 6 connected to bottom of package.
TOP VIEW

Order Number LM110D or LM210D
See Package 1

typical applications**



Fast Inverting Amplifier with High Input Impedance



Fast Integrator with Low Input Current

**Pin connections shown are for metal can.

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Input Voltage (Note 2)	±15V
Output Short Circuit Duration (Note 3)	Indefinite
Operating Temperature Range LM110	-55°C to 125°C
LM210	-25°C to 85°C
Storage Temperature Range	-65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	T_A = 25°C		1.5	4.0	mV
Input Bias Current	T_A = 25°C		1.0	3.0	nA
Input Resistance	T_A = 25°C	10^{10}	10^{12}		Ω
Input Capacitance			1.5		pF
Large Signal Voltage Gain	T_A = 25°C, V_S = ±15V V_{OUT} = ±10V, R_L = 8KΩ	0.999	0.9997		V/V
Output Resistance	T_A = 25°C		0.75	2.5	Ω
Supply Current	T_A = 25°C		3.9	5.5	mA
Input Offset Voltage				6.0	mV
Offset Voltage Temperature Drift	-55°C ≤ T_A ≤ 85°C T_A = 125°C		6 12		μV/°C μV/°C
Input Bias Current				10	nA
Large Signal Voltage Gain	V_S = ±15V, V_{OUT} = ±10V R_L = 10KΩ	0.999			V/V
Output Voltage Swing (Note 5)	V_S = ±15V, R_L = 10KΩ	±10			V
Supply Current	T_A = 125°C		2.0	4.0	mA
Supply Voltage Rejection Ratio	±5V ≤ V_S ≤ ±18V	70	80		dB

Note 1: The maximum junction temperature of the LM110 is 150°C, while that of the LM210 is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

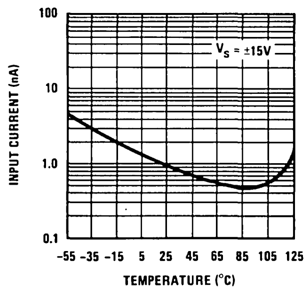
Note 3: Continuous short circuit is allowed for case temperatures to 125°C and ambient temperatures to 70°C. It is necessary to insert a resistor greater than 2kΩ in series with the input when the amplifier is driven from low impedance sources to prevent damage when the output is shorted.

Note 4: These specifications apply for ±5V ≤ V_S ≤ ±18V and -55°C ≤ T_A ≤ 125°C, unless otherwise specified. With the LM210, however, all temperature specifications are limited to -25°C ≤ T_A ≤ 85°C.

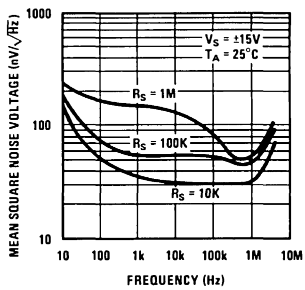
Note 5: Increased output swing under load can be obtained by connecting an external resistor between the booster and V^- terminals. See curve.

typical performance characteristics

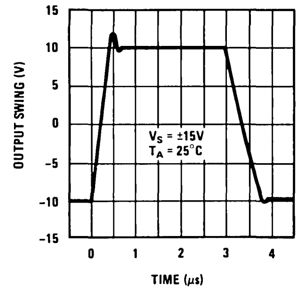
Input Current



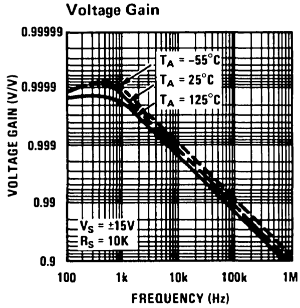
Output Noise Voltage



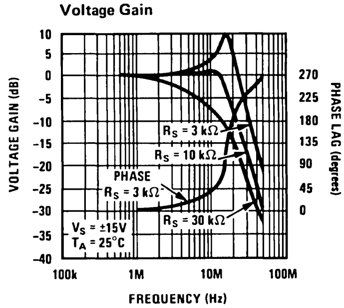
Large Signal Pulse Response



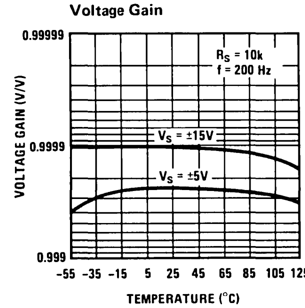
Voltage Gain



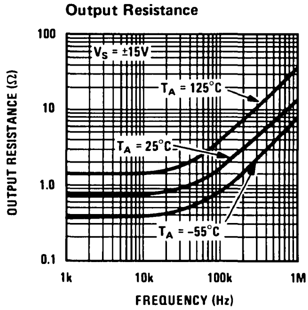
Voltage Gain



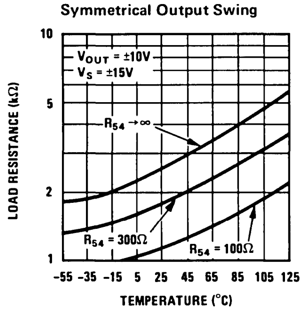
Voltage Gain



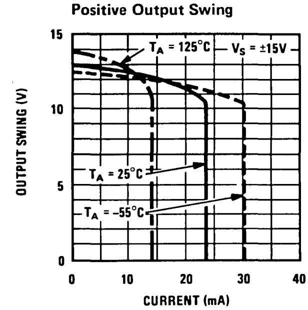
Output Resistance



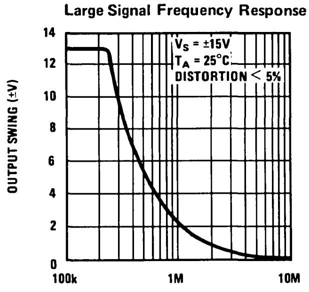
Symmetrical Output Swing



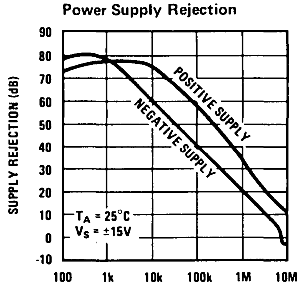
Positive Output Swing



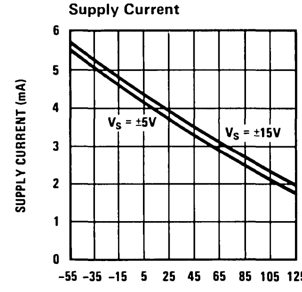
Large Signal Frequency Response



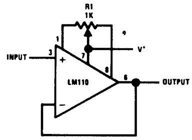
Power Supply Rejection



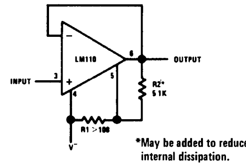
Supply Current



auxiliary circuits

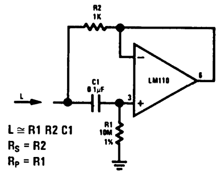


Offset Balancing Circuit

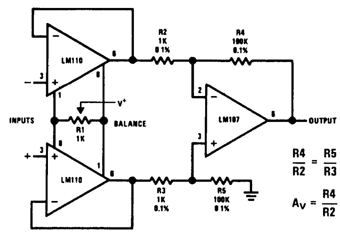


Increasing Negative Swing Under Load

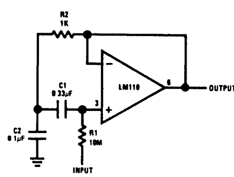
typical applications** (con't)



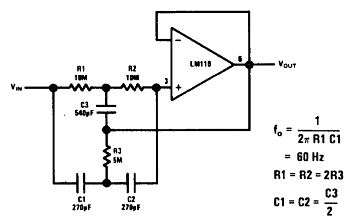
Simulated Inductor



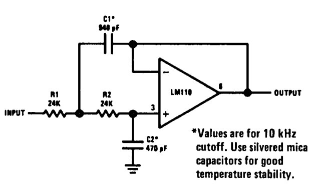
Differential Input Instrumentation Amplifier



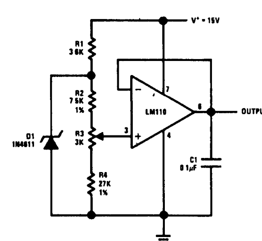
Bandpass Filter



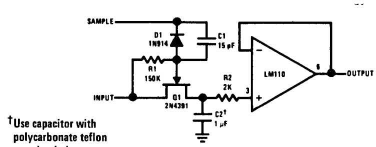
High Q Notch Filter



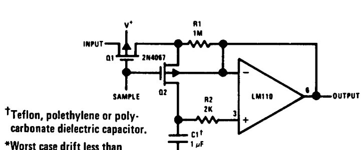
Low Pass Active Filter



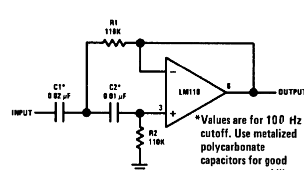
Buffered Reference Source



Sample and Hold



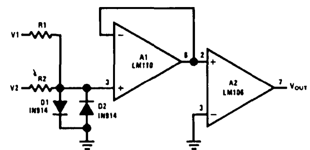
Low Drift Sample and Hold*



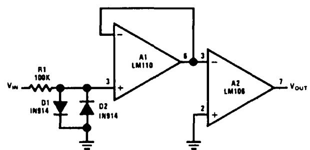
High Pass Active Filter

**Pin connections shown are for metal can.

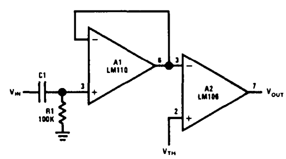
typical applications** (con't)



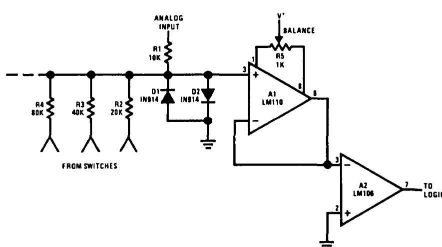
Comparator for Signals of Opposite Polarity



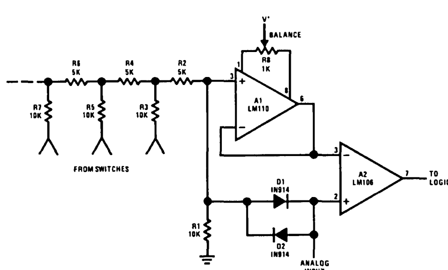
Zero Crossing Detector



Comparator for AC Coupled Signals

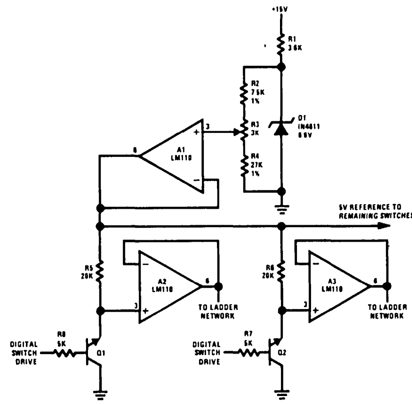


Comparator for A/D Converter
Using a Binary-Weighted Network

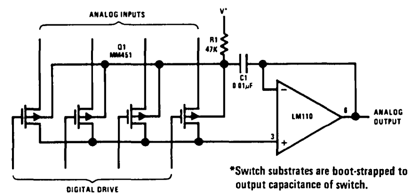


Comparator for A/D Converter
Using a Ladder Network

**Pin connections shown are for metal can.

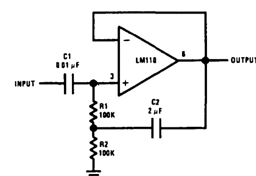


Driver for A/D Ladder Network

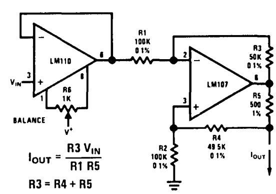


*Switch substrates are boot-strapped to reduce output capacitance of switch.

Buffer for Analog Switch*



High Input Impedance AC Amplifier

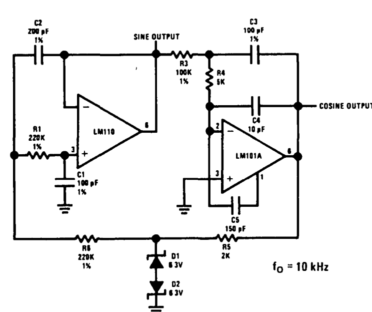


$$I_{OUT} = \frac{R3\ V_{IN}}{R1\ R5}$$

R3 = R4 + R5

R1 = R2

Bilateral Current Source



f_O = 10 kHz

Sine Wave Oscillator

2

Operational Amplifiers

LM310 voltage follower

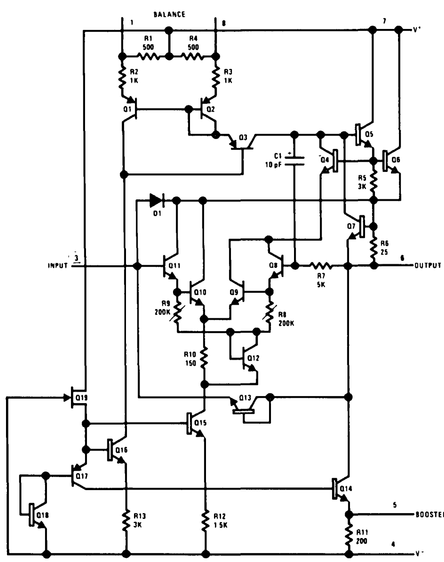
general description

The LM310 is a monolithic operational amplifier internally connected as a unity-gain non-inverting amplifier. It uses super-gain transistors in the input stage to get low bias current without sacrificing speed. Directly interchangeable with 301, 741C and 709C in voltage follower applications, this device has internal frequency compensation and provision for offset balancing. Outstanding characteristics include:

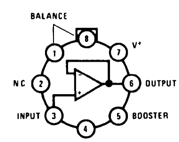
- Input current: 10 nA max. over temperature
- Small signal bandwidth: 20 MHz
- Slew rate: 30V/µs
- Supply voltage range: ±5V to ±18V

The LM310 is useful in fast sample and hold circuits, active filters or as a general-purpose buffer. Further, the frequency response is enough better than standard IC amplifiers that the follower can be included in the feedback loop without introducing instability. It is a plug-in replacement for the LM302 voltage follower, offering lower offset voltage, drift, bias current and noise in addition to higher speed and wider operating voltage range.

schematic** and connection diagrams



Metal Can

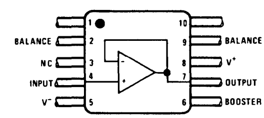


Note: Pin 4 connected to case.

TOP VIEW

Order Number LM310H
See Package 11

Flat Package

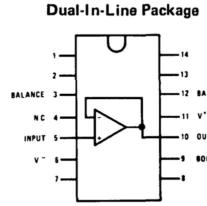


Note: Pin 5 connected to bottom of package.

TOP VIEW

Order Number LM310F
See Package 3

Dual-In-Line Package

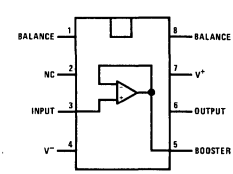


Note: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM310D
See Package 1

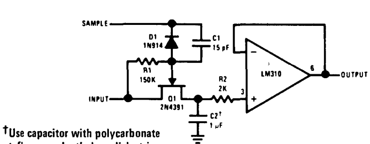
Dual-In-Line Package



TOP VIEW

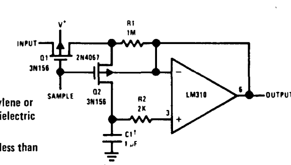
Order Number LM310N
See Package 20.

typical applications**



†Use capacitor with polycarbonate teflon or polyethylene dielectric.

Sample and Hold



†Teflon, polyethylene or polycarbonate dielectric capacitor.

*Worst case drift less than 3 mV/sec.

Low Drift Sample and Hold*

**Pin connections shown are for metal can.

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Input Voltage (Note 2)	±15V
Output Short Circuit Duration (Note 3)	Indefinite
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	-65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	T_A = 25°C		2.5	7.5	mV
Input Bias Current	T_A = 25°C		2.0	7.0	nA
Input Resistance	T_A = 25°C	10^{10}	10^{12}		Ω
Input Capacitance			1.5		pF
Large Signal Voltage Gain	T_A = 25°C, V_S = ±15V V_{OUT} = ±10V, R_L = 8KΩ	0.999	0.9999		V/V
Output Resistance	T_A = 25°C		0.75	2.5	Ω
Supply Current	T_A = 25°C		3.9	5.5	mA
Input Offset Voltage				10	mV
Offset Voltage Temperature Drift			10		μV/°C
Input Bias Current				10	nA
Large Signal Voltage Gain	V_S = ±15V, V_{OUT} = ±10V R_L = 10KΩ	0.999			V/V
Output Voltage Swing (Note 5)	V_S = ±15V, R_L = 10KΩ	±10			V
Supply Voltage Rejection Ratio	$\pm 5V \leq V_S \leq \pm 18V$	70	80		dB

Note 1: The maximum junction temperature of the LM310 is 85°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: Continuous short circuit is allowed for case temperatures to 70°C and ambient temperatures to 55°C. It is necessary to insert a resistor greater than 2 kΩ in series with the input when the amplifier is driven from low impedance sources to prevent damage when the output is shorted.

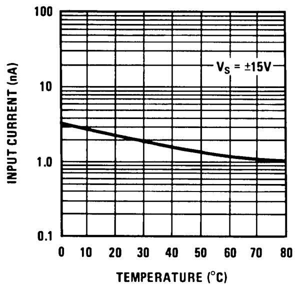
Note 4: These specifications apply for $\pm 5V \leq V_S \leq \pm 18V$ and $0°C \leq T_A \leq 70°C$, unless otherwise specified.

Note 5: Increased output swing under load can be obtained by connecting an external resistor between the booster and V^- terminals. See curve.

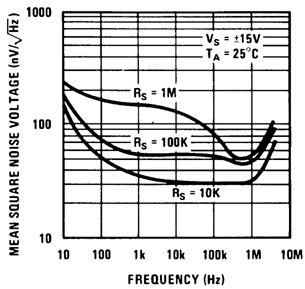
2

typical performance characteristics

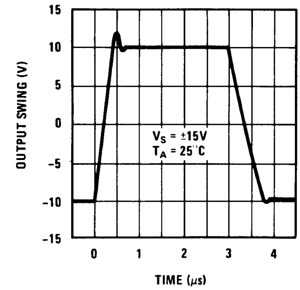
Input Current



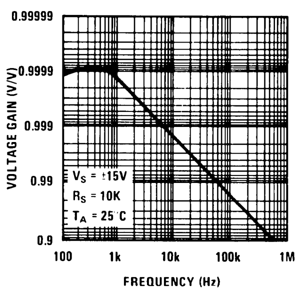
Output Noise Voltage



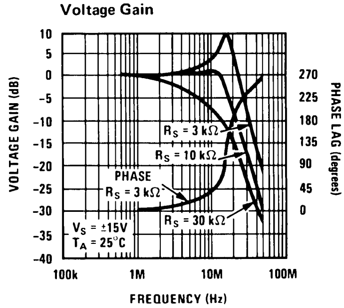
Large Signal Pulse Response



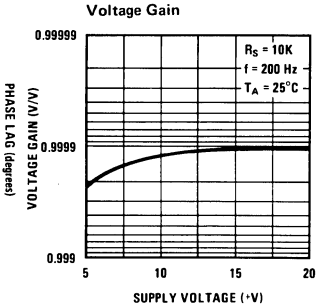
Voltage Gain



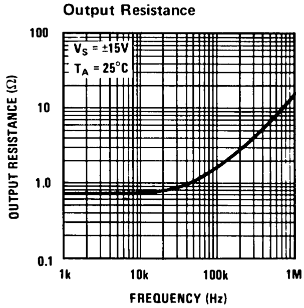
Voltage Gain



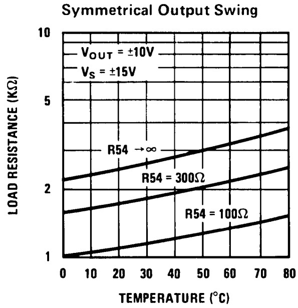
Voltage Gain



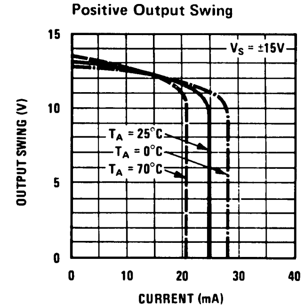
Output Resistance



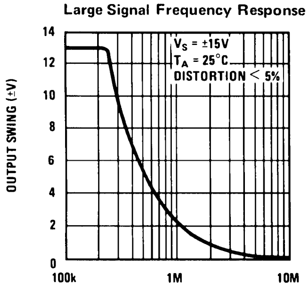
Symmetrical Output Swing



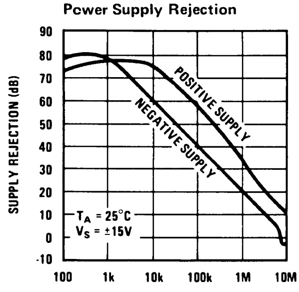
Positive Output Swing



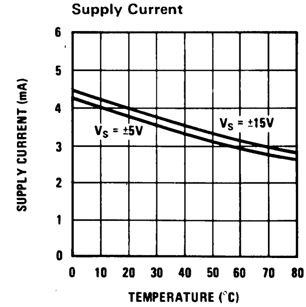
Large Signal Frequency Response



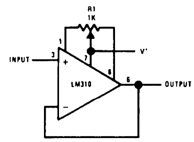
Power Supply Rejection



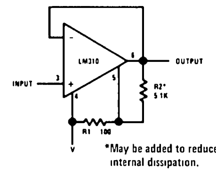
Supply Current



auxiliary circuits **

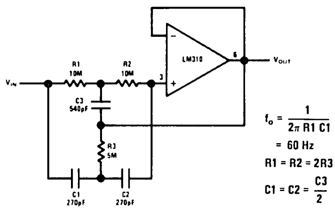


Offset Balancing Circuit



Increasing Negative Swing Under Load

typical applications** (con't)

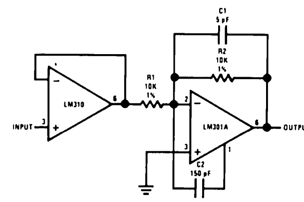


$$f_o = \frac{1}{2\pi R1\, C1} = 60\ \text{Hz}$$

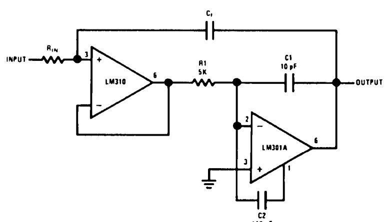
$$R1 = R2 = 2R3$$

$$C1 = C2 = \frac{C3}{2}$$

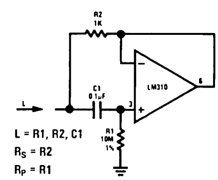
High Q Notch Filter



Fast Inverting Amplifier with High Input Impedance



Fast Integrator with Low Input Current

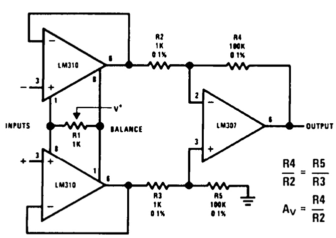


L = R1, R2, C1

R_S = R2

R_P = R1

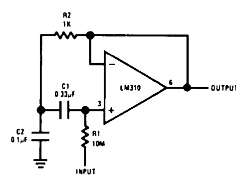
Simulated Inductor



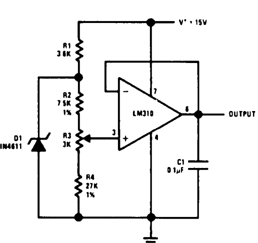
$$\frac{R4}{R2} = \frac{R5}{R3}$$

$$A_V = \frac{R4}{R2}$$

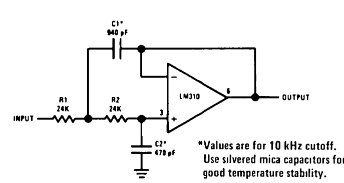
Differential Input Instrumentation Amplifier



Bandpass Filter

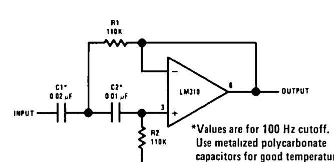


Buffered Reference Source



*Values are for 10 kHz cutoff. Use silvered mica capacitors for good temperature stability.

Low Pass Active Filter

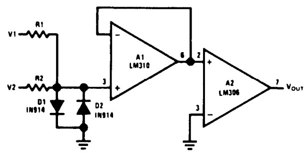


*Values are for 100 Hz cutoff. Use metalized polycarbonate capacitors for good temperature stability.

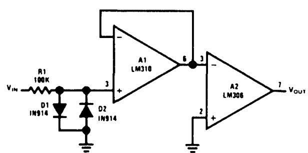
High Pass Active Filter

**Pin connections shown are for metal can.

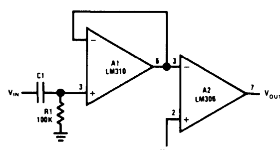
typical applications** (con't)



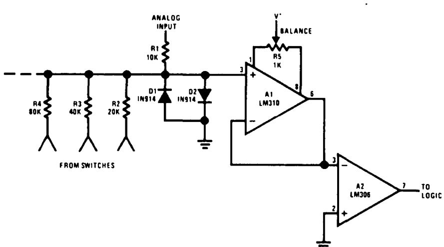
Comparator for Signals of Opposite Polarity



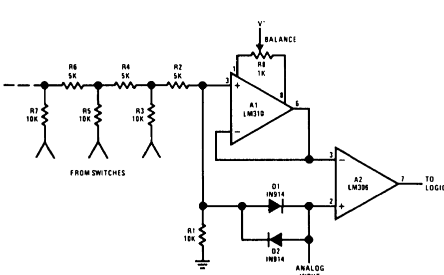
Zero Crossing Detector



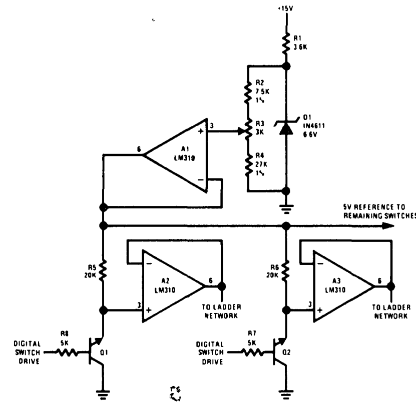
Comparator for AC Coupled Signals



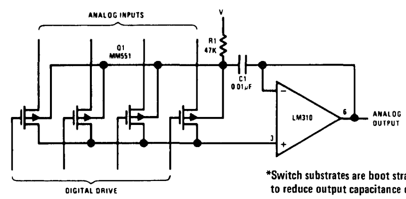
Comparator for A/D Converter
Using a Binary-Weighted Network



Comparator for A/D Converter
Using a Ladder Network

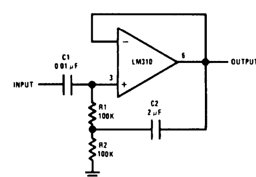


Driver for A/D Ladder Network

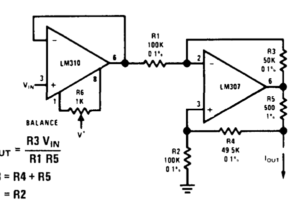


*Switch substrates are boot strapped
to reduce output capacitance of switch.

Buffer for Analog Switch*



High Input Impedance AC Amplifier

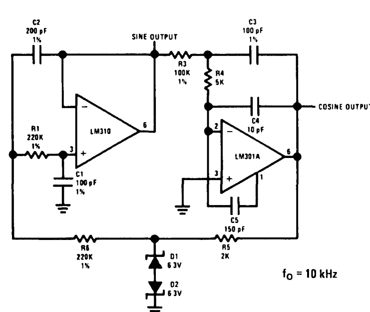


$$I_{OUT} = \frac{R3\ V_{IN}}{R1\ R5}$$

R3 = R4 + R5

R1 = R2

Bilateral Current Source



Sine Wave Oscillator

**Pin connections shown are for metal can.

Operational Amplifiers

LM112/LM212 operational amplifier general description

The LM112 and LM212 are micropower operational amplifiers with very low offset-voltage and input-current errors—at least a factor of ten better than FET amplifiers over a −55°C to 125°C temperature range. Similar to the LM108 series, that also use supergain transistors,* they differ in that they include internal frequency compensation and have provisions for offset adjustment with a single potentiometer.

These amplifiers will operate on supply voltages of ±2V to ±20V, drawing a quiescent current of only 300 μA. Performance is not appreciably affected over this range of voltages, so operation from unregulated power sources is easily accomplished. They can also be run from a single supply like the 5V used for digital circuits. Some noteworthy features are:

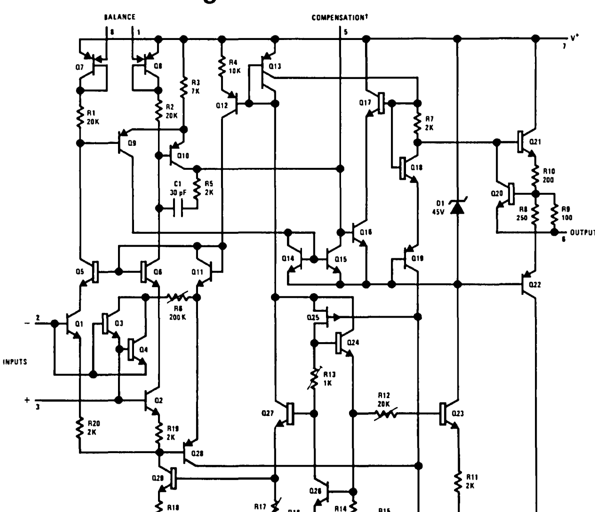
- Maximum input bias current of 3.0 nA over temperature
- Offset current less than 400 pA over temperature
- Low noise
- Guaranteed drift specifications

The LM112 series are the first IC amplifiers to improve reliability by including overvoltage protection for the MOS compensation capacitor. Without this feature, IC's have been known to suffer catastrophic failure caused by short-duration overvoltage spikes on the supplies. Unlike other internally-compensated IC amplifiers, it is possible to overcompensate with an external capacitor to increase stability margin.

The LM212 is identical to the LM112, except that the LM212 has its performance guaranteed over a −25°C to 85°C temperature range instead of −55°C to 125°C.

*Patent pending

schematic diagram**

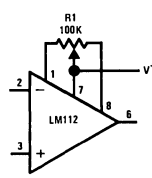


†Not brought out on flat package

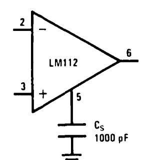
**Pin connections shown are for metal can.

auxiliary circuits**

Offset Balancing

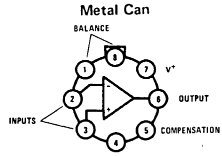


Overcompensation for Greater Stability Margin



connection diagrams

Metal Can

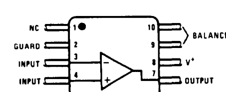


Note: Pin 4 connected to case.

TOP VIEW

Order Number LM112H or LM212H
See Package 11

Flat Package

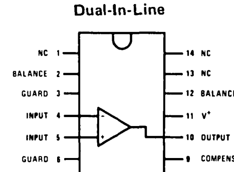


Note: Pin 6 connected to bottom of package. Compensation terminal not brought out on flat package.

TOP VIEW

Order Number LM112F or LM212F
See Package 3

Dual-In-Line



Note: Pin 7 connected to bottom of package.

TOP VIEW

Order Number LM112D or LM212D
See Package 1

absolute maximum ratings

Supply Voltage		±20V
Power Dissipation (Note 1)		500 mW
Differential Input Current (Note 2)		±10 mA
Input Voltage (Note 3)		±15V
Output Short-Circuit Duration		Indefinite
Operating Temperature Range	LM112	-55°C to 125°C
	LM212	-25°C to 85°C
Storage Temperature Range		-65°C to 150°C
Lead Temperature (Soldering, 10 sec)		300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$		0.7	2.0	mV
Input Offset Current	$T_A = 25°C$		0.05	0.2	nA
Input Bias Current	$T_A = 25°C$		0.8	2.0	nA
Input Resistance	$T_A = 25°C$	30	70		MΩ
Supply Current	$T_A = 25°C$		0.3	0.6	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm15V$ $V_{OUT} = \pm10V$, $R_L \geq 10\ k\Omega$	50	300		V/mV
Input Offset Voltage				3.0	mV
Average Temperature Coefficient of Input Offset Voltage			3.0	15	μV/°C
Input Offset Current				0.4	nA
Average Temperature Coefficient of Input Offset Current			0.5	2.5	pA/°C
Input Bias Current				3.0	nA
Supply Current	$T_A = +125°C$		0.15	0.4	mA
Large Signal Voltage Gain	$V_S = \pm15V$, $V_{OUT} = \pm10V$ $R_L \geq 10\ k\Omega$	25			V/mV
Output Voltage Swing	$V_S = \pm15V$, $R_L = 10\ k\Omega$	±13	±14		V
Input Voltage Range	$V_S = \pm15V$	±13.5			V
Common Mode Rejection Ratio		85	100		dB
Supply Voltage Rejection Ratio		80	96		dB

Note 1: The maximum junction temperature of the LM112 is 150°C, while that of the LM212 is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

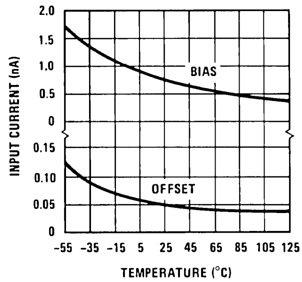
Note 2: The inputs are shunted with shunt diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

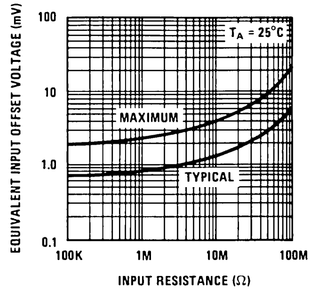
Note 4: These specifications apply for $\pm5V \leq V_S \leq \pm20V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise specified. With the LM212, however, all temperature specifications are limited to $-25°C \leq T_A \leq 85°C$.

typical performance characteristics

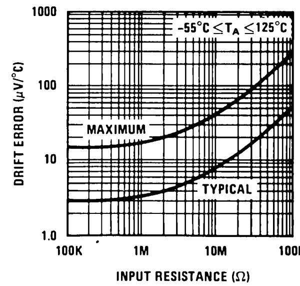
Input Currents



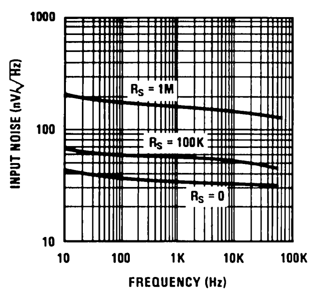
Offset Error



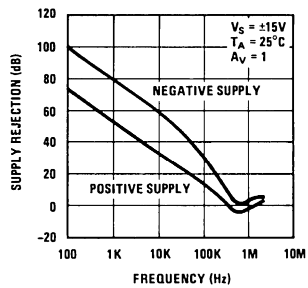
Drift Error



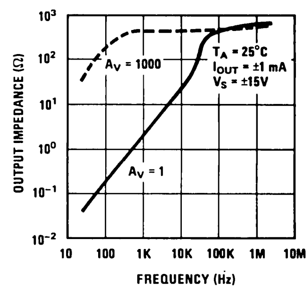
Input Noise Voltage



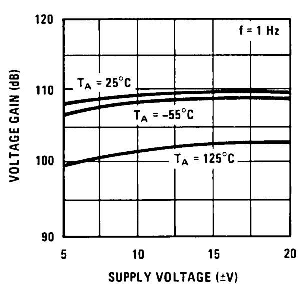
Power Supply Rejection



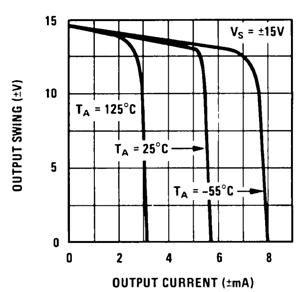
Closed Loop Output Impedance



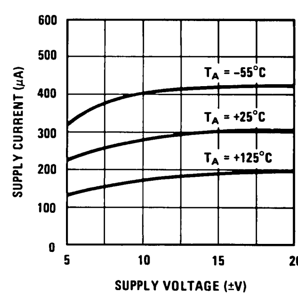
Voltage Gain



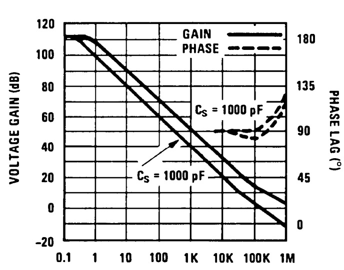
Output Swing



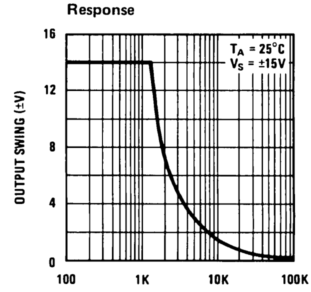
Supply Current



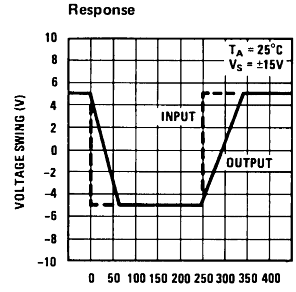
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



2

Operational Amplifiers

LM312 operational amplifier general description

The LM312 is a micropower operational amplifier with very low offset voltage and input-current errors—approaching that of FET amplifiers over its operating temperature range. Similar to the LM308 series, that also uses supergain transistors†, it differs in that it includes internal frequency compensation and has provisions for offset adjustment with a single potentiometer.

This amplifier will operate on supply voltages of ±2V to ±20V, drawing a quiescent current of only 300 μA. Performance is not appreciably affected over this range of voltages, so operation from unregulated power sources is easily accomplished. It can also be run from a single supply like the 5V used for digital circuits. Some noteworthy features are:

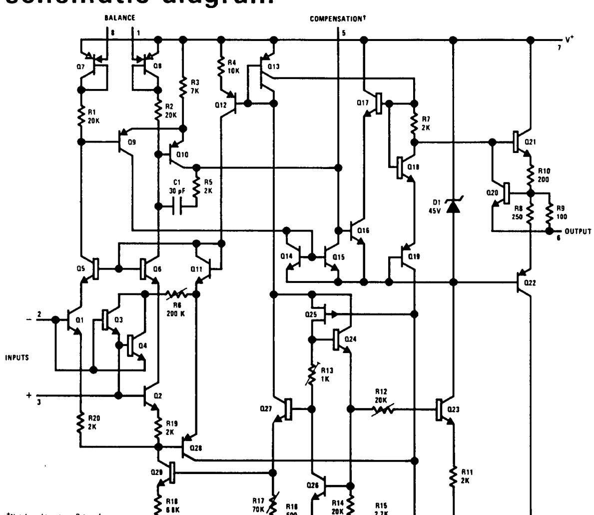
- Maximum input bias current of 7.0 nA
- Offset current less than 1.0 nA
- Low noise
- Guaranteed drift specifications

The LM312 series is the first IC amplifier to improve reliability by including overvoltage protection for the MOS compensation capacitor. Without this feature, IC's have been known to be sensitive to catastrophic failure caused by short-duration overvoltage spikes on the supplies. Unlike other internally-compensated IC amplifiers, it is possible to overcompensate with an external capacitor to increase stability margin.

The low current error of the LM312 makes possible many designs that are not practical with conventional amplifiers. In fact, it operates from 10 MΩ source resistances, introducing less error than devices like the 709C with 10 kΩ sources. Integrators with worst case drifts less than 1 mV/sec and analog time delays in excess of one hour can be made using capacitors no larger than 1 μF. The device is well suited for use with piezo-electric, electrostatic or other capacitive tranducers, in addition to low frequency active filters with small capacitor values.

†Patent pending

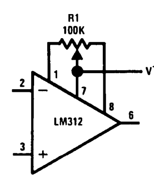
schematic diagram**



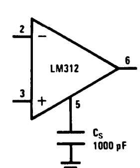
**Pin connections shown are for metal can.

auxiliary circuits**

Offset Balancing

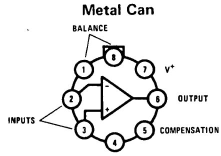


Overcompensation for Greater Stability Margin



connection diagrams

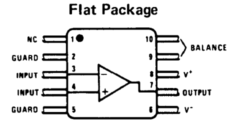
Metal Can



Note: Pin 4 connected to case.
TOP VIEW

Order Number LM312H
See Package 11

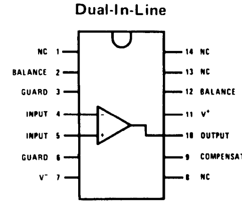
Flat Package



Note: Pin 6 connected to bottom of package.
Compensation terminal not brought out on flat package.
TOP VIEW

Order Number LM312F
See Package 3

Dual-In-Line



Note: Pin 7 connected to bottom of package.
TOP VIEW

Order Number LM312D
See Package 1

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Differential Input Current (Note 2)	±10 mA
Input Voltage (Note 3)	±15V
Output Short-Circuit Duration	Indefinite
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$		2.0	7.5	mV
Input Offset Current	$T_A = 25°C$		0.2	1	nA
Input Bias Current	$T_A = 25°C$		1.5	7	nA
Input Resistance	$T_A = 25°C$	10	40		MΩ
Supply Current	$T_A = 25°C$, $V_S = ±15V$		0.3	0.8	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = ±15V$ $V_{OUT} = ±10V$, $R_L \geq 10\ k\Omega$	25	300		V/mV
Input Offset Voltage				10	mV
Average Temperature Coefficient of Input Offset Voltage			6.0	30	μV/°C
Input Offset Current				1.5	nA
Average Temperature Coefficient of Input Offset Current			2.0	10	pA/°C
Input Bias Current				10	nA
Large Signal Voltage Gain	$V_S = ±15V$, $V_{OUT} = ±10V$ $R_L \geq 10\ k\Omega$	15			V/mV
Output Voltage Swing	$V_S = ±15V$, $R_L = 10\ k\Omega$	±13	±14		V
Input Voltage Range	$V_S = ±15V$	±14			V
Common Mode Rejection Ratio		80	100		dB
Supply Voltage Rejection Ratio		80	96		dB

Note 1: The maximum junction temperature of the LM312 is 85°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

Note 2: The inputs are shunted with shunt diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

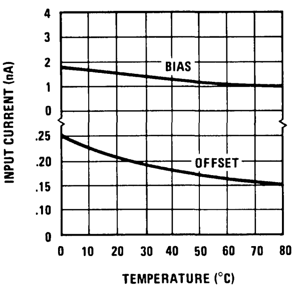
Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 4: These specifications apply for $±5V \leq V_S \leq ±15V$ and $0°C \leq T_A \leq 70°C$, unless otherwise specified.

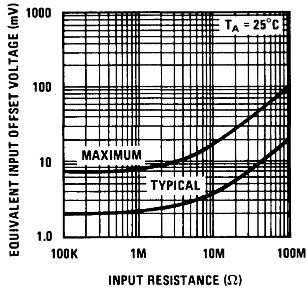
2

typical performance characteristics

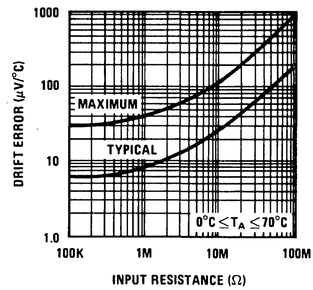
Input Currents



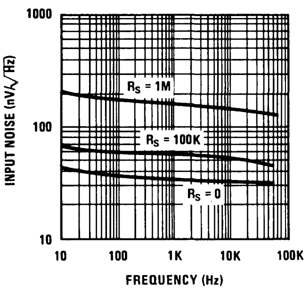
Offset Error



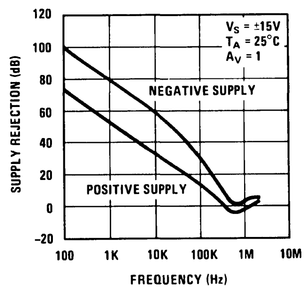
Drift Error



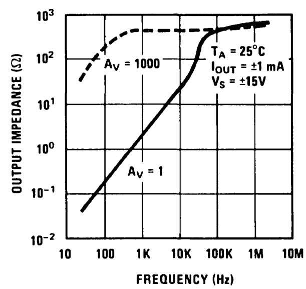
Input Noise Voltage



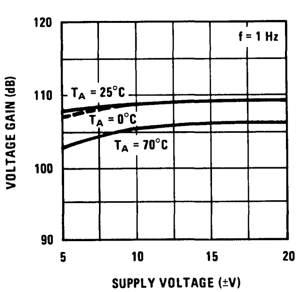
Power Supply Rejection



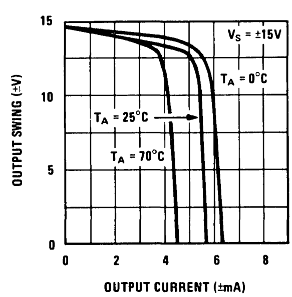
Closed Loop Output Impedance



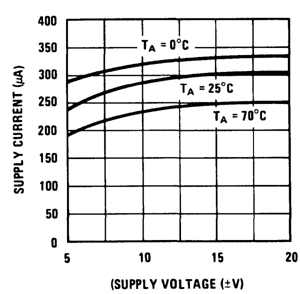
Voltage Gain



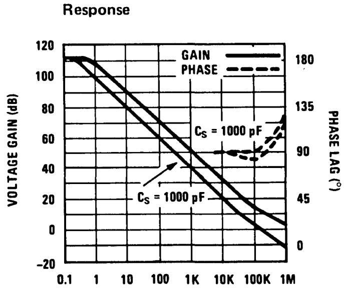
Output Swing



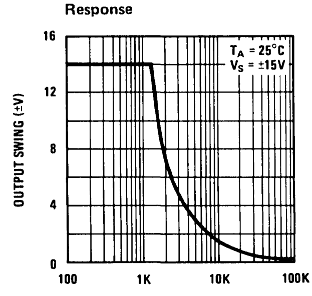
Supply Current



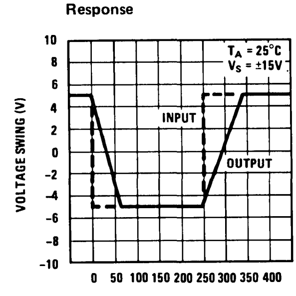
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



Operational Amplifiers

LM216/LM216A/LM316/LM316A operational amplifier

general description

These devices are precision, high input impedance operational amplifiers designed for applications requiring extremely low input-current errors. They use supergain transistors in a Darlington input stage to get input bias currents that are equal to high-quality FET amplifiers—even in limited temperature range operation. The low input current is, however, obtained with some sacrifice to offset voltage, offset voltage drift and noise when compared to the non-Darlington LM112 series. Noteworthy specifications include:

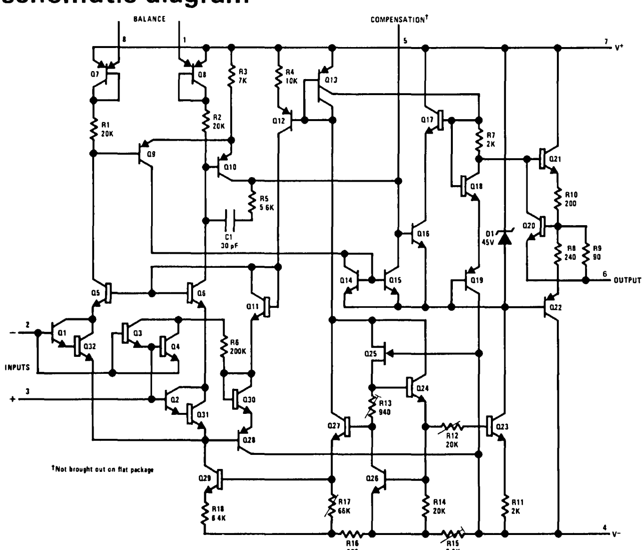
- Guaranteed bias currents as low as 50 pA
- Maximum offset currents down to 15 pA
- Operates from supplies of ±3V to ±20V
- Supply current only 300 μA at ±20V

These operational amplifiers are internally frequency compensated and have provisions for offset balancing with a single external potentiometer. Further, unlike most other internally compensated amplifiers, the MOS compensation capacitor is protected to prevent catastrophic failure from overvoltage spikes on the supplies.

The low current error of these amplifiers make possible many designs that were previously impractical with monolithic amplifiers. They will operate from 100 MΩ source resistances, introducing less error than general purpose amplifiers with 10 kΩ sources. Integrators with worst case drifts less than 10 μV/sec and analog time delays in excess of one day can also be made using capacitors no larger than 1 μF.

The LM216A and LM316A are high performance versions of the LM216 and LM316. The LM216 and LM216A are specified for operation from −25°C to 85°C, while the LM316 and LM316A are specified from 0°C to 55°C.

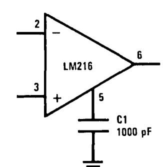
schematic diagram



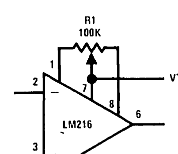
**Pin connections shown are for metal can.

auxiliary circuits**

Overcompensation for Greater Stability Margin

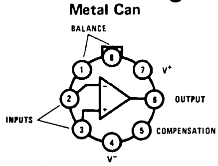


Offset Balancing



connection diagrams

Metal Can



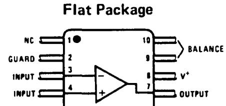
Note: Pin 4 connected to case.

TOP VIEW

Order Number LM216H or LM216AH or LM316H or LM316AH

See Package 11

Flat Package



Note: Pin 6 connected to bottom of package.

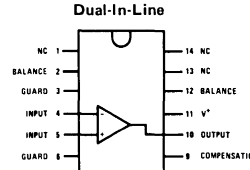
Compensation terminal not brought out on flat package.

TOP VIEW

Order Number LM216F or LM216AF or LM316F or LM316AF

See Package 3

Dual-In-Line



Note: Pin 7 connected to bottom of package.

TOP VIEW

Order Number LM216D or LM216AD or LM316D or LM316AD

See Package 1

absolute maximum ratings

Supply Voltage		±20V
Power Dissipation (Note 1)		500 mW
Differential Input Current (Note 2)		±10 mA
Input Voltage (Note 3)		±15V
Output Short-Circuit Duration		Indefinite
Operating Temperature Range	LM216/LM216A	−25°C to 85°C
	LM316/LM316A	0°C to 70°C
Storage Temperature Range		−65°C to 150°C
Lead Temperature (Soldering, 10 sec)		300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	LM216	LM216A	LM316	LM316A	UNITS
Input Offset Voltage	$T_A = 25°C$	10	3	10	3	mV
Input Offset Current	$T_A = 25°C$	50	15	50	15	pA
Input Bias Current	$T_A = 25°C$	150	50	150	50	pA
Input Resistance	$T_A = 25°C$	1	5	1	5	GΩ
Supply Current	$T_A = 25°C$	0.8	0.6	0.8	0.6	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = ±15V$ $V_{OUT} = ±10V$, $R_L \geq 10\ k\Omega$	20	40	20	40	V/mV
Input Offset Voltage		15	6	15	6	mV
Input Offset Current		100	30	100	30	pA
Input Bias Current		250	100	250	100	pA
Supply Current	$T_A = T_{MAX}$		0.5		0.5	mA
Large Signal Voltage Gain	$V_S = ±15V$, $V_{OUT} = ±10V$ $R_L \geq 10\ k\Omega$	10	20	15	30	V/mV
Output Voltage Swing	$V_S = ±15V$, $R_L = 10\ k\Omega$	±13	±13	±13	±13	V
Input Voltage Range	$V_S = ±15V$	±13	±13	±13	±13	V
Common Mode Rejection Ratio		80	80	80	80	dB
Supply Voltage Rejection Ratio		80	80	80	80	dB

Note 1: The maximum junction temperature of the LM216 and LM216A is 100°C, while that of the LM316 and LM316A is 70°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

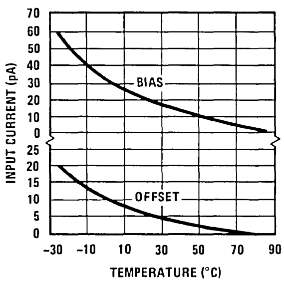
Note 2: The inputs are shunted with back-to-back diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

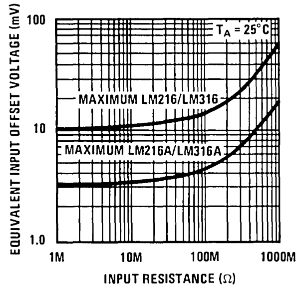
Note 4: These specifications apply for $±5V \leq V_S \leq ±20V$ and $-25°C \leq T_A \leq 85°C$, unless otherwise specified. With the LM316 and LM316A however, all temperature specifications are limited to $0°C \leq T_A \leq 55°C$.

typical performance characteristics

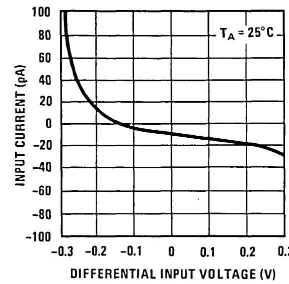
Input Currents



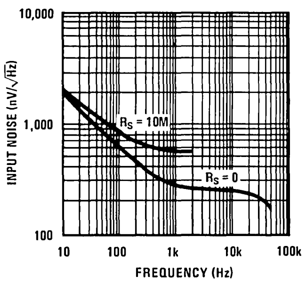
Offset Error



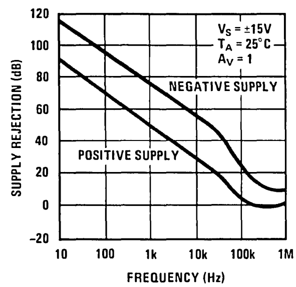
Input Current



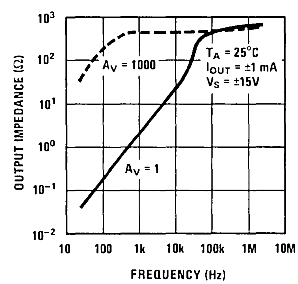
Input Noise Voltage



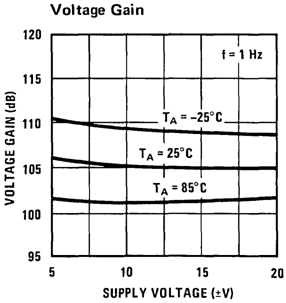
Power Supply Rejection



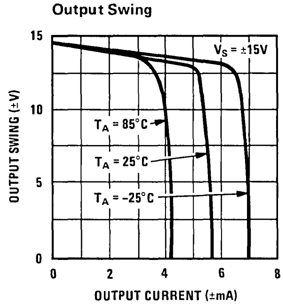
Closed Loop Output Impedance



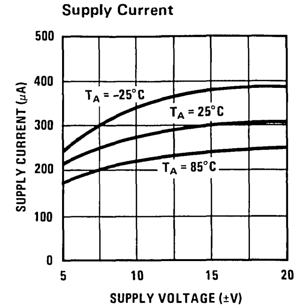
Voltage Gain



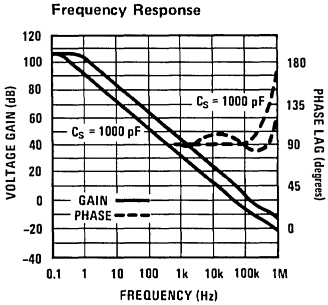
Output Swing



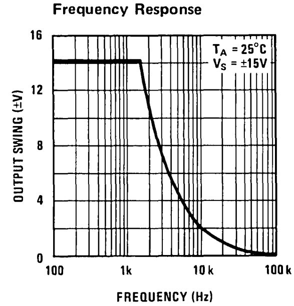
Supply Current



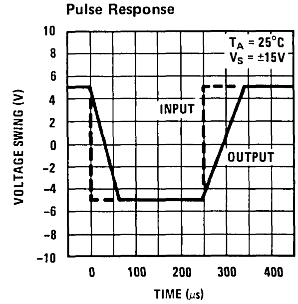
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



Operational Amplifiers

LM118/LM218 operational amplifier general description

The LM118 and LM218 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.

features

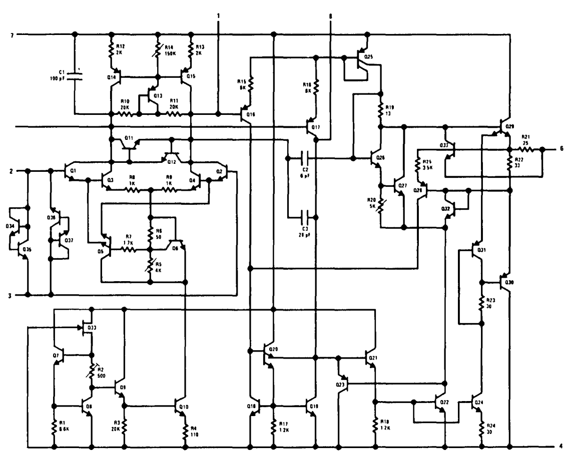
- 15 MHz small signal bandwidth
- Guaranteed 50V/μs slew rate
- Maximum bias current of 250 nA
- Operates from supplies of ±5V to ±20V
- Internal frequency compensation
- Input and output overload protected
- Pin compatible with general purpose op amps

The LM118 has internal unity gain frequency compensation. This considerably simplifies its application since no external components are necessary for operation. However, unlike most internally compensated amplifiers, external frequency com pensation may be added for optimum performance For inverting applications, feedforward compen sation will boost the slew rate to over 150V/μs and almost double the bandwidth. Overcompensation can be used with the amplifier for greater stability when maximum bandwidth is not needed. Further, a single capacitor can be added to reduce the 0.1% settling time to under 1 μs.

The high speed and fast settling time of these op amps make them useful in A/D converters, oscillators, active filters, sample and hold circuits, or general purpose amplifiers. These devices are easy to apply and offer an order of magnitude better AC performance than industry standards such as the LM709.

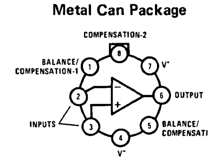
The LM218 is identical to the LM118 except that the LM218 has its performance specified over a −25°C to 85°C temperature range, instead of −55°C to 125°C.

schematic and connection diagrams



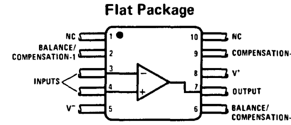
*Pin connections shown on schematic diagram and typical applications are for TO-5 package.

Metal Can Package



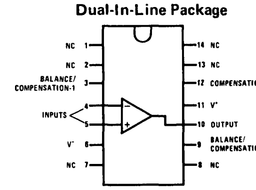
Order Number LM118H or LM218H
See Package 11

Flat Package



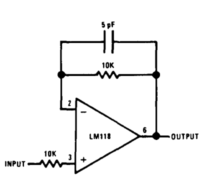
Order Number LM118F or LM218F
See Package 3

Dual-In-Line Package

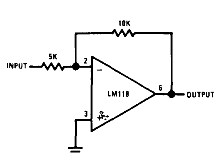


Order Number LM118D or LM218D
See Package 1

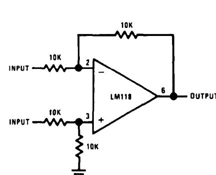
typical applications



Fast Voltage Follower



Fast Summing Amplifier



Differential Amplifier

absolute maximum ratings

Supply Voltage	±20V
Power Dissipation (Note 1)	500 mW
Differential Input Current (Note 2)	±10 mA
Input Voltage (Note 3)	±15V
Output Short-Circuit Duration	Indefinite
Operating Temperature Range LM118	−55°C to 125°C
LM218	−25°C to 85°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$		2	4	mV
Input Offset Current	$T_A = 25°C$		6	50	nA
Input Bias Current	$T_A = 25°C$		120	250	nA
Input Resistance	$T_A = 25°C$	1	3		MΩ
Supply Current	$T_A = 25°C$		5	8	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = ±15V$ $V_{OUT} = ±10V$, $R_L \geq 2\ k\Omega$	50	200		V/mV
Slew Rate	$T_A = 25°C$, $V_S = ±15V$, $A_V = 1$	50	70		V/μs
Small Signal Bandwidth	$T_A = 25°C$, $V_S = ±15V$		15		MHz
Input Offset Voltage				6	mV
Input Offset Current				100	nA
Input Bias Current				500	nA
Supply Current	$T_A = +125°C$		4.5	7	mA
Large Signal Voltage Gain	$V_S = ±15V$, $V_{OUT} = ±10V$ $R_L \geq 2\ k\Omega$	25			V/mV
Output Voltage Swing	$V_S = ±15V$, $R_L = 2\ k\Omega$	±12	±13		V
Input Voltage Range	$V_S = ±15V$	±11.5			V
Common Mode Rejection Ratio		80	100		dB
Supply Voltage Rejection Ratio		70	80		dB

Note 1: The maximum junction temperature of the LM118 is 150°C, while that of the LM218 is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

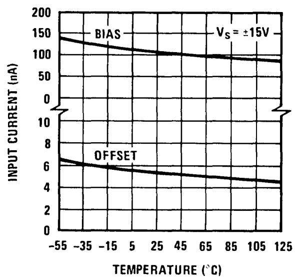
Note 2: The inputs are shunted with back-to-back diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

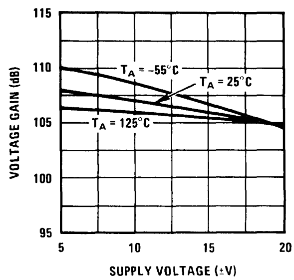
Note 4: These specifications apply for $±5V \leq V_S \leq ±20V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise specified. With the LM218, however, all temperature specifications are limited to $-25°C \leq T_A \leq 85°C$. Also, power supplies must be bypassed with 0.1 μF disc capacitors.

typical performance characteristics

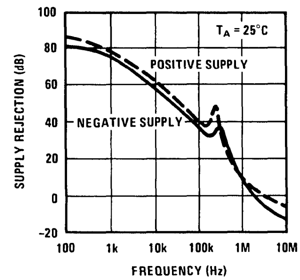
Input Current



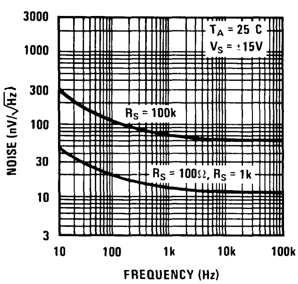
Voltage Gain



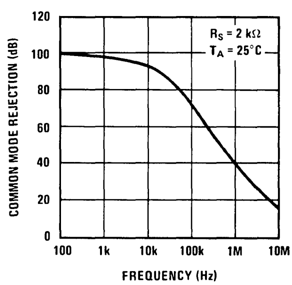
Power Supply Rejection



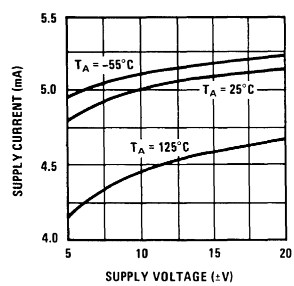
Input Noise Voltage



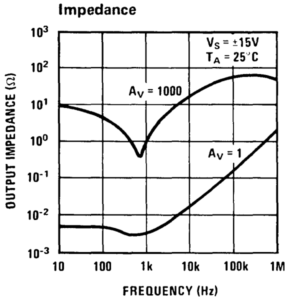
Common Mode Rejection



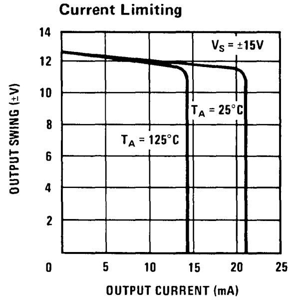
Supply Current



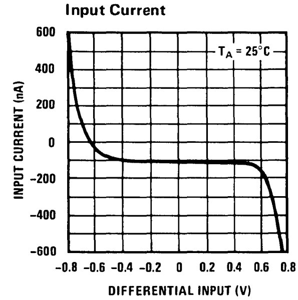
Closed Loop Output Impedance



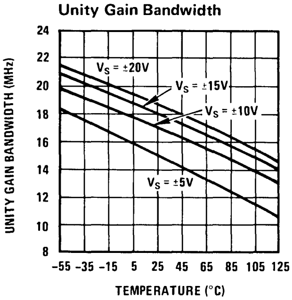
Current Limiting



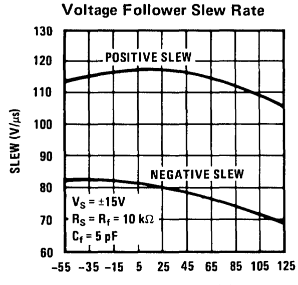
Input Current



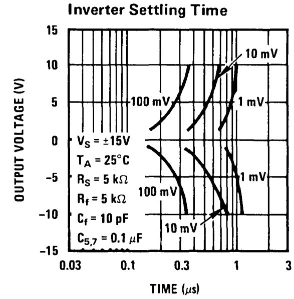
Unity Gain Bandwidth



Voltage Follower Slew Rate

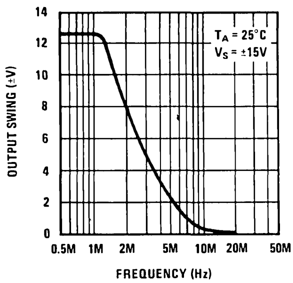


Inverter Settling Time

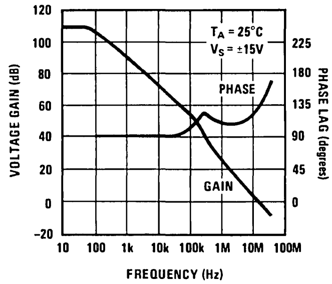


typical performance characteristics (con't)

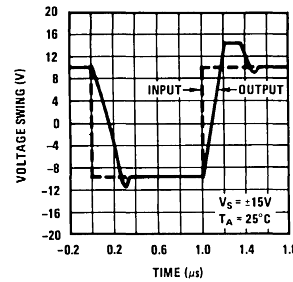
Large Signal Frequency Response



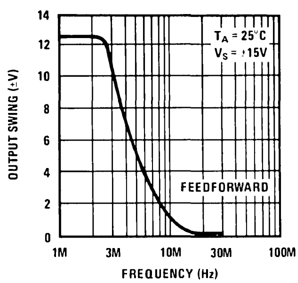
Open Loop Frequency Response



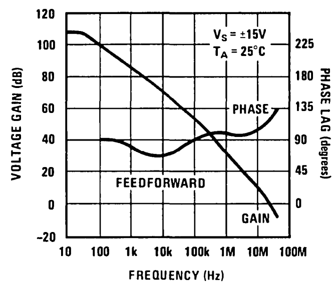
Voltage Follower Pulse Response



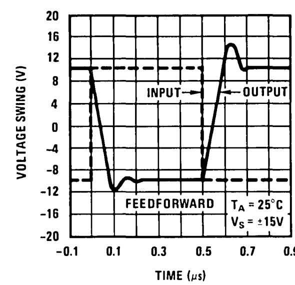
Large Signal Frequency Response



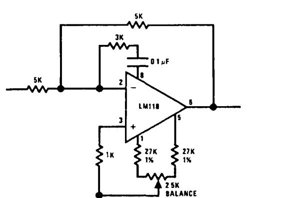
Open Loop Frequency Response



Inverter Pulse Response

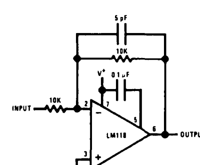


auxiliary circuits



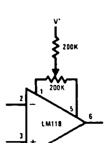
†Slew rate typically 150/Vµs.

Feedforward Compensation for Greater Inverting Slew Rate†

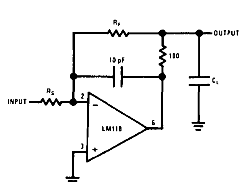


†Slew and setting time to 0.1% for a 10V step change is 800 ns.

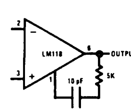
Compensation for Minimum Settling† Time



Offset Balancing

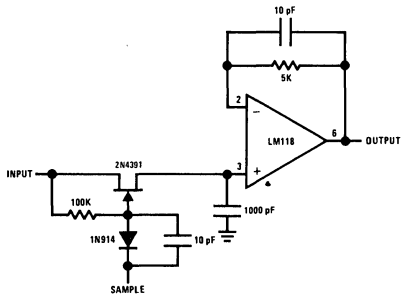


Isolating Large Capacitive Loads

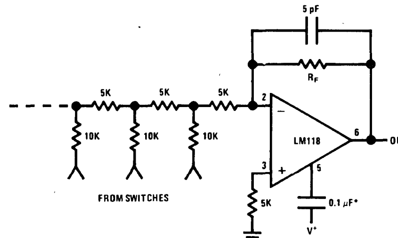


Overcompensation

typical applications (con't)

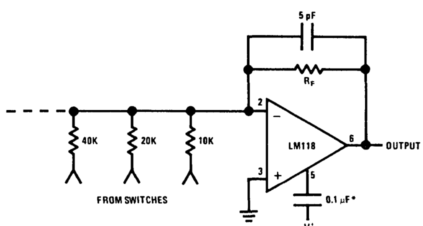


Fast Sample and Hold



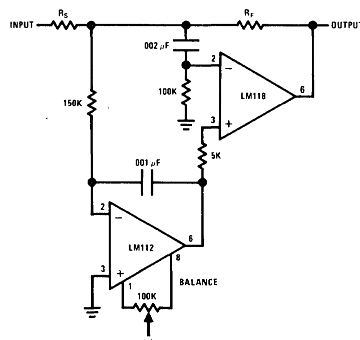
*Optional – Reduces settling time.

D/A Converter Using Ladder Network

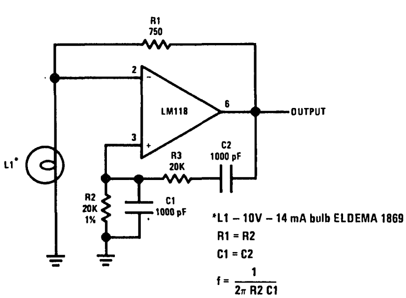


*Optional – Reduces settling time.

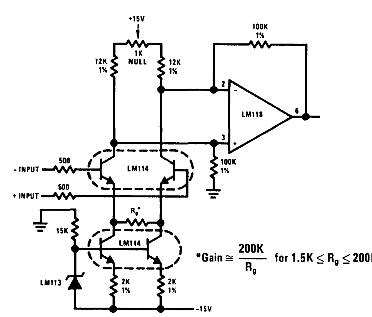
D/A Converter Using Binary Weighted Network



Fast Summing Amplifier
with Low Input Current



Wein Bridge Sine Wave Oscillator



Instrumentation Amplifier

Operational Amplifiers

LM318 operational amplifier general description

The LM318 is a precision high speed operational amplifier designed for applications requiring wide bandwidth and high slew rate. It features a factor of ten increase in speed over general purpose devices without sacrificing DC performance.

features

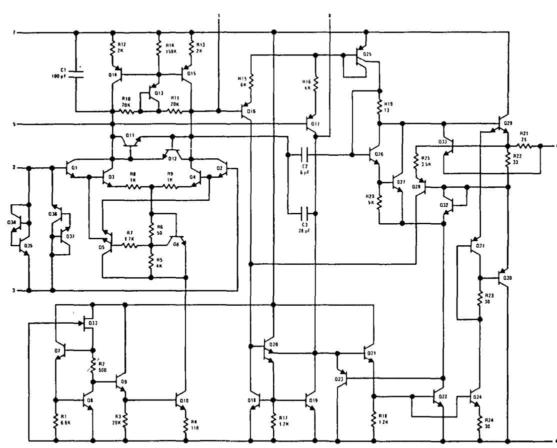
- 15 MHz small signal bandwidth
- Guaranteed 50V/μs slew rate
- Maximum bias current of 500 nA
- Operates from supplies of ±5V to ±20V
- Internal frequency compensation
- Input and output overload protected
- Pin compatible with general purpose op amps

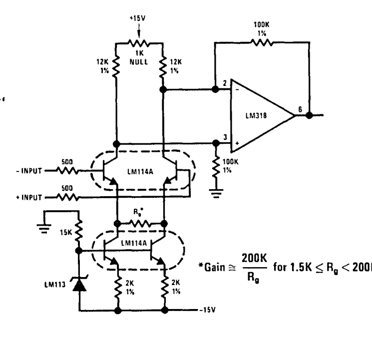
The LM318 has internal unity gain frequency compensation. This considerably simplifies its application since no external components are necessary for operation. However, unlike most internally compensated amplifiers, external frequency compensation may be added for optimum performance. For inverting applications, feedforward compensation will boost the slew rate to over 150V/μs and almost double the bandwidth. Overcompensation can be used with the amplifier for greater stability when maximum bandwidth is not needed. Further, a single capacitor can be added to reduce the 0.1% settling time to under 1 μs.

The high speed and fast settling time of these op amps make them useful in A/D converters, oscillators, active filters, sample and hold circuits, or general purpose amplifiers. These devices are easy to apply and offer an order of magnitude better AC performance than industry standards such as the LM709.

The LM318 is specified for operation over 0°C to 70°C.

schematic diagram and typical application

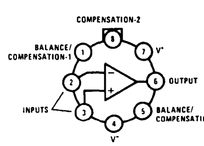




Instrumentation Amplifier

connection diagrams

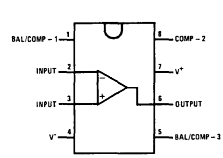
Metal Can Package*



***Pin connections shown on schematic diagram and typical applications are for TO-5 package.**

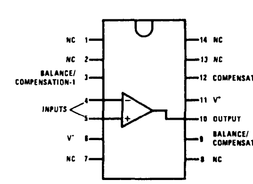
Order Number LM318H
See Package 11

Dual-In-Line Package



Order Number LM318N
See Package 20

Dual-In-Line Package



Order Number LM318D
See Package 1

absolute maximum ratings

Supply Voltage	±20V
Power Dissipation (Note 1)	500 mW
Differential Input Current (Note 2)	±10 mA
Input Voltage (Note 3)	±15V
Output Short-Circuit Duration	Indefinite
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$		4	10	mV
Input Offset Current	$T_A = 25°C$		30	200	nA
Input Bias Current	$T_A = 25°C$		150	500	nA
Input Resistance	$T_A = 25°C$	0.5	3		MΩ
Supply Current	$T_A = 25°C$		5	10	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = ±15V$, $V_{OUT} = ±10V$, $R_L \geq 2\ k\Omega$	25	200		V/mV
Slew Rate	$T_A = 25°C$, $V_S = ±15V$, $A_V = 1$	50	70		V/µs
Small Signal Bandwidth	$T_A = 25°C$, $V_S = ±15V$		15		MHz
Input Offset Voltage				15	mV
Input Offset Current				300	nA
Input Bias Current				750	nA
Large Signal Voltage Gain	$V_S = ±15V$, $V_{OUT} = ±10V$, $R_L \geq 2\ k\Omega$	20			V/mV
Output Voltage Swing	$V_S = ±15V$, $R_L = 2\ k\Omega$	±12	±13		V
Input Voltage Range	$V_S = ±15V$	±11.5			V
Common Mode Rejection Ratio		70	100		dB
Supply Voltage Rejection Ratio		65	80		dB

Note 1: The maximum junction temperature of the LM318 is 85°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

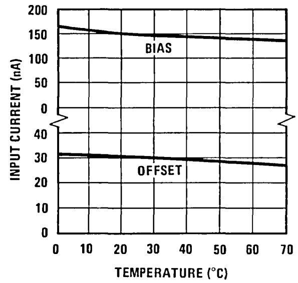
Note 2: The inputs are shunted with back-to-back diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

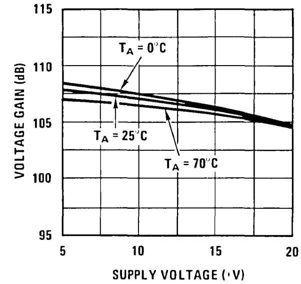
Note 4: These specifications apply for $±5V \leq V_S \leq ±20V$ and $0°C \leq T_A \leq 70°C$, unless otherwise specified. For proper operation, the power supplies must be bypassed with 0.1 µF disc capacitors.

typical performance characteristics

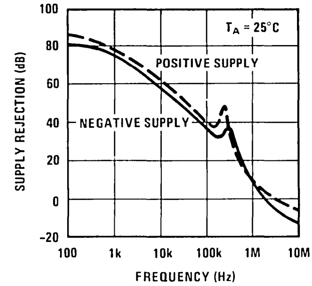
Input Current



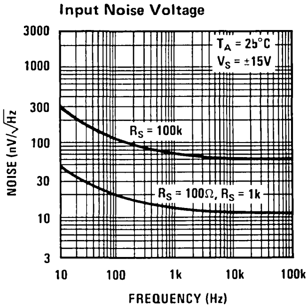
Voltage Gain



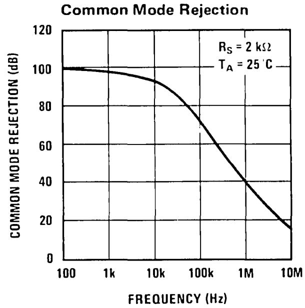
Power Supply Rejection



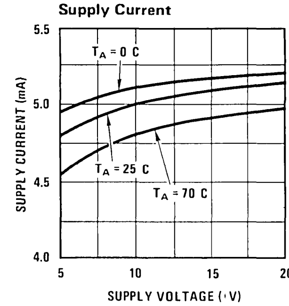
Input Noise Voltage



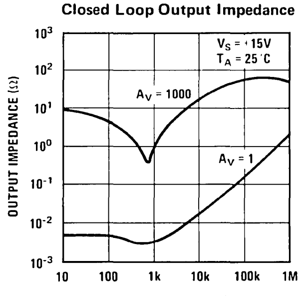
Common Mode Rejection



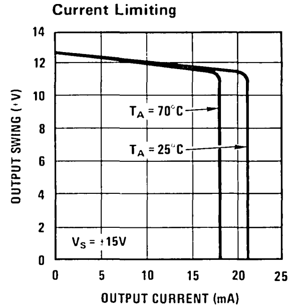
Supply Current



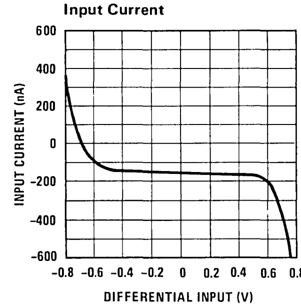
Closed Loop Output Impedance



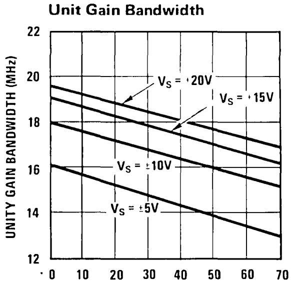
Current Limiting



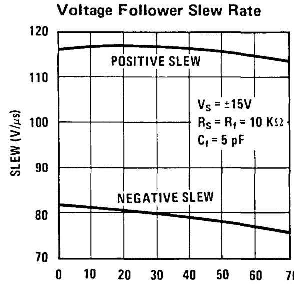
Input Current



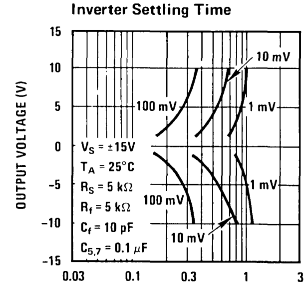
Unit Gain Bandwidth



Voltage Follower Slew Rate

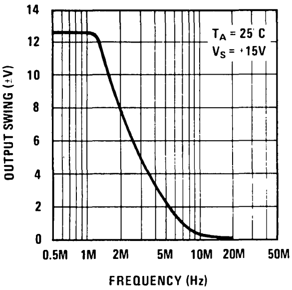


Inverter Settling Time

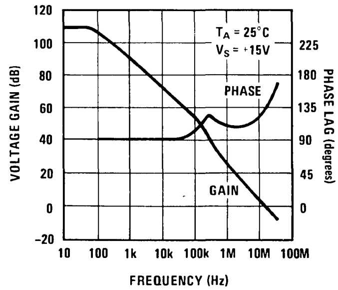


typical performance characteristics (con't)

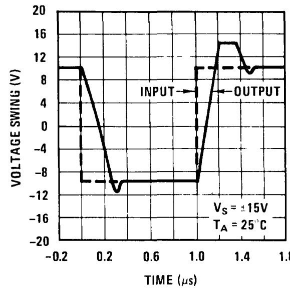
Large Signal Frequency Response



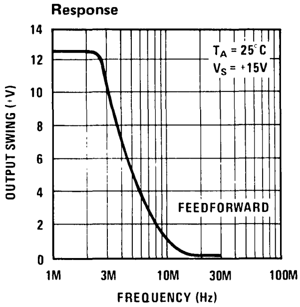
Open Loop Frequency Response



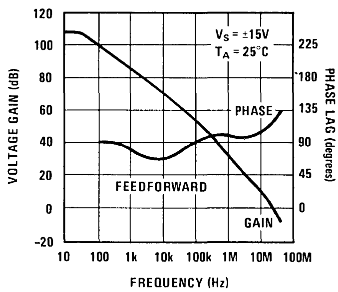
Voltage Follower Pulse Response



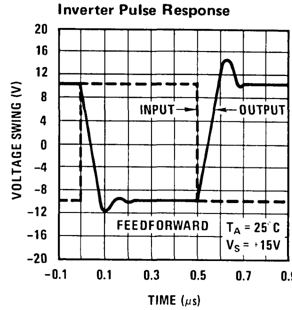
Large Signal Frequency Response



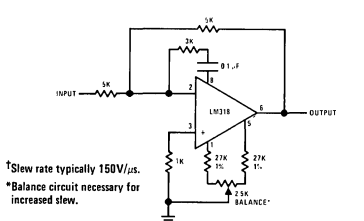
Open Loop Frequency Response



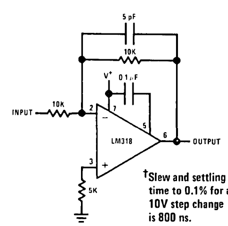
Inverter Pulse Response



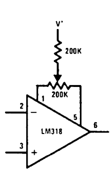
auxiliary circuits



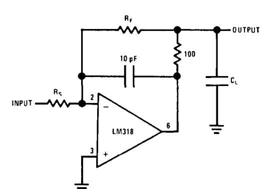
Feedforward Compensation for Greater Inverting Slew Rate†



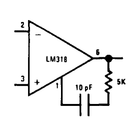
Compensation for Minimum Settling† Time



Offset Balancing

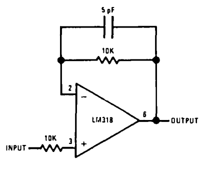


Isolating Large Capacitive Loads

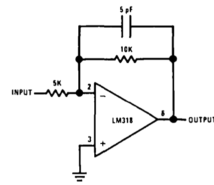


Overcompensation

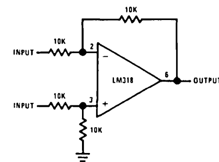
typical applications (con't)



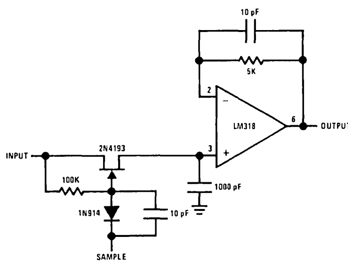
Fast Voltage Follower



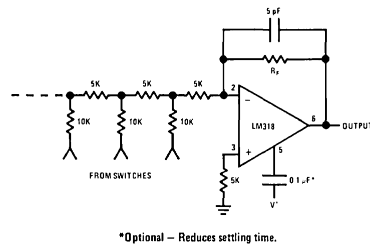
Fast Summing Amplifier



Differential Amplifier

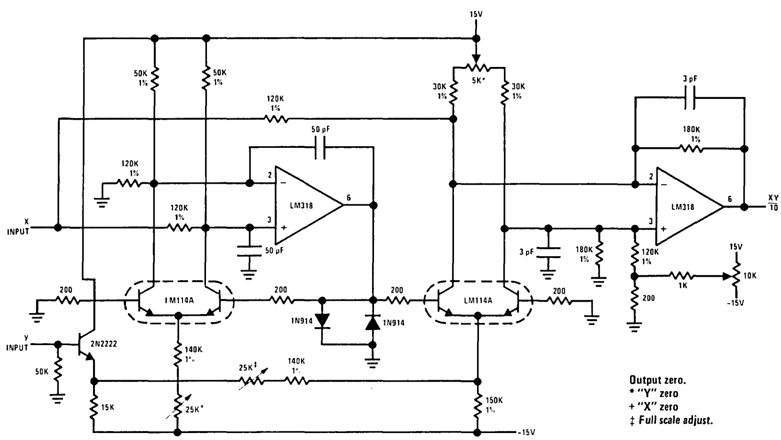


Fast Sample and Hold



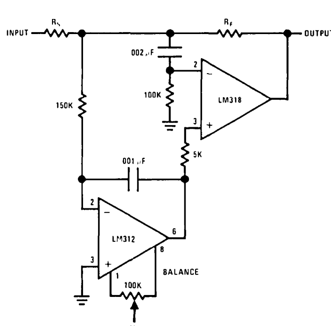
*Optional – Reduces settling time.

D/A Converter Using Ladder Network

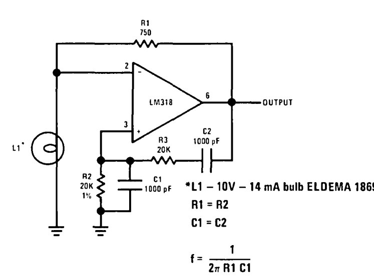


Output zero.
* "Y" zero
+ "X" zero
‡ Full scale adjust.

Four Quadrant Multiplier



Fast Summing Amplifer with Low Input Current



*L1 – 10V – 14 mA bulb ELDEMA 1869
R1 = R2
C1 = C2

$$f = \frac{1}{2\pi R1\ C1}$$

Wein Bridge Sine Wave Oscillator

2

Operational Amplifiers

LM121/LM221/LM321 precision preamplifier

general description

The LM121 series are precision preamplifiers designed to operate with general purpose operational amplifiers to drastically decrease DC errors. Drift, bias current, common mode and supply rejection are more than a factor of 10 better than standard op amps alone. Further, the added DC gain of the LM121 decreases the closed loop gain error.

The LM121 operates with supply voltages from ±3V to ±20V and has sufficient supply rejection to operate from unregulated supplies. The operating current is programmable from 5μA to 200μA so bias current, offset current, gain and noise can be optimized for the particular application while still realizing very low drift. Super-gain transistors are used for the input stage so input error currents are lower than conventional amplifiers at the same operating current. Further, the initial offset voltage is easily nulled to zero.

advantages

- Permits optimization of general purpose op amps
- Replaces many specialized op amps

features

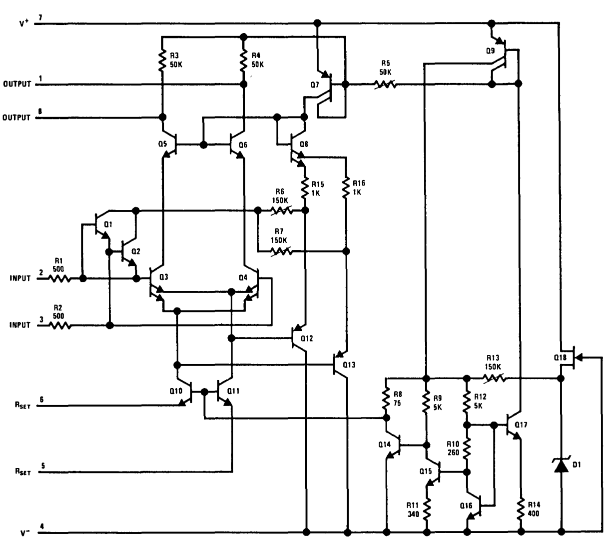
- Guaranteed drift less than 1μV/°C when nulled
- Offset voltage less than 0.7 mV
- Bias current less than 10 nA at 10μA operating current
- CMRR 120 dB minimum
- 114 dB supply rejection
- Easily nulled offset voltage

The extremely low drift of the LM121 will improve accuracy on almost any precision DC circuit. For example, instrumentation amplifier, strain gauge amplifiers and thermocouple amplifiers now using chopper amplifiers can be made with the LM121. The full differential input and high common mode rejection are another advantage over choppers. For applications where low bias current is more important than drift, the operating current can be reduced to low values. High operating currents can be used for low voltage noise with low source resistance. The programmable operating current of the LM121 allows tailoring the input characteristics to match those of specialized op amps.

The LM121 is specified over a −55°C to 125°C temperature range, the LM221 over a −25°C to 85°C range and the LM321 over a 0°C to 70°C temperature range.

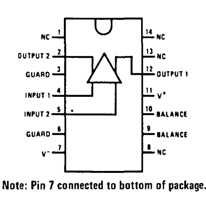
A lower drift version of the LM121 – the LM121A series – is available for applications requiring 0.2μV/°C offset voltage drift.

schematic and connection diagrams



*Pin connections shown on schematic diagram and typical applications are for TO-5 package.

Dual-In-Line Package

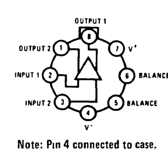


Note: Pin 7 connected to bottom of package.

TOP VIEW

Order Number LM121D, LM221D or LM321D
See Package 1

Metal Can Package

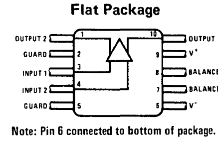


Note: Pin 4 connected to case.

TOP VIEW

Order Number LM121H, LM221H or LM321H
See Package 11

Flat Package



Note: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM121F, LM221F or LM321F
See Package 3

Note: Outputs are inverting from the input of the same number.

absolute maximum ratings

Supply Voltage	±20V
Power Dissipation (Note 1)	500mW
Differential Input Voltage (Notes 2, 3)	±15V
Input Voltage (Note 3)	±15V
Operating Temperature Range	
LM121	−55°C to 125°C
LM221	−25°C to 85°C
LM321	0°C to 70°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	LM121 LM221	LM321	UNITS	
Input Offset Voltage	$T_A = 25°C$ $6.4k \leq R_{Set} \leq 70k$	0.7	1.5	mV	Max
Input Offset Current	$T_A = 25°C$ $R_{Set} = 70k$ $R_{Set} = 6.4k$	1 10	2 20	nA nA	Max Max
Input Bias Current	$T_A = 25°C$ $R_{Set} = 70k$ $R_{Set} = 6.4k$	10 100	18 180	nA nA	Max Max
Input Resistance	$T_A = 25°C$ $R_{Set} = 70k$ $R_{Set} = 6.4k$	4 0.4	2 0.2	MΩ MΩ	Min Min
Supply Current	$T_A = 25°C$	1.5	2.2	mA	Max
Input Offset Voltage	$6.4k \leq R_{Set} = 70k$	1	2.5	mV	Max
Input Bias Current	$R_{Set} = 70k$ $R_{Set} = 6.4k$	30 300	28 280	nA nA	Max Max
Input Offset Current	$R_{Set} = 70k$ $R_{Set} = 6.4k$	3 30	4 40	nA nA	Max Max
Average Temperature Coefficient of Input Offset Voltage	$R_S \leq 200\Omega$ $6.4k \leq R_{Set} \leq 70k$ Offset Voltage Nulled	1	1	μV/°C	Max
Supply Current		2.5	3.5	mA	Max
Input Voltage Range	$V_S = \pm 15V$ $R_{Set} = 70k$	±13	±13	V	Min
	$R_{Set} = 6.4k$ (Note 5)	+7 −13	+7 −13	V	Min
Common Mode Rejection Ratio	$R_{Set} = 70k$ $R_{Set} = 6.4k$	120 114	114 114	dB dB	Min Min
Supply Voltage Rejection Ratio	$R_{Set} = 70k$ $R_{Set} = 6.4k$	120 114	114 114	dB dB	Min Min
Noise	$R_{Set} = 0$	8	8	$mV/\sqrt{Hz}$	Typ
Voltage Gain	$T_A = 25°C$ $R_{Set} = 70k$ $R_L > 3$ meg	16	12	V/V	Min

Note 1: The maximum junction temperature of the LM121 is 150°C, while that of the LM221 is 100°C. The maximum junction temperature of the LM321 is 85°C. For operating at elevated temperature, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/6-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce cooper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

Note 2: The inputs are shunted with back-to-back diodes in series with a 500Ω resistor for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 4: These specifications apply for $\pm 5 \leq V_S < \pm 20V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise specified. With the LM221, however, all temperature specifications are limited to $-25°C \leq T_A \leq 85°C$, and for the LM321 the specifications apply over a 0°C to 70°C temperature range.

Note 5: External precision resistors—0.1%—can be placed from pins 1 and 8 to 7 to increase positive common mode range.

typical applications

Low Drift Op Amp Using the LM121 as a Preamp

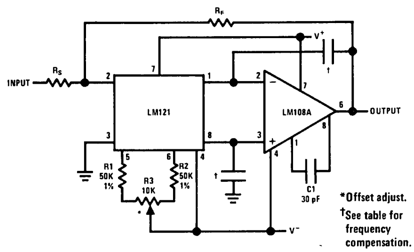


FIGURE 1.

Gain of 1000 Instrumentation Amplifier‡

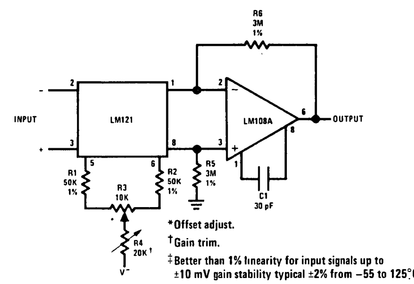


FIGURE 2.

frequency compensation

Universal Frequency Compensation

The additional gain of the LM121 preamplifier when used with an operational amplifier usually necessitates additional frequency compensation. When the closed loop gain of the op amp with the LM121 is less than the gain of the LM121 alone, more compensation is needed. The worst case situation is when there is 100% feedback – such as a voltage follower or integrator – and the gain of the LM121 is high. When high closed loop gains are used – for example $A_V = 1000$ – and only an addition gain of 200 is inserted by the LM121, the frequency compensation of the op amp will usually suffice.

The frequency compensation shown here is designed to operate with any unity-gain stable op amp. Figure 1 shows the basic configuration of frequency stabilizing network. In operation the output of the LM121 is rendered single ended by a 0.01µF bypass capacitor to ground. Overall frequency compensation then is achieved by an integrating capacitor around the op amp.

$$\text{Bandwidth at unity gain} \cong \frac{12}{2\pi R_{Set}\, C}$$

$$\text{for 0.5 MHz bandwidth } C = \frac{4}{10^6 R_{Set}}$$

For use with higher frequency op amps such as the LM118 the bandwidth may be increased to about 2 MHz.

If the closed loop gain is greater than unity "C" may be decreased by

$$C = \frac{4}{10^6 A_{CL} R_{Set}}$$

Alternate Compensation

The two compensation capacitors can be made equal for improved power supply rejection. In this case the formula for the compensation capacitor is

$$C = \frac{8}{10^6 A_{CL} R_{Set}}$$

Table 1 shows typical values for the two compensating capacitors for various gains and operating currents.

TABLE 1.

CLOSED LOOP GAIN	CURRENT SET RESISTOR				
	120kΩ	60kΩ	30kΩ	12kΩ	6kΩ
$A_V = 1$	68	130	270	680	1300
$A_V = 5$	15	27	56	130	270
$A_V = 10$	10	15	27	68	130
$A_V = 50$	1	3	5	15	27
$A_V = 100$	–	1	3	5	10
$A_V = 500$	–	–	1	1	3
$A_V = 1000$	–	–	–	–	–

This table applies for the LM108, LM101A, LM741, LM118. Capacitance is in pF.

Design equations for the LM121 series:

$$\text{Gain } A_V \approx \frac{1.2 \times 10^6}{R_{Set}}$$

Null Pot Value should be 10% of R_{Set}

$$\text{Operating Current} \approx \frac{2 \times 0.65V}{R_{Set}}$$

$$\text{Positive Common Mode Limit} \approx V^+ - 0.6 + \left[\frac{0.65V \times 50k}{R_{Set}}\right]$$

Operational Amplifiers

LM121A/LM221A/LM321A precision preamplifiers

general description

The LM121A series are precision preamplifiers designed to operate with general purpose operational amplifiers to drastically decrease dc errors. Drift, bias current, common mode and supply rejection are more than a factor of 50 better than standard op amps alone. Further, the added dc gain of the LM121A decreases the closed loop gain error.

The LM121A operates with supply voltages from ±3V to ±20V and has sufficient supply rejection to operate from unregulated supplies. The operating current is programmable from 5μA to 200μA so bias current, offset current, gain and noise can be optimized for the particular application while still realizing very low drift. Super-gain transistors are used for the input stage so input error currents are lower than conventional amplifiers at the same operating current. Further, the initial offset voltage is easily nulled to zero.

advantages

- No chopper noise
- Allows optimized input characteristics
- Improves dc accuracy

features

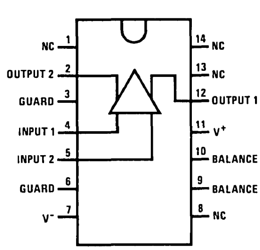
- Guaranteed drift less than 0.2μV/°C when nulled
- Offset voltage less than 0.4 mV
- Bias current less than 10 nA at 10μA operating current
- CMRR 126 dB minimum
- 120 dB supply rejection
- Easily nulled offset voltage

The extremely low drift of the LM121A will improve accuracy on almost any precision dc circuit. For example, instrumentation amplifier, strain gauge amplifiers and thermocouple amplifiers now using chopper amplifiers can be made with the LM121A. The full differential input and high common-mode rejection are another advantage over choppers. For applications where low bias current is more important than drift, the operating current can be reduced to low values. High operating currents can be used for low voltage noise with low source resistance. The programmable operating current of the LM121A allows tailoring the input characteristics to match those of specialized op amps.

The LM121A is specified over a −55°C to +125°C temperature range, the LM221A over a −25°C to +85°C range and the LM321A over a 0°C to +70°C temperature range.

connection diagrams

Dual-In-Line Package

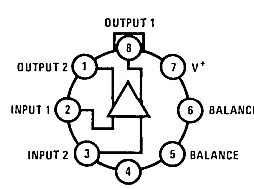


NOTE: Pin 7 connected to bottom of package.

TOP VIEW

Order Number LM121AD, LM221AD or LM321AD See Package 1

Metal Can Package

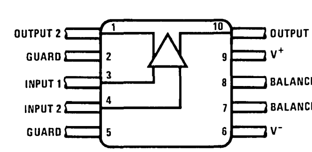


Note: Pin 4 connected to case.

TOP VIEW

Order Number LM121AH, LM221AH or LM321AH See Package 11

Flat Package



NOTE: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM121AF, LM221AF or LM321AF See Package 3

Note: Outputs are inverting from the input of the same number.

absolute maximum ratings

Supply Voltage	±20V
Power Dissipation (Note 1)	500 mW
Differential Input Voltage (Notes 2 and 3)	±15V
Input Voltage (Note 3)	±15V
Operating Temperature Range	
LM121A	−55°C to +125°C
LM221A	−25°C to +85°C
LM321A	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	LM121A, LM221A			LM321A			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$, $6.4k \leq R_{SET} \leq 70k$		0.2	0.4		0.2	0.4	mV
Input Offset Current	$T_A = 25°C$, $R_{SET} = 70k$		0.3	0.5		0.3	0.5	nA
	$R_{SET} = 6.4k$			5			5	nA
Input Bias Current	$T_A = 25°C$, $R_{SET} = 70k$		5	10		5	15	nA
	$R_{SET} = 6.4k$		50	100		50	150	nA
Input Resistance	$T_A = 25°C$, $R_{SET} = 70k$	4	8		2	8		MΩ
	$R_{SET} = 6.4k$	0.4			0.2			MΩ
Supply Current	$T_A = 25°C$, $R_{SET} = 70k$		0.8	1.5		0.8	2.2	mA
Input Offset Voltage	$6.4k \leq R_{SET} \leq 70k$		0.5	0.65		0.5	0.65	mV
Input Bias Current	$R_{SET} = 70k$		15	30		15	25	nA
	$R_{SET} = 6.4k$		150	300		150	250	nA
Input Offset Current	$R_{SET} = 70k$		0.5	1		0.5	1	nA
	$R_{SET} = 6.4k$		5	10		5	10	nA
Input Offset Current Drift	$R_{SET} = 70k$		3			3		pA/°C
Average Temperature Coefficient of Input Offset Voltage	$R_S \leq 200\Omega$, $6.4k \leq R_{SET} \leq 70k$ Offset Voltage Nulled		0.07	0.2		0.07	0.2	μV/°C
Long Term Stability			3			3		μV/yr
Supply Current			1	2.5		1	3.5	mA
Input Voltage Range	$V_S = \pm15V$, $R_{SET} = 70k$	±13			±13			V
	(Note 5) $R_{SET} = 6.4k$	+7, −13			+7, −13			V
Common-Mode Rejection Ratio	$R_{SET} = 70k$	126	140		126	140		dB
	$R_{SET} = 6.4k$	120	130		120	130		dB
Supply Voltage Rejection Ratio	$R_{SET} = 70k$	120	126		118	126		dB
	$R_{SET} = 6.4k$	114	120		114	120		dB
Voltage Gain	$T_A = 25°C$, $R_{SET} = 70k$, $R_L > 3$ meg	16	20		12	20		V/V

Note 1: The maximum junction temperature of the LM121A is 150°C, while that of the LM221A is 100°C. The maximum junction temperature of the LM321A is 85°C. For operating at elevated temperature, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/6-inch-thick epoxy glass board with ten, 0.03-inch wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package if 100°C/W junction to ambient.

Note 2: The inputs are shunted with back-to-back diodes in series with a 500Ω resistor for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 4: These specifications apply for $\pm5 \leq V_S \leq \pm20V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise specified. With the LM221A, however, all temperature specifications are limited to $-25°C \leq T_A \leq 85°C$, and for the LM321A the specifications apply over a 0°C to 70°C temperature range.

Note 5: External precision resistor—0.1%—can be placed from pins 1 and 8 to 7 to increase positive common-mode range.

frequency compensation

UNIVERSAL COMPENSATION

The additional gain of the LM121A preamplifier when used with an operational amplifier usually necessitates additional frequency compensation. When the closed loop gain of the op amp with the LM121A is less than the gain of the LM121A alone, more compensation is needed. The worst case situation is when there is 100% feedback—such as a voltage follower or integrator—and the gain of the LM121A is high. When high closed loop gains are used—for example $A_V = 1000$—and only an addition gain of 200 is inserted by the LM121A, the frequency compensation of the op amp will usually suffice.

The frequency compensation shown here is designed to operate with any unity-gain stable op amp. *Figure 1* shows the basic configuration of frequency stabilizing network. In operation the output of the LM121A is rendered single ended by a 0.01μF bypass capacitor to ground. Overall frequency compensation then is achieved by an integrating capacitor around the op amp.

$$\text{Bandwidth at unity-gain} \cong \frac{12}{2\pi R_{SET} C}$$

$$\text{for 0.5 MHz bandwidth } C = \frac{4}{10^6 R_{SET}}$$

For use with higher frequency op amps such as the LM118 the bandwidth may be increased to about 2 MHz.

If the closed loop gain is greater than unity, "C" may be decreased to:

$$C = \frac{4}{10^6 A_{CL} R_{SET}}$$

ALTERNATE COMPENSATION

The two compensation capacitors can be made equal for improved power supply rejection. In this case the formula for the compensation capacitor is:

$$C = \frac{8}{10^6 A_{CL} R_{SET}}$$

Table I shows typical values for the two compensating capacitors for various gains and operating currents.

TABLE I

CLOSED LOOP GAIN	CURRENT SET RESISTOR				
	120 kΩ	60 kΩ	30 kΩ	12 kΩ	6 kΩ
$A_V = 1$	68	130	270	680	1300
$A_V = 5$	15	27	56	130	270
$A_V = 10$	10	15	27	68	130
$A_V = 50$	1	3	5	15	27
$A_V = 100$	–	1	3	5	10
$A_V = 500$	–	–	1	1	3
$A_V = 1000$	–	–	–	–	–

This table applies for the LM108, LM101A, LM741, LM118. Capacitance is in pF.

DESIGN EQUATIONS FOR THE LM121A SERIES

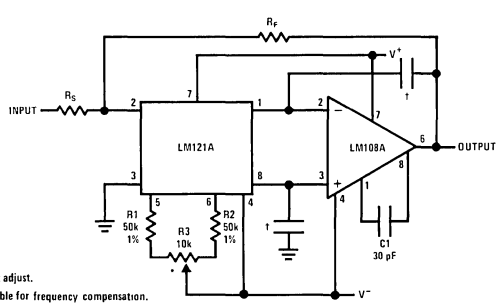
$$\text{Gain } A_V \approx \frac{1.2 \times 10^6}{R_{SET}}$$

Null Pot Value should be 10% of R_{SET}

$$\text{Operating Current} \approx \frac{2 \times 0.65V}{R_{SET}}$$

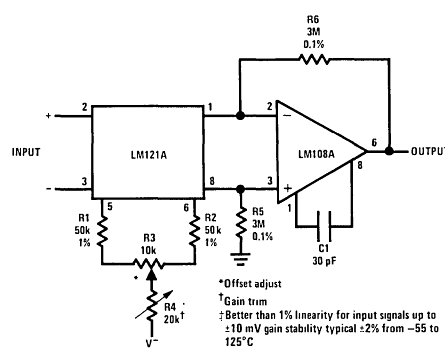
$$\text{Positive Common-Mode Limit} \approx V^+ - \left[0.6 - \frac{0.65V \times 50k}{R_{SET}}\right]$$

typical applications



*Offset adjust.
†See table for frequency compensation.

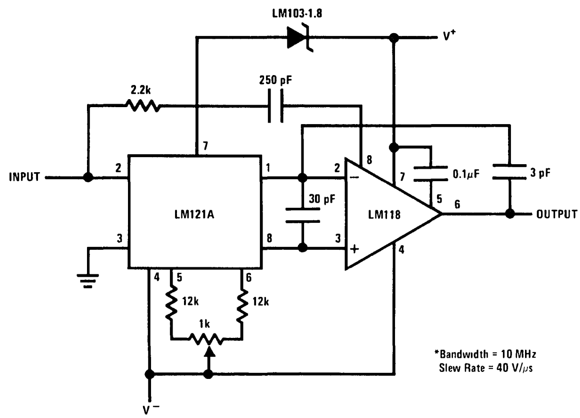
FIGURE 1. Low Drift Op Amp Using the LM121A as a Preamp



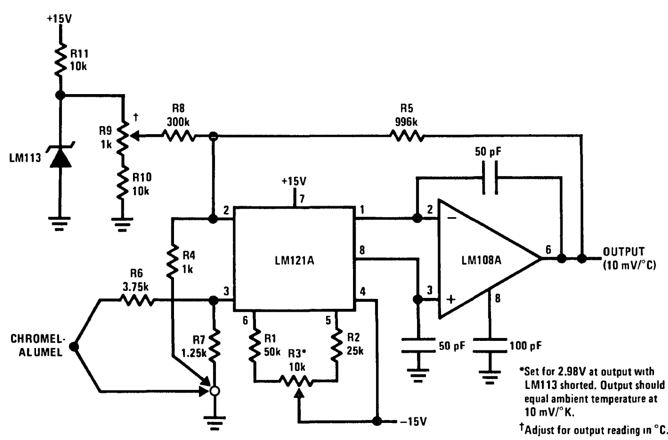
*Offset adjust
†Gain trim
‡Better than 1% linearity for input signals up to ±10 mV gain stability typical ±2% from −55 to 125°C
Match of R5 and R6 effect power supply rejection

Gain of 1000 Instrumentation Amplifier‡

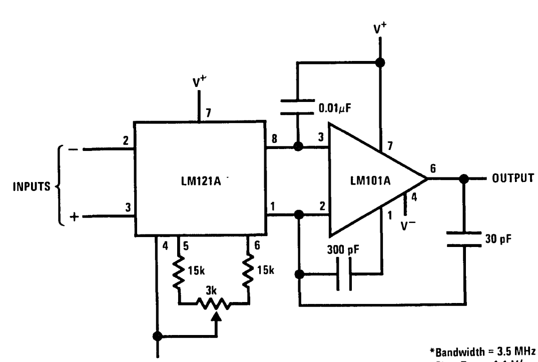
typical applications (con't)



High Speed* Inverting Amplifier with Low Drift

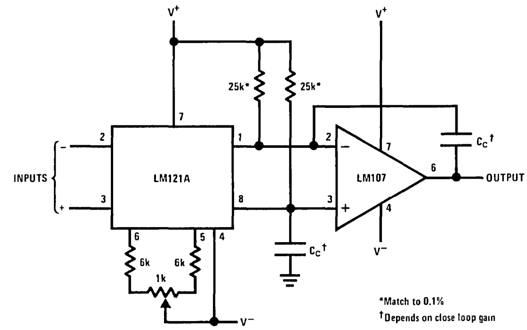


Thermocouple Amplifier with Cold Junction Compensation



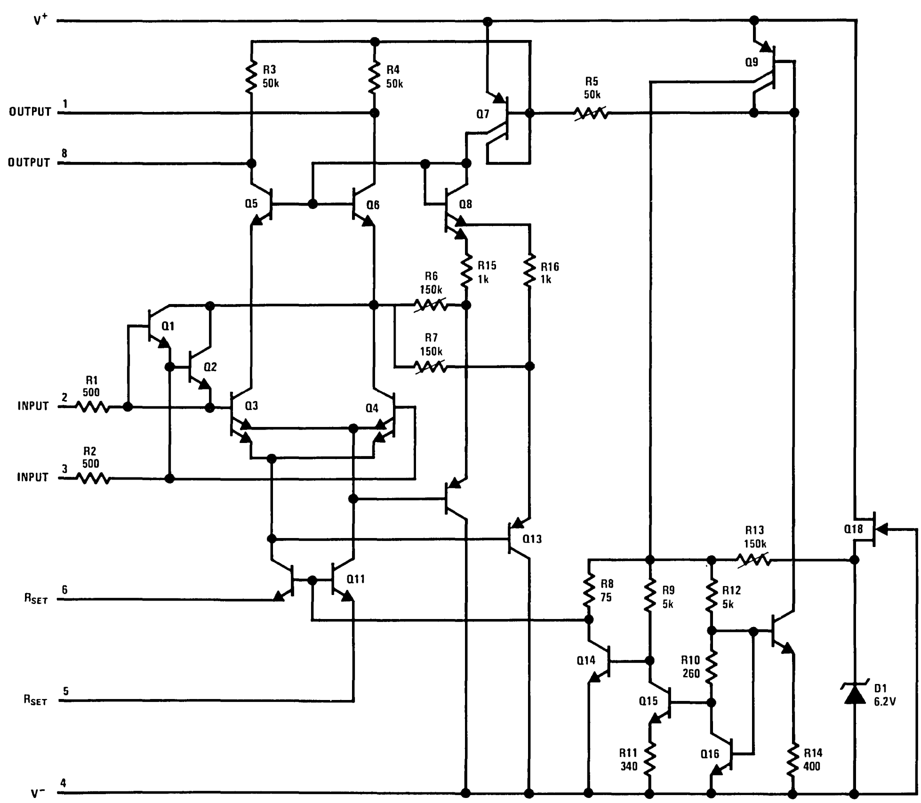
Medium Speed* General Purpose Amplifier

typical applications (con't)



Increased Common-Mode Range at High Operating Currents

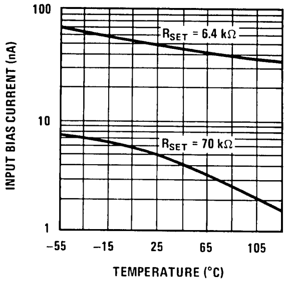
schematic diagram*



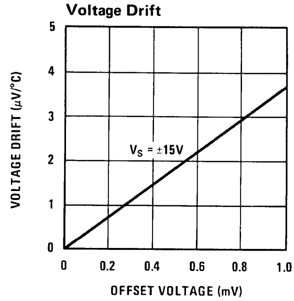
*Pin connections shown on schematic diagram and typical applications are for TO-5 package.

typical performance characteristics

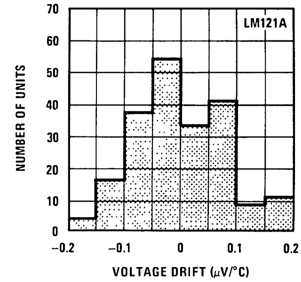
Input Bias Current



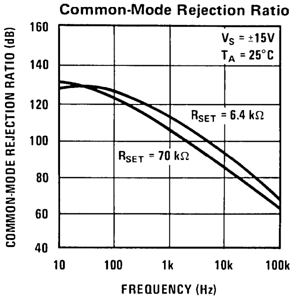
Voltage Drift



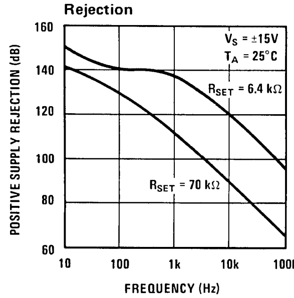
Distribution of Offset Voltage Drift (Nulled)



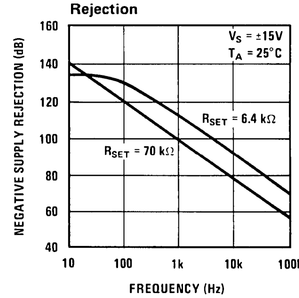
Common-Mode Rejection Ratio



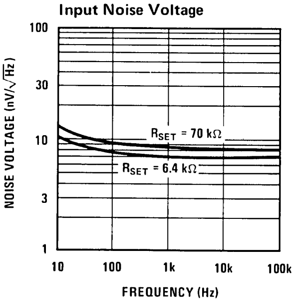
Positive Power Supply Rejection



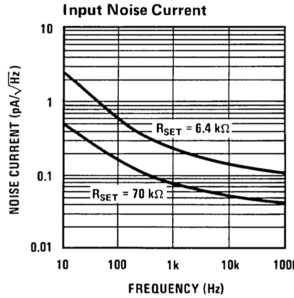
Negative Power Supply Rejection



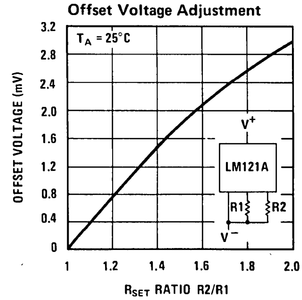
Input Noise Voltage



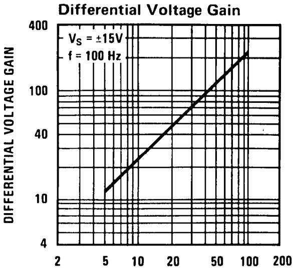
Input Noise Current



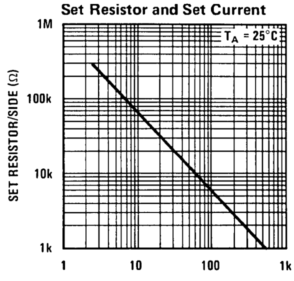
Offset Voltage Adjustment



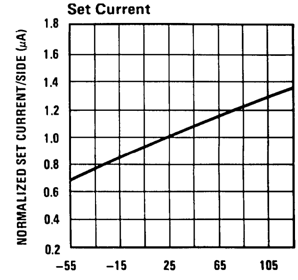
Differential Voltage Gain



Set Resistor and Set Current

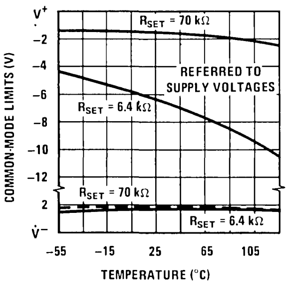


Set Current

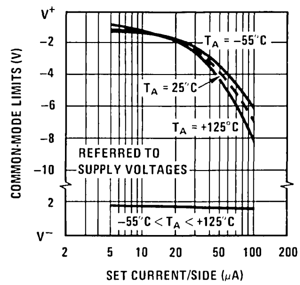


typical performance characteristics (con't)

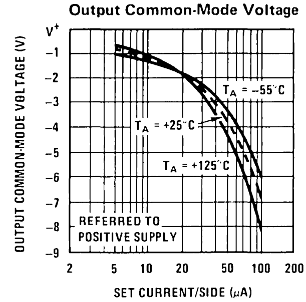
Common-Mode Limits



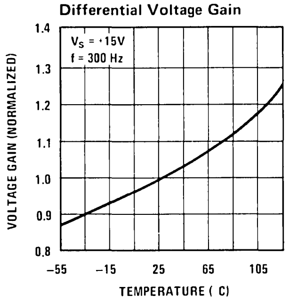
Common-Mode Limits



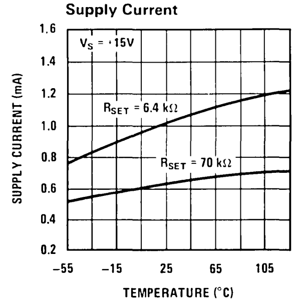
Output Common-Mode Voltage



Differential Voltage Gain



Supply Current



2

Operational Amplifiers

LM124/LM224/LM324 quad op amps

general description

The LM124 series consists of four independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, dc gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM124 series can be directly operated off of the standard +5 V_{DC} power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15 V_{DC} power supplies.

unique characteristics

- In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage.
- The unity gain cross frequency is temperature compensated.
- The input bias current is also temperature compensated.

advantages

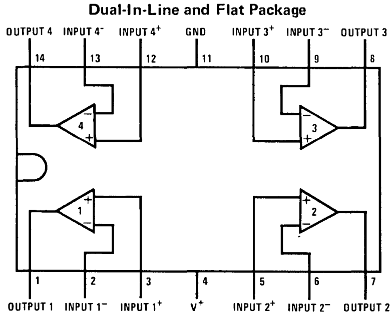
- Eliminates need for dual supplies
- Four internally compensated op amps in a single package
- Allows directly sensing near GND and V_{OUT} also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation

features

- Internally frequency compensated for unity gain
- Large dc voltage gain: 100 dB
- Wide bandwidth (unity gain) (temperature compensated): 1 MHz
- Wide power supply range:
  - Single supply: 3 V_{DC} to 30 V_{DC}
  - or dual supplies: ±1.5 V_{DC} to ±15 V_{DC}
- Very low supply current drain (800μA) — essentially independent of supply voltage (1 mW/op amp at +5 V_{DC})
- Low input biasing current (temperature compensated): 45 nA_{DC}
- Low input offset voltage: 2 mV_{DC}; and offset current: 5 nA_{DC}
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Large output voltage swing: 0 V_{DC} to $V^+ - 1.5$ V_{DC}

connection diagram

Dual-In-Line and Flat Package

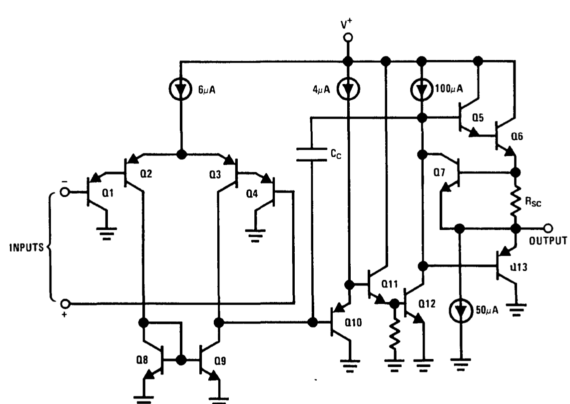


Order Number LM124D, LM224D or LM324D
See Package 1

Order Number LM124F
See Package 4

Order Number LM324N
See Package 22

schematic diagram (Each Amplifier)



absolute maximum ratings

Supply Voltage, V^+	32 V_{DC} or ±16 V_{DC}
Differential Input Voltage	32 V_{DC}
Input Voltage	−0.3 V_{DC} to +32 V_{DC}
Power Dissipation (Note 1)	
Molded DIP (LM324N)	570 mW
Cavity DIP (LM124D, LM224D & LM324D)	900 mW
Flat Pack (LM124F)	800 mW
Output Short-Circuit to GND (Note 2) (One Amplifier) $V^+ \leq 15\ V_{DC}$ and T_A = 25°C	Continuous
Input Current ($V_{IN} < -0.3\ V_{OL}$) (Note 3)	50 mA
Operating Temperature Range	
LM324	0°C to +70°C
LM224	−25°C to +85°C
LM124	−55°C to +125°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (V^+ = +5.0 V_{DC}, Note 4) LM124

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	T_A = +25°C (Note 5)		±2	±5	mV_{DC}
Input Bias Current (Note 6)	$I_{IN(+)}$ or $I_{IN(-)}$, T_A = +25°C		45	150	nA_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, T_A = +25°C		±3	±30	nA_{DC}
Input Common-Mode Voltage Range (Note 7)	V^+ = 30 V_{DC}, T_A = +25°C	0		V^+−1.5	V_{DC}
Supply Current	$R_L = \infty$ On All Op Amps Over Full Temperature Range		0.8	2	mA_{DC}
Large Signal Voltage Gain	V^+ = +15 V_{DC} (For Large V_O Swing) $R_L \geq 2\ k\Omega$, T_A = +25°C	50	100		V/mV
Common-Mode Rejection Ratio	DC, T_A = +25°C	70	85		dB
Power Supply Rejection Ratio	DC, T_A = +25°C	65	100		dB
Amplifier-to-Amplifier Coupling (Note 8)	f = 1 kHz to 20 kHz, T_A = +25°C (Input Referred)		−120		dB
Output Current					
Source	V_{IN}^+ = +1 V_{DC}, V_{IN}^- = 0 V_{DC}, V^+ = 15 V_{DC}, T_A = +25°C	20	40		mA_{DC}
Sink	V_{IN}^- = +1 V_{DC}, V_{IN}^+ = 0 V_{DC}, V^+ = 15 V_{DC}, T_A = +25°C	10	20		mA_{DC}
	V_{IN}^- = +1 V_{DC}, V_{IN}^+ = 0 V_{DC}, T_A = +25°C, V_O = 200 mV_{DC}	12	50		μA_{DC}
Input Offset Voltage	(Note 5)			±7	mV_{DC}
Input Offset Voltage Drift	R_S = 0Ω		7		μV/°C
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$			±100	nA_{DC}
Input Offset Current Drift			10		pA_{DC}/°C
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$			300	nA_{DC}
Input Common-Mode Voltage Range (Note 7)	V^+ = 30 V_{DC}	0		V^+−2	V_{DC}
Large Signal Voltage Gain	V^+ = +15 V_{DC} (For Large V_O Swing) $R_L \geq 2\ k\Omega$	25			V/mV
Output Voltage Swing					
V_{OH}	V^+ = +30 V_{DC}, R_L = 2 kΩ	26			V_{DC}
	$R_L \geq 10\ k\Omega$	27	28		V_{DC}
V_{OL}	V^+ = +5 V_{DC}, $R_L \leq 10\ k\Omega$		5	20	mV_{DC}
Output Current					
Source	V_{IN}^+ = +1 V_{DC}, V_{IN}^- = 0 V_{DC}, V^+ = 15 V_{DC}	10	20		mA
Sink	V_{IN}^- = +1 V_{DC}, V_{IN}^+ = 0 V_{DC}, V^+ = 15 V_{DC}	5	8		mA
Differential Input Voltage (Note 7)				V^+	V_{DC}

electrical characteristics ($V^+ = +5.0\ V_{DC}$, Note 4) LM224, LM324

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = +25°C$ (Note 5)		±2	±7	mV_{DC}
Input Bias Current (Note 6)	$I_{IN(+)}$ or $I_{IN(-)}$, $T_A = +25°C$		45	250	nA_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $T_A = +25°C$		±5	±50	nA_{DC}
Input Common-Mode Voltage Range (Note 7)	$V^+ = 30\ V_{DC}$, $T_A = +25°C$	0		$V^+-1.5$	V_{DC}
Supply Current	$R_L = \infty$ On All Op Amps Over Full Temperature Range		0.8	2	mA_{DC}
Large Signal Voltage Gain	$V^+ = +15\ V_{DC}$ (For Large V_O Swing) $R_L \geq 2\ k\Omega$, $T_A = +25°C$	25	100		V/mV
Common-Mode Rejection Ratio	DC, $T_A = +25°C$	65	85		dB
Power Supply Rejection Ratio	DC, $T_A = +25°C$	65	100		dB
Amplifier-to-Amplifier Coupling (Note 8)	f = 1 kHz to 20 kHz, $T_A = +25°C$ (Input Referred)		−120		dB
Output Current					
Source	$V_{IN}^+ = +1\ V_{DC}$, $V_{IN}^- = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$, $T_A = +25°C$	20	40		mA_{DC}
Sink	$V_{IN}^- = +1\ V_{DC}$, $V_{IN}^+ = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$, $T_A = +25°C$	10	20		mA_{DC}
	$V_{IN}^- = +1\ V_{DC}$, $V_{IN}^+ = 0\ V_{DC}$, $T_A = +25°C$, $V_O = 200\ mV_{DC}$	12	50		μA_{DC}
Input Offset Voltage	(Note 5)			±9	mV_{DC}
Input Offset Voltage Drift	$R_S = 0\Omega$		7		$\mu V/°C$
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$			±150	nA_{DC}
Input Offset Current Drift			10		$pA_{DC}/°C$
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$			500	nA_{DC}
Input Common-Mode Voltage Range (Note 7)	$V^+ = 30\ V_{DC}$	0		V^+-2	V_{DC}
Large Signal Voltage Gain	$V^+ = +15\ V_{DC}$ (For Large V_O Swing) $R_L \geq 2\ k\Omega$	15			V/mV
Output Voltage Swing					
V_{OH}	$V^+ = +30\ V_{DC}$, $R_L = 2\ k\Omega$	26			V_{DC}
	$R_L \geq 10\ k\Omega$	27	28		V_{DC}
V_{OL}	$V^+ = +5\ V_{DC}$, $R_L \leq 10\ k\Omega$		5	20	mV_{DC}
Output Current					
Source	$V_{IN}^+ = +1\ V_{DC}$, $V_{IN}^- = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$	10	20		mA
Sink	$V_{IN}^- = +1\ V_{DC}$, $V_{IN}^+ = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$	5	8		mA
Differential Input Voltage (Note 7)				V^+	V_{DC}

Note 1: For operating at high temperatures, the LM324 must be derated based on a +125°C maximum junction temperature and a thermal resistance of 175°C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM224 and LM124 can be derated based on a +150°C maximum junction temperature. The dissipation is the total of all four amplifiers—use external resistors, where possible, to allow the amplifier to saturate or to reduce the power which is dissipated in the integrated circuit.

Note 2: Short circuits from the output to V^+ can cause excessive heating and eventual destruction. The maximum output current is approximately 40 mA independent of the magnitude of V^+. At values of supply voltage in excess of +15 V_{DC}, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction.

Note 3: This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the op amps to go to the V^+ voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than −0.3 V_{DC}.

Note 4: These specifications apply for $V^+ = +5\ V_{DC}$ and $-55°C \leq T_A \leq +125°C$, unless otherwise stated. With the LM224, all temperature specifications are limited to $-25°C \leq T_A \leq +85°C$ and the LM324 temperature specifications are limited to $0°C \leq T_A \leq +70°C$.

Note 5: $V_O \cong 1.4\ V_{DC}$, $R_S = 0\Omega$ with V^+ from 5 V_{DC} to 30 V_{DC}; and over the full input common-mode range (0 V_{DC} to $V^+ - 1.5\ V_{DC}$).

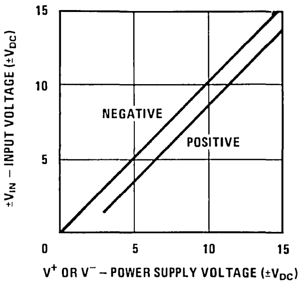
Note 6: The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.

Note 7: The input common-mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3V. The upper end of the common-mode voltage range is $V^+ - 1.5V$, but either or both inputs can go to +32 V_{DC} without damage.

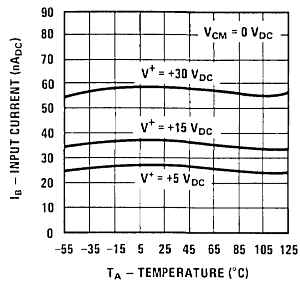
Note 8: Due to proximity of external components, insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitive coupling increases at higher frequencies.

typical performance characteristics

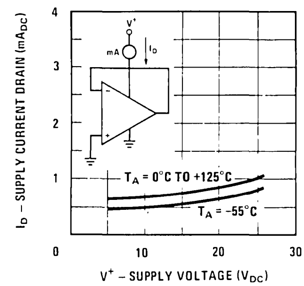
Input Voltage Range



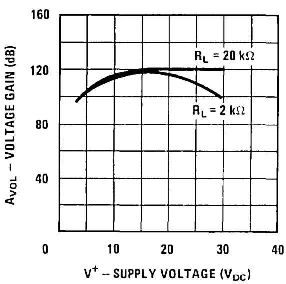
Input Current



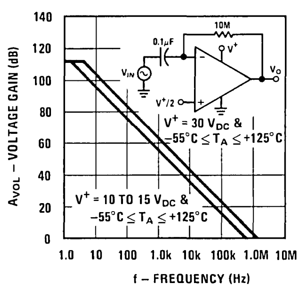
Supply Current



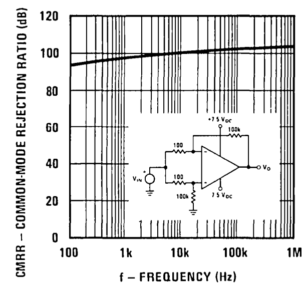
Voltage Gain



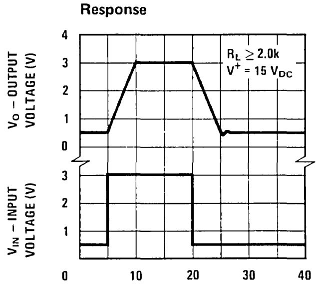
Open Loop Frequency Response



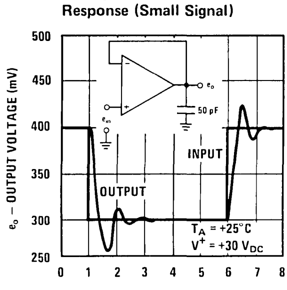
Common Mode Rejection Ratio



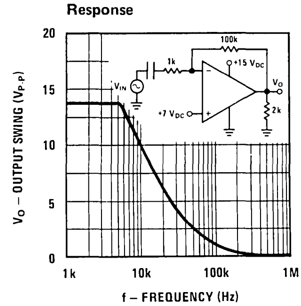
Voltage Follower Pulse Response



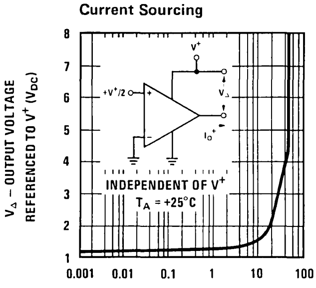
Voltage Follower Pulse Response (Small Signal)



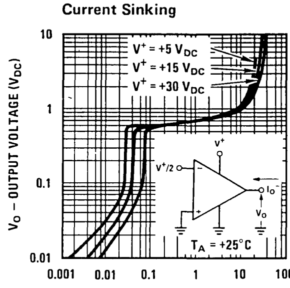
Large Signal Frequency Response



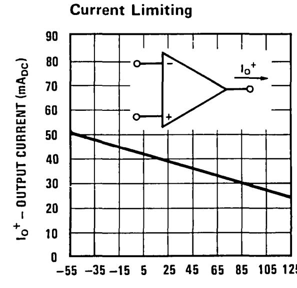
Output Characteristics Current Sourcing



Output Characteristics Current Sinking



Current Limiting



application hints

The LM124 series are op amps which operate with only a single power supply voltage, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of 0 V_{DC}. These amplifiers operate over a wide range of power supply voltage with little change in performance characteristics. At 25°C amplifier operation is possible down to a minimum supply voltage of 2.3 V_{DC}.

The pinouts of the package have been designed to simplify PC board layouts. Inverting inputs are adjacent to outputs for all of the amplifiers and the outputs have also been placed at the corners of the package (pins 1, 7, 8, and 14).

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a test socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Large differential input voltages can be easily accommodated and, as input differential voltage protection diodes are not needed, no large input currents result from large differential input voltages. The differential input voltage may be larger than V^+ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than −0.3 V_{DC} (at 25°C). An input clamp diode with a resistor to the IC input terminal can be used.

To reduce the power supply current drain, the amplifiers have a class A output stage for small signal levels which converts to class B in a large signal mode. This allows the amplifiers to both source and sink large output currents. Therefore both NPN and PNP external current boost transistors can be used to extend the power capability of the basic amplifiers. The output voltage needs to raise approximately 1 diode drop above ground to bias the on-chip vertical PNP transistor for output current sinking applications.

For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor should be used, from the output of the amplifier to ground to increase the class A bias current and prevent crossover distortion. Where the load is directly coupled, as in dc applications, there is no crossover distortion.

Capacitive loads which are applied directly to the output of the amplifier reduce the loop stability margin. Values of 50 pF can be accommodated using the worst-case non-inverting unity gain connection. Large closed loop gains or resistive isolation should be used if larger load capacitance must be driven by the amplifier.

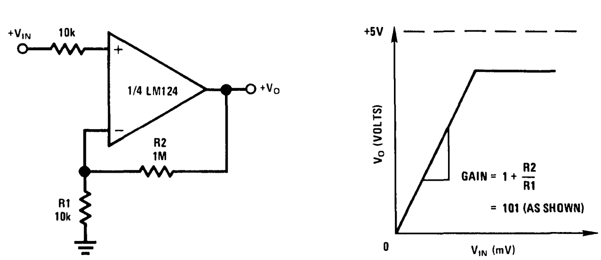
The bias network of the LM124 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from 3 V_{DC} to 30 V_{DC}.

Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperatures. Putting direct short-circuits on more than one amplifier at a time will increase the total IC power dissipation to destructive levels, if not properly protected with external dissipation limiting resistors in series with the output leads of the amplifiers. The larger value of output source current which is available at 25°C provides a larger output current capability at elevated temperatures (see typical performance characteristics) than a standard IC op amp.

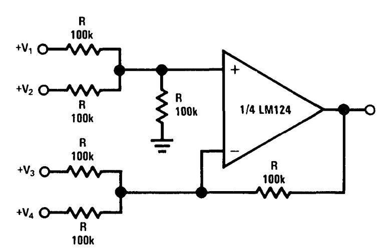
The circuits presented in the section on typical applications emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op amp circuits can be used. In general, introducing a pseudo-ground (a bias voltage reference of $V^+/2$) will allow operation above and below this value in single power supply systems. Many application circuits are shown which take advantage of the wide input common-mode voltage range which includes ground. In most cases, input biasing is not required and input voltages which range to ground can easily be accommodated.

typical single-supply applications ($V^+ = 5.0\ V_{DC}$)

Non-Inverting DC Gain (0V Input = 0V Output)



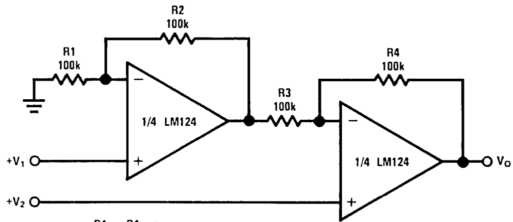
DC Summing Amplifier
(V_{IN}'S ≥ 0 V_{DC} AND V_O ≥ 0 V_{DC})



Where: $V_O = V_1 + V_2 - V_3 - V_4$
$(V_1 + V_2) \geq (V_3 + V_4)$ to keep $V_O > 0\ V_{DC}$

typical single-supply applications (con't) ($V^+ = 5.0\ V_{DC}$)

High Input Z, DC Differential Amplifier

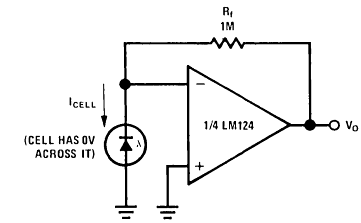


For $\frac{R1}{R2} = \frac{R4}{R3}$ (CMRR depends on this resistor ratio match)

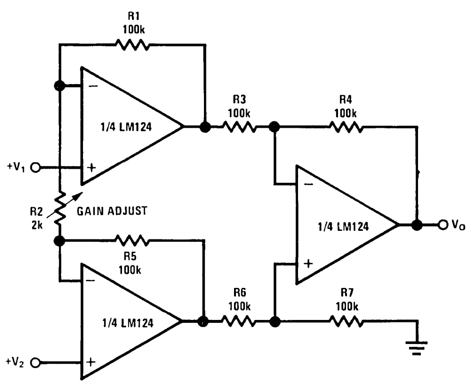
$V_O = 1 + \frac{R4}{R3}\ (V_2 - V_1)$

As shown: $V_O = 2\,(V_2 - V_1)$

Photo Voltaic-Cell Amplifier



High Input Z Adjustable-Gain DC Instrumentation Amplifier

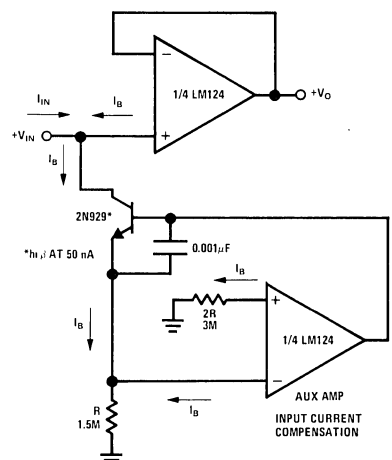


If R1 = R5 & R3 = R4 = R6 = R7 (CMRR depends on match)

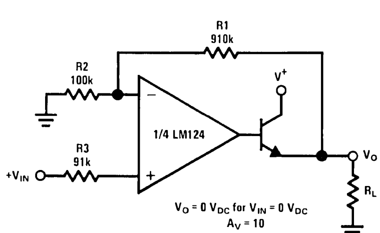
$V_O = 1 + \frac{2R1}{R2}\ (V_2 - V_1)$

As shown $V_O = 101\ (V_2 - V_1)$

Using Symmetrical Amplifiers to Reduce Input Current (General Concept)



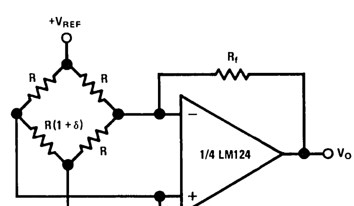
Power Amplifier



$V_O = 0\ V_{DC}$ for $V_{IN} = 0\ V_{DC}$

$A_V = 10$

Bridge Current Amplifier



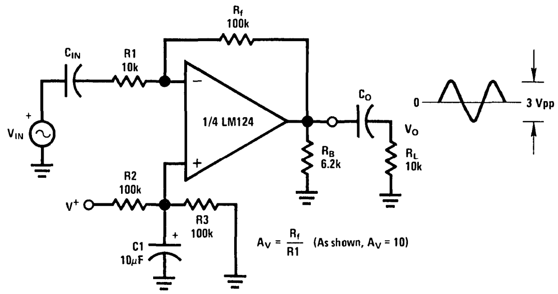
For $\delta << 1$ and $R_f >> R$

$V_O \cong V_{REF}\left(\frac{\delta}{2}\right)\frac{R_f}{R}$

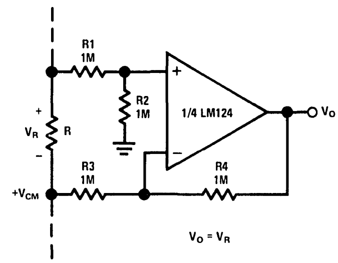
2

typical single-supply applications (con't) ($V^+ = 5.0\ V_{DC}$)

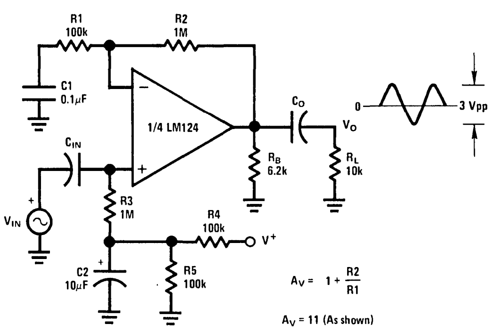
AC Coupled Inverting Amplifier



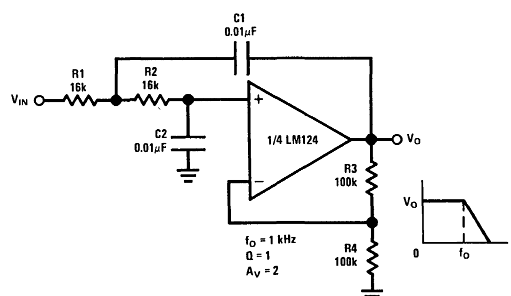
Ground Referencing A Differential Input Signal



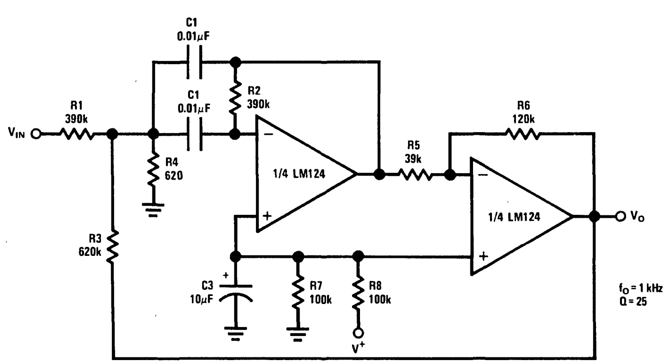
AC Coupled Non-Inverting Amplifier



DC Coupled Low-Pass RC Active Filter

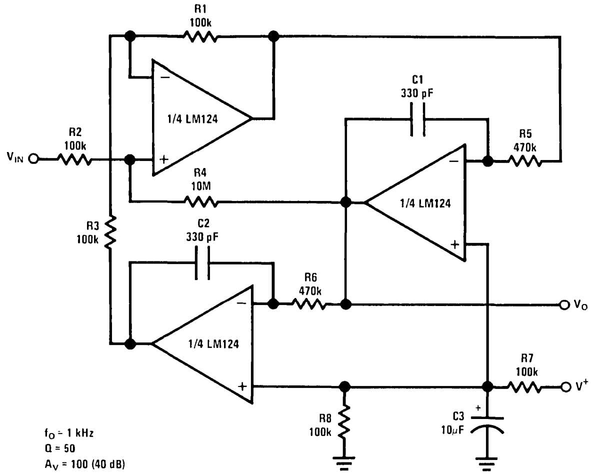


Bandpass Active Filter

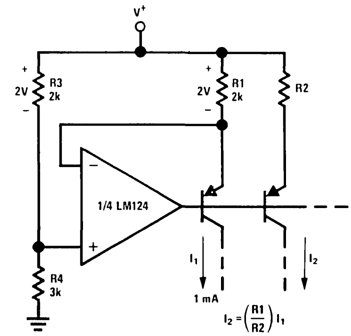


typical single-supply applications (con't) ($V^+ = 5.0\ V_{DC}$)

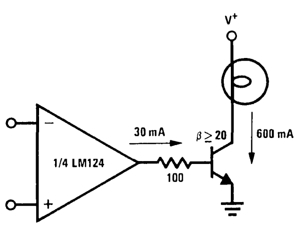
"BI-QUAD" RC Active Bandpass Filter



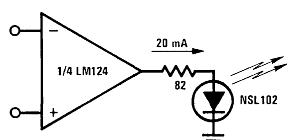
Fixed Current Sources



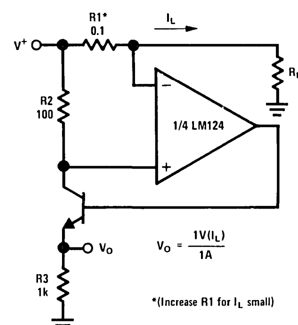
Lamp Driver



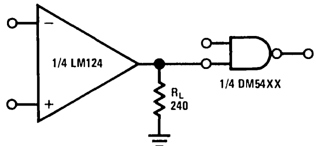
LED Driver



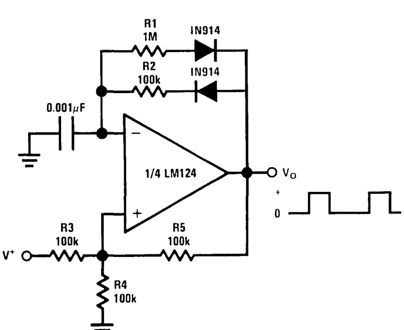
Current Monitor



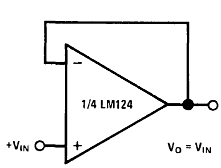
Driving TTL



Pulse Generator

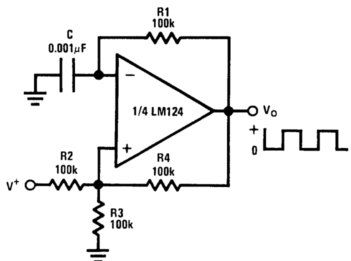


Voltage Follower

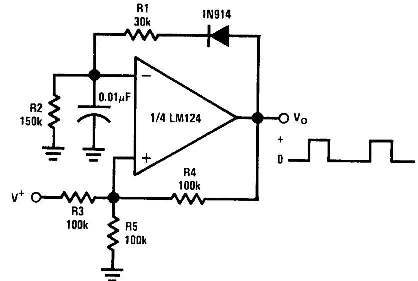


typical single-supply applications (con't) ($V^+ = 5.0\ V_{DC}$)

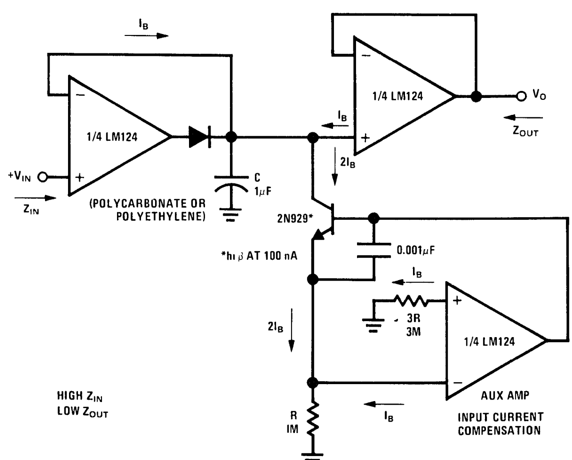
Squarewave Oscillator



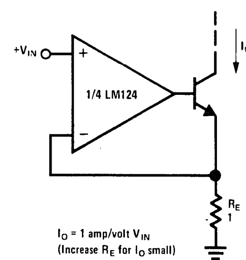
Pulse Generator



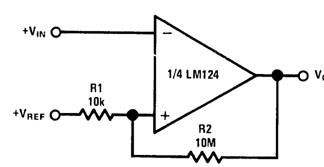
Low Drift Peak Detector



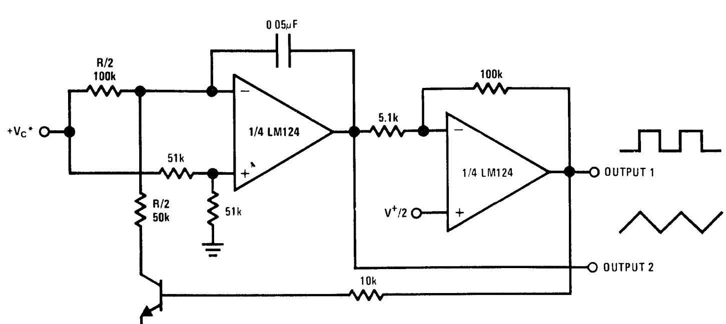
High Compliance Current Sink



Comparator with Hysteresis



Voltage Controlled Oscillator (VCO)



*Wide Control Voltage Range: $0\ V_{DC} < V_C < 2\ (V^+ - 1.5\ V_{DC})$

Operational Amplifiers

LM143/LM343 high voltage operational amplifier

general description

The LM143 is a general purpose high voltage operational amplifier featuring operation to ±40V, complete input overvoltage protection up to ±40V and input currents comparable to those of other super-β op amps. Increased slew rate, together with higher common-mode and supply rejection, insure improved performance at high supply voltages. Operating characteristics, in particular supply current, slew rate and gain, are virtually independent of supply voltage and temperature. Furthermore, gain is unaffected by output loading at high supply voltages due to thermal symmetry on the die. The LM143 is pin compatible with general purpose op amps and has offset null capability.

Application areas include those of general purpose op amps, but can be extended to higher voltages and higher output power when externally boosted. For example, when used in audio power applications, the LM143 provides a power bandwidth that covers the entire audio spectrum. In addition, the LM143 can be reliably operated in environments with large overvoltage spikes on the power supplies, where other internally-compensated op amps would suffer catastrophic failure.

The LM343 is similar to the LM143 for applications in less severe supply voltage and temperature environments.

features

- Wide supply voltage range ±4.0V to ±40V
- Large output voltage swing ±37V
- Wide input common-mode range ±38V
- Input overvoltage protection Full ±40V
- Supply current is virtually independent of supply voltage and temperature

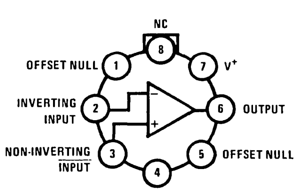
unique characteristics

- Low input bias current 8.0 nA
- Low input offset current 1.0 nA
- High slew rate—essentially independent of temperature and supply voltage 2.5V/μs
- High voltage gain—virtually independent of resistive loading, temperature, and supply voltage 100k min
- Internally compensated for unity gain
- Output short circuit protection
- Pin compatible with general purpose op amps

2

connection diagrams

Metal Can Package

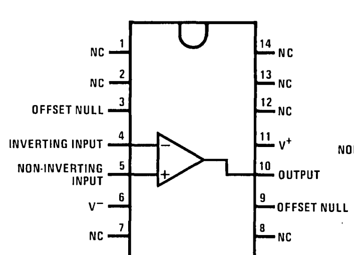


NOTE: Pin 4 connected to case.

TOP VIEW

Order Number LM143H or LM343H
See Package 11

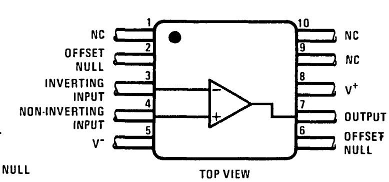
Dual-In-Line Package



TOP VIEW

Order Number LM143D or LM343D
See Package 1

Flat Package



TOP VIEW

Note: Pin 5 connected to bottom of package.

Order Number LM143F
See Package 3

absolute maximum ratings

	LM143	LM343
Supply Voltage	±40V	±34V
Power Dissipation (Note 1)	500 mW	500 mW
Differential Input Voltage (Note 2)	80V	68V
Input Voltage (Note 2)	±40V	±34V
Operating Temperature Range	−55°C to +125°C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C
Output Short Circuit Duration	5 seconds	5 seconds
Lead Temperature (Soldering, 10 seconds)	300°C	300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	LM143			LM343			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$		2.0	5.0		2.0	8.0	mV
Input Offset Current	$T_A = 25°C$		1.0	3.0		1.0	10	nA
Input Bias Current	$T_A = 25°C$		8.0	20		8.0	40	nA
Supply Voltage Rejection Ratio	$T_A = 25°C$		10	100		10	200	μV/V
Output Voltage Swing	$T_A = 25°C$, $R_L \geq 5\ k\Omega$	22	25		20	25		V
Large Signal Voltage Gain	$T_A = 25°C$, $V_{OUT} = \pm10V$, $R_L \geq 100\ k\Omega$	100k	180k		70k	180k		V/V
Common-Mode Rejection Ratio	$T_A = 25°C$	80	90		70	90		dB
Input Voltage Range	$T_A = 25°C$	24	26		22	26		V
Supply Current (Note 4)	$T_A = 25°C$		2.0	4.0		2.0	5.0	mA
Short Circuit Current	$T_A = 25°C$		20			20		mA
Slew Rate	$T_A = 25°C$, $A_V = 1$		2.5			2.5		V/μs
Power Bandwidth	$T_A = 25°C$, $V_{OUT} = 40\ V_{P\text{-}P}$, $R_L = 5\ k\Omega$, THD $\leq 1\%$		20k			20k		Hz
Unity Gain Frequency	$T_A = 25°C$		1.0M			1.0M		Hz
Input Offset Voltage	T_A = Max T_A = Min			6.0 6.0			10 10	mV mV
Input Offset Current	T_A = Max T_A = Min		0.8 1.8	4.5 7.0		0.8 1.8	14 14	nA nA
Input Bias Current	T_A = Max T_A = Min		5.0 16	35 35		5.0 16	55 55	nA nA
Large Signal Voltage Gain	$R_L \geq 100\ k\Omega$, T_A = Max $R_L \geq 100\ k\Omega$, T_A = Min	50k 50k	150k 220k		50k 50k	150k 220k		V/V V/V
Output Voltage Swing	$R_L \geq 5.0\ k\Omega$, T_A = Max $R_L \geq 5.0\ k\Omega$, T_A = Min	22 22	26 25		20 20	26 25		V V

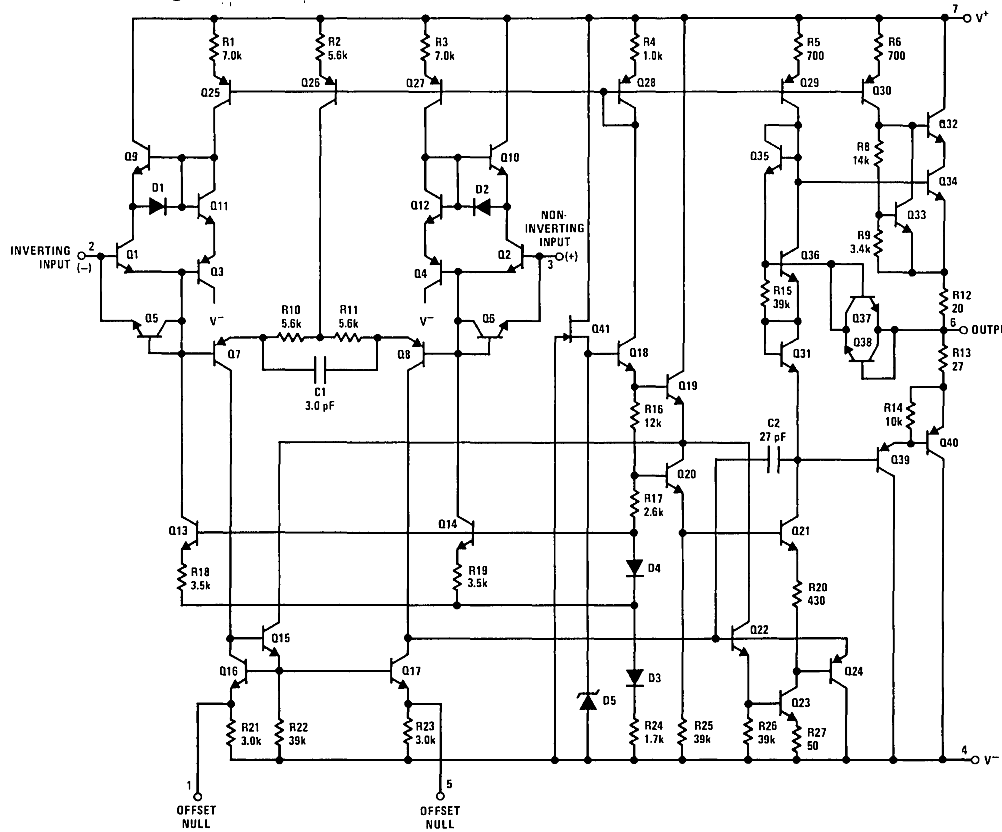
Note 1: The maximum junction temperature of the LM143 is 150°C, while that of the LM343 is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

Note 2: For supply voltage less than ±40V for the LM143 and less than ±34V for the LM343, the absolute maximum input voltage is equal to the supply voltage.

Note 3: These specifications apply for $V_S = \pm28V$ unless otherwise specified.
For LM143, T_A = max = 125°C and T_A = min = −55°C.
For LM343, T_A = max = 70°C and T_A = min = 0°C.

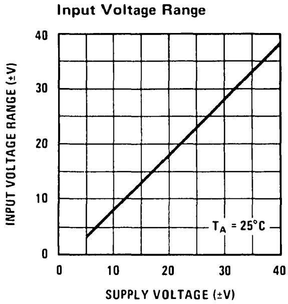
Note 4: The maximum supply currents are guaranteed at $V_S = \pm40V$ for the LM143 and $V_S = \pm34V$ for the LM343.

schematic diagram

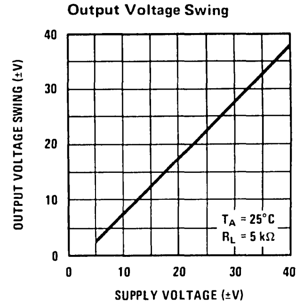


typical performance characteristics

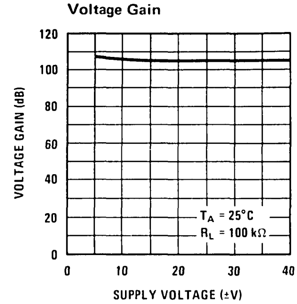
Input Voltage Range



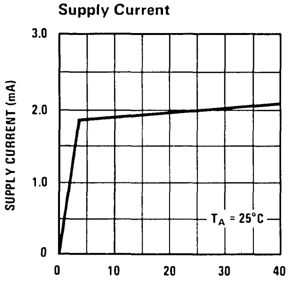
Output Voltage Swing



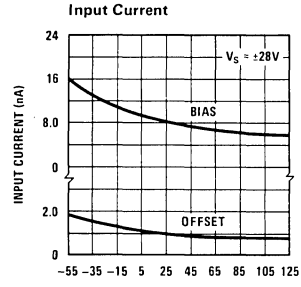
Voltage Gain



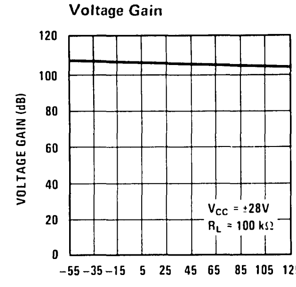
Supply Current



Input Current

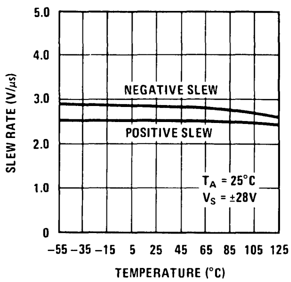


Voltage Gain

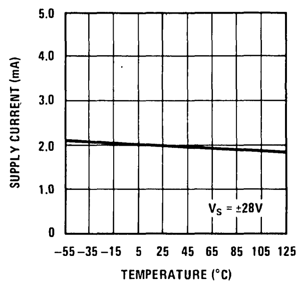


typical performance characteristics (con't)

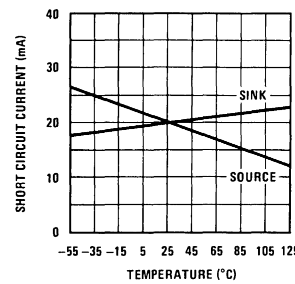
Voltage Follower Slew Rate



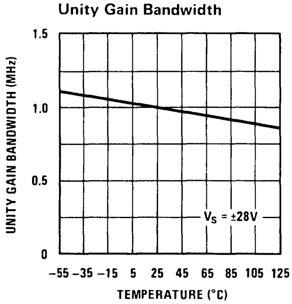
Supply Current



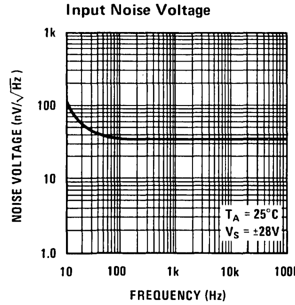
Short Circuit Current



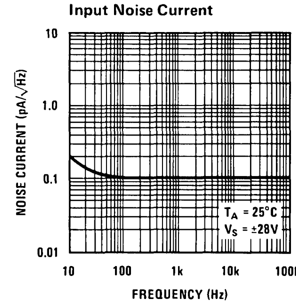
Unity Gain Bandwidth



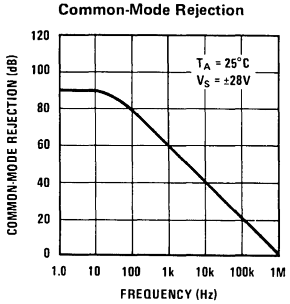
Input Noise Voltage



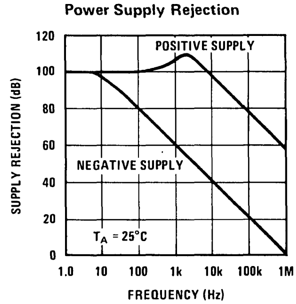
Input Noise Current



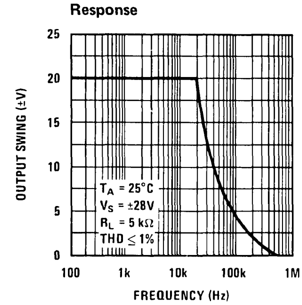
Common-Mode Rejection



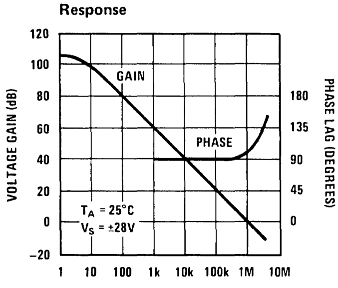
Power Supply Rejection



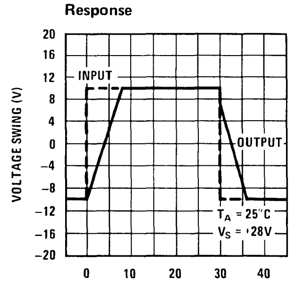
Large Signal Frequency Response



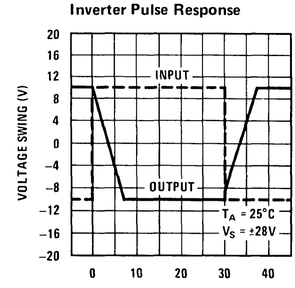
Open Loop Frequency Response



Voltage Follower Pulse Response



Inverter Pulse Response



application hints

The LM143 is designed for trouble free operation at any supply voltage up to and including the guaranteed maximum of ±40V. Input overvoltage protection, both common-mode and differential, is 100% tested and guaranteed at the maximum supply voltage. Furthermore, all possible high voltage destructive modes during supply voltage turn-on have been eliminated by design. As with most IC op amps, however, certain precautions should be observed to insure that the LM143 remains virtually blow-out proof.

Although output short circuits to ground or either supply can be sustained indefinitely at lower supply voltages, these short circuits should be of short duration when operating at higher supply voltages. Units can be destroyed by the resulting high power dissipation which causes failure due to excessive die temperature. This is also true when driving low impedance loads or loads that can revert to low impedance; for example, the LM143 can drive most general purpose op amps outside of their maximum input voltage range, causing heavy current to flow and possibly destroying both devices.

Precautions should be taken to insure that the power supplies never become reversed in polarity—even under transient conditions. With reverse voltage, the IC will conduct excessive current, fusing the internal aluminum interconnects. Voltage reversal between the power supplies will almost always result in a destroyed unit.

In high voltage applications which are sensitive to very low input currents, special precautions should be exercised. For example, with high source resistances, care should be taken to prevent the magnitude of the PC board leakage currents, although quite small, from approaching those of the op amp input currents. These leakage currents become larger at 125°C and are made worse by high supply voltages. To prevent this, PC boards should be properly cleaned and coated to prevent contamination and to provide protection from condensed water vapor when operating below 0°C. A guard ring is also recommended to significantly reduce leakage currents from the op amp input pins to the adjacent high voltage pins in the standard op amp pin connection as shown in *Figure 1. Figures 2, 3 and 4* show how the guard ring is connected for the three most common op amp configurations.

Finally, caution should be exercised in high voltage applications as electrical shock hazards are present. Since the negative supply is connected to the case, users may inadvertantly contact voltages equal to those across the power supplies.

The LM143 can be used as a plug-in replacement in most general purpose op amp applications. The circuits presented in the following section emphasize those applications which take advantage of the unique high voltage capabilities of the LM143.

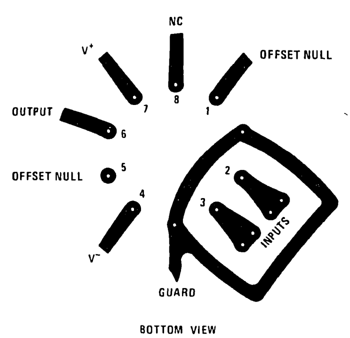


FIGURE 1. Printed Circuit Layout for Input Guarding with TO-5 Package

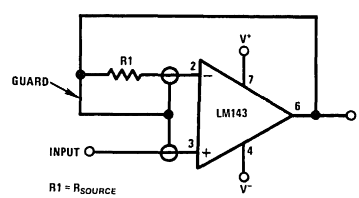


FIGURE 2. Guarded Voltage Follower

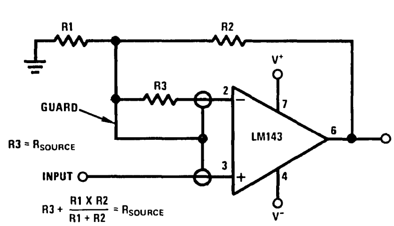


FIGURE 3. Guarded Non-Inverting Amplifier

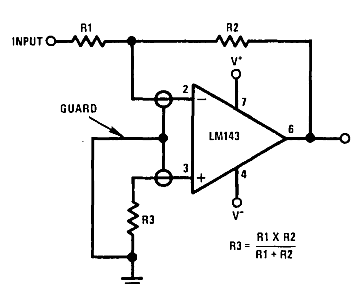
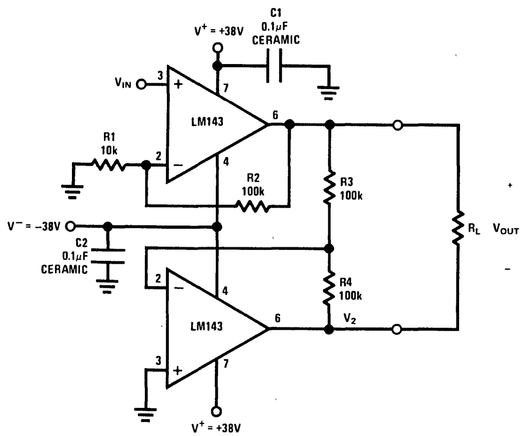
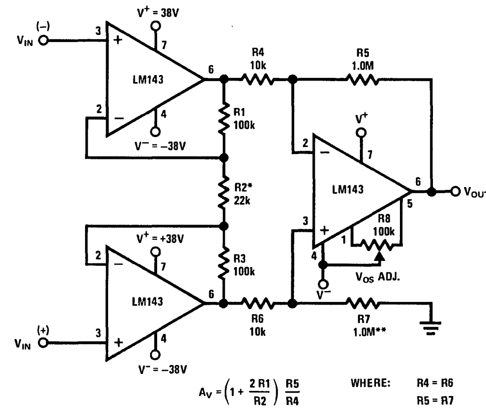


FIGURE 4. Guarded Inverting Amplifier

typical applications ‡ (For more detail see AN-127)



140 Vp-p Drive Across a Floating Load

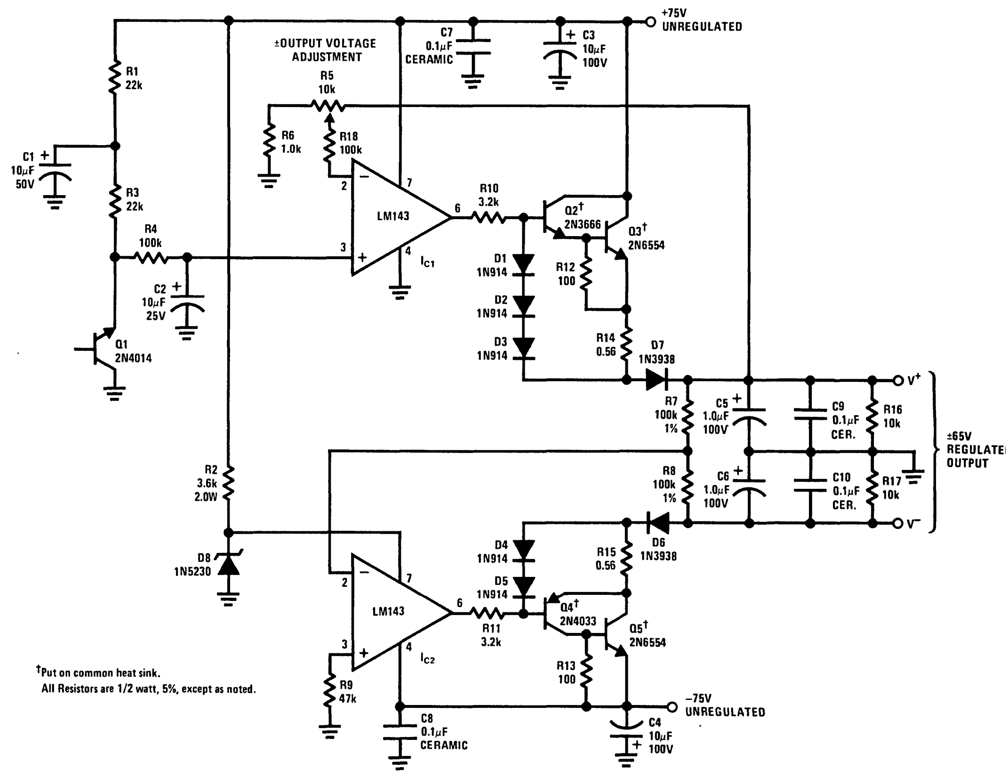


$$A_V = \left(1 + \frac{2\,R1}{R2}\right)\frac{R5}{R4}$$

WHERE: R4 = R6
R5 = R7

*R2 may be adjustable to trim the gain.
**R7 may be adjusted to compensate for the resistance tolerance of R4 – R7 for best CMR.

±36V Common-Mode Instrumentation Amplifier

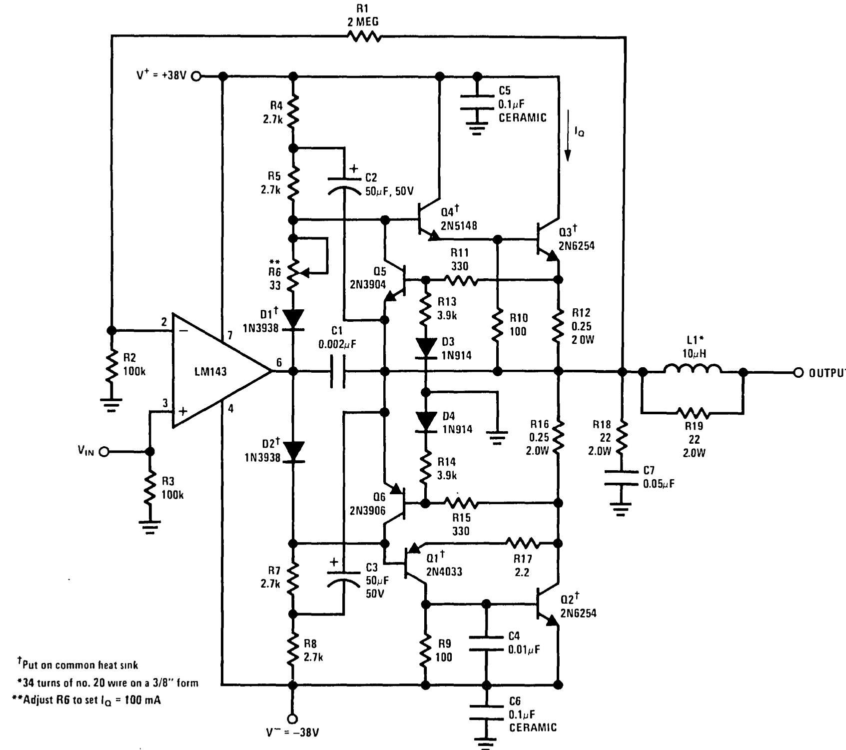


†Put on common heat sink.
All Resistors are 1/2 watt, 5%, except as noted.

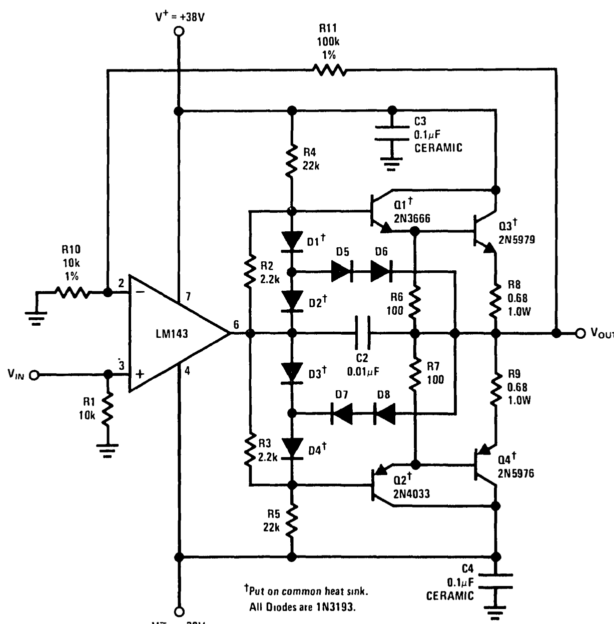
Tracking ±65V, 1 Amp Power Supply with Short Circuit Protection

‡The 38V supplies allow for a 5% voltage tolerance. All resistors are 1/2 watt, except as noted.

typical applications ‡ (con't) (For more detail see AN-127)



100W Audio Power Amplifier with Safe Area Protection



1 Amp Power Amplifier with Short Circuit Protection

‡The 38V supplies allow for a 5% voltage tolerance. All resistors are 1/2 watt, except as noted.

Operational Amplifiers

LM158/LM258/LM358 dual op amps

general description

The LM158 series consists of two independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, dc gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM158 series can be directly operated off of the standard +5 V_{DC} power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15 V_{DC} power supplies.

unique characteristics

- In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage.
- The unity gain cross frequency is temperature compensated.
- The input bias current is also temperature compensated.

advantages

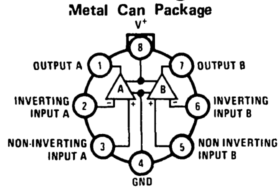
- Eliminates need for dual supplies
- Two internally compensated op amps in a single package
- Allows directly sensing near GND and V_{OUT} also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation
- Pin-out same as LM1558/LM1458 dual operational amplifier

features

- Internally frequency compensated for unity gain
- Large dc voltage gain — 100 dB
- Wide bandwidth (unity gain) (temperature compensated) — 1 MHz
- Wide power supply range:
  - Single supply — 3 V_{DC} to 30 V_{DC}
  - or dual supplies — ±1.5 V_{DC} to ±15 V_{DC}
- Very low supply current drain (500μA) – essentially independent of supply voltage (1 mW/op amp at +5 V_{DC})
- Low input biasing current (temperature compensated) — 45 nA_{DC}
- Low input offset voltage — 2 mV_{DC}
  and offset current — 5 nA_{DC}
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Large output voltage swing — 0 V_{DC} to V^+ – 1.5 V_{DC}

connection diagrams

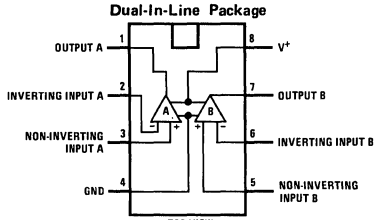
Metal Can Package



TOP VIEW

Order Number LM158H, LM258H or LM358H
See Package 11

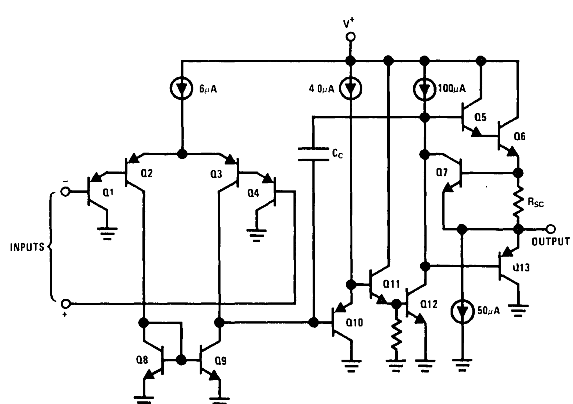
Dual-In-Line Package



TOP VIEW

Order Number LM358N
See Package 20

schematic diagram (Each Amplifier)



absolute maximum ratings

Supply Voltage, V^+	32 V_{DC} or ±16 V_{DC}
Differential Input Voltage	32 V_{DC}
Input Voltage	−0.3 V_{DC} to +32 V_{DC}
Power Dissipation (Note 1)	
Molded DIP (LM358N)	570 mW
Metal Can (LM158H, LM258H & LM358H)	500 mW
Output Short-Circuit to GND (Note 2) (One Amplifier) $V^+ \leq 15\ V_{DC}$ and $T_A = 25°C$	Continuous
Input Current ($V_{IN} < -0.3\ V_{OL}$) (Note 3)	50 mA
Operating Temperature Range	
LM358	0°C to +70°C
LM258	−25°C to +85°C
LM158	−55°C to +125°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics ($V^+ = +5.0\ V_{DC}$, Note 4) LM158

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = +25°C$ (Note 5)		±2	±5	mV_{DC}
Input Bias Current (Note 6)	$I_{IN(+)}$ or $I_{IN(-)}$, $T_A = +25°C$		45	150	nA_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $T_A = +25°C$		±3	±30	nA_{DC}
Input Common-Mode Voltage Range (Note 7)	$V^+ = 30\ V_{DC}$, $T_A = +25°C$	0		$V^+-1.5$	V_{DC}
Supply Current	$R_L = \infty$ On All Op Amps Over Full Temperature Range		0.5	1.2	mA_{DC}
Large Signal Voltage Gain	$V^+ = +15\ V_{DC}$ (For Large V_O Swing) $R_L \geq 2\ k\Omega$, $T_A = +25°C$	50	100		V/mV
Common-Mode Rejection Ratio	DC, $T_A = +25°C$	70	85		dB
Power Supply Rejection Ratio	DC, $T_A = +25°C$	65	100		dB
Amplifier-to-Amplifier Coupling (Note 8)	f = 1 kHz to 20 kHz, $T_A = +25°C$ (Input Referred)		−120		dB
Output Current					
Source	$V_{IN}^+ = +1\ V_{DC}$, $V_{IN}^- = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$, $T_A = +25°C$	20	40		mA_{DC}
Sink	$V_{IN}^- = +1\ V_{DC}$, $V_{IN}^+ = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$, $T_A = +25°C$	10	20		mA_{DC}
	$V_{IN}^- = +1\ V_{DC}$, $V_{IN}^+ = 0\ V_{DC}$, $T_A = +25°C$, $V_O = 200\ mV_{DC}$	12	50		μA_{DC}
Input Offset Voltage	(Note 5)			±7	mV_{DC}
Input Offset Voltage Drift	$R_S = 0\Omega$		7		$\mu V/°C$
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$			±100	nA_{DC}
Input Offset Current Drift			10		$pA_{DC}/°C$
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$			300	nA_{DC}
Input Common-Mode Voltage Range (Note 7)	$V^+ = 30\ V_{DC}$	0		V^+-2	V_{DC}
Large Signal Voltage Gain	$V^+ = +15\ V_{DC}$ (For Large V_O Swing) $R_L \geq 2\ k\Omega$	25			V/mV
Output Voltage Swing					
V_{OH}	$V^+ = +30\ V_{DC}$, $R_L = 2\ k\Omega$	26			V_{DC}
	$R_L \geq 10\ k\Omega$	27	28		V_{DC}
V_{OL}	$V^+ = +5\ V_{DC}$, $R_L \leq 10\ k\Omega$		5	20	mV_{DC}
Output Current					
Source	$V_{IN}^+ = +1\ V_{DC}$, $V_{IN}^- = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$	10	20		mA
Sink	$V_{IN}^- = +1\ V_{DC}$, $V_{IN}^+ = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$	5	8		mA
Differential Input Voltage (Note 7)				V^+	V_{DC}

electrical characteristics ($V^+ = +5.0\ V_{DC}$, Note 4) LM258, LM358

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = +25°C$ (Note 5)		±2	±6	mV_{DC}
Input Bias Current (Note 6)	$I_{IN(+)}$ or $I_{IN(-)}$, $T_A = +25°C$		45	250	nA_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $T_A = +25°C$		±5	±50	nA_{DC}
Input Common-Mode Voltage Range (Note 7)	$V^+ = 30\ V_{DC}$, $T_A = +25°C$	0		V^+−1.5	V_{DC}
Supply Current	$R_L = \infty$ On All Op Amps Over Full Temperature Range		0.5	1.2	mA_{DC}
Large Signal Voltage Gain	$V^+ = +15\ V_{DC}$ (For Large V_O Swing) $R_L \geq 2\ k\Omega$, $T_A = +25°C$	25	100		V/mV
Common-Mode Rejection Ratio	DC, $T_A = +25°C$	70	70		dB
Power Supply Rejection Ratio	DC, $T_A = +25°C$	65	100		dB
Amplifier-to-Amplifier Coupling (Note 8)	f = 1 kHz to 20 kHz, $T_A = +25°C$ (Input Referred)		−120		dB
Output Current					
Source	$V_{IN}^+ = +1\ V_{DC}$, $V_{IN}^- = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$, $T_A = +25°C$	20	40		mA_{DC}
Sink	$V_{IN}^- = +1\ V_{DC}$, $V_{IN}^+ = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$, $T_A = +25°C$	10	20		mA_{DC}
	$V_{IN}^- = +1\ V_{DC}$, $V_{IN}^+ = 0\ V_{DC}$, $T_A = +25°C$, $V_O = 200\ mV_{DC}$	12	50		μA_{DC}
Input Offset Voltage	(Note 5)			±7.5	mV_{DC}
Input Offset Voltage Drift	$R_S = 0\Omega$		7		$\mu V/°C$
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$			±150	nA_{DC}
Input Offset Current Drift			10		$pA_{DC}/°C$
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$			500	nA_{DC}
Input Common-Mode Voltage Range (Note 7)	$V^+ = 30\ V_{DC}$	0		V^+−2	V_{DC}
Large Signal Voltage Gain	$V^+ = +15\ V_{DC}$ (For Large V_O Swing) $R_L \geq 2\ k\Omega$	15			V/mV
Output Voltage Swing					
V_{OH}	$V^+ = +30\ V_{DC}$, $R_L = 2\ k\Omega$	26			V_{DC}
	$R_L \geq 10\ k\Omega$	27	28		V_{DC}
V_{OL}	$V^+ = +5\ V_{DC}$, $R_L < 10\ k\Omega$		5	20	mV_{DC}
Output Current					
Source	$V_{IN}^+ = +1\ V_{DC}$, $V_{IN}^- = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$	10	20		mA
Sink	$V_{IN}^- = +1\ V_{DC}$, $V_{IN}^+ = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$	5	8		mA
Differential Input Voltage (Note 7)				V^+	V_{DC}

Note 1: For operating at high temperatures, the LM358 must be derated based on a +125°C maximum junction temperature and a thermal resistance of 175°C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM258 and LM158 can be derated based on a +150°C maximum junction temperature. The dissipation is the total of both amplifiers—use external resistors, where possible, to allow the amplifier to saturate or to reduce the power which is dissipated in the integrated circuit.

Note 2: Short circuits from the output to V^+ can cause excessive heating and eventual destruction. The maximum output current is approximately 40 mA independent of the magnitude of V^+. At values of supply voltage in excess of +15 V_{DC}, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction.

Note 3: This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the op amps to go to the V^+ voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than −0.3 V_{DC}.

Note 4: These specifications apply for $V^+ = +5\ V_{DC}$ and $-55°C \leq T_A \leq +125°C$, unless otherwise stated. With the LM258, all temperature specifications are limited to $-25°C \leq T_A \leq +85°C$ and the LM358 temperature specifications are limited to $0°C \leq T_A \leq +70°C$.

Note 5: $V_O \cong 1.4\ V_{DC}$, $R_S = 0\Omega$ with V^+ from 5 V_{DC} to 30 V_{DC}; and over the full input common-mode range (0 V_{DC} to $V^+ - 1.5\ V_{DC}$).

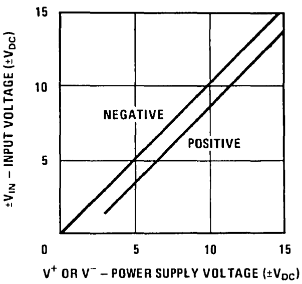
Note 6: The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.

Note 7: The input common-mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3V. The upper end of the common-mode voltage range is $V^+ - 1.5V$, but either or both inputs can go to +32 V_{DC} without damage.

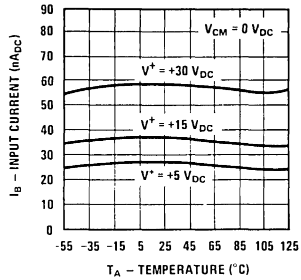
Note 8: Due to proximity of external components, insure that coupling is not originating via the stray capacitance between these external parts. This typically can be detected as this type of capacitive coupling increases at higher frequencies.

typical performance characteristics

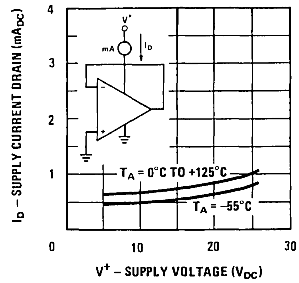
Input Voltage Range



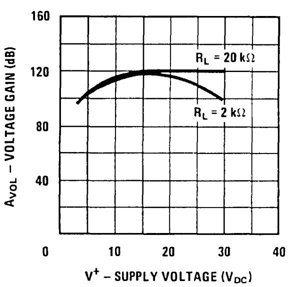
Input Current



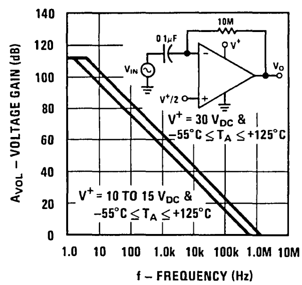
Supply Current



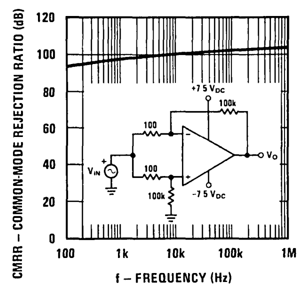
Voltage Gain



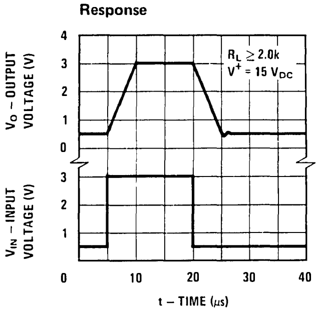
Open Loop Frequency Response



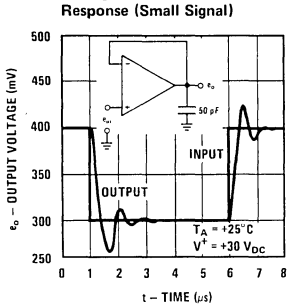
Common Mode Rejection Ratio



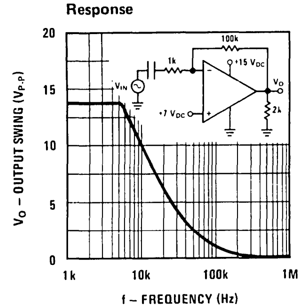
Voltage Follower Pulse Response



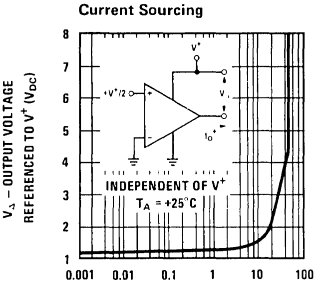
Voltage Follower Pulse Response (Small Signal)



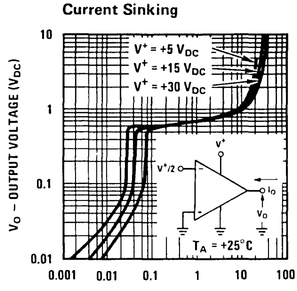
Large Signal Frequency Response



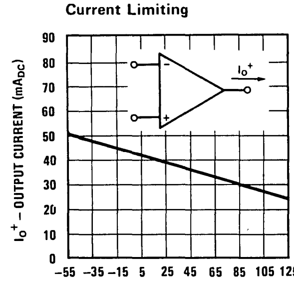
Output Characteristics Current Sourcing



Output Characteristics Current Sinking



Current Limiting



application hints

The LM158 series are op amps which operate with only a single power supply voltage, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of 0 V_{DC}. These amplifiers operate over a wide range of power supply voltages with little change in performance characteristics. At 25°C amplifier operation is possible down to a minimum supply voltage of 2.3 V_{DC}.

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a test socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Large differential input voltages can be easily accommodated and, as input differential voltage protection diodes are not needed, no large input currents result from large differential input voltages. The differential input voltage may be larger than V^+ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than −0.3 V_{DC} (at 25°C). An input clamp diode with a resistor to the IC input terminal can be used.

To reduce the power supply current drain, the amplifiers have a class A output stage for small signal levels which converts to class B in a large signal mode. This allows the amplifiers to both source and sink large output currents. Therefore both NPN and PNP external current boost transistors can be used to extend the power capability of the basic amplifiers. The output voltage needs to raise approximately 1 diode drop above ground to bias the on-chip vertical PNP transistor for output current sinking applications.

For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor should be used, from the output of the amplifier to ground to increase the class A bias current and prevent crossover distortion. Where the load is directly coupled, as in dc applications, there is no crossover distortion.

Capacitive loads which are applied directly to the output of the amplifier reduce the loop stability margin. Values of 50 pF can be accommodated using the worst-case non-inverting unity gain connection. Large closed loop gains or resistive isolation should be used if larger load capacitance must be driven by the amplifier.

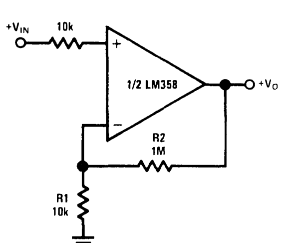
The bias network of the LM158 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from 3 V_{DC} to 30 V_{DC}.

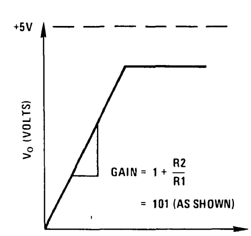
Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperatures. Putting direct short-circuits on more than one amplifier at a time will increase the total IC power dissipation to destructive levels, if not properly protected with external dissipation limiting resistors in series with the output leads of the amplifiers. The larger value of output source current which is available at 25°C provides a larger output current capability at elevated temperatures (see typical performance characteristics) than a standard IC op amp.

The circuits presented in the section on typical applications emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op amp circuits can be used. In general, introducing a pseudo-ground (a bias voltage reference of $V^+/2$) will allow operation above and below this value in single power supply systems. Many application circuits are shown which take advantage of the wide input common-mode voltage range which includes ground. In most cases, input biasing is not required and input voltages which range to ground can easily be accommodated.

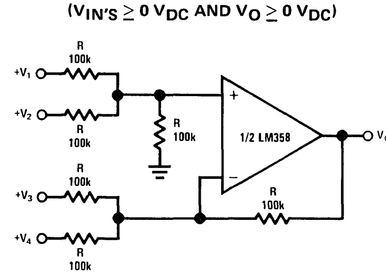
typical single-supply applications (V^+ = 5.0 V_{DC})

Non-Inverting DC Gain (0V Input = 0V Output)





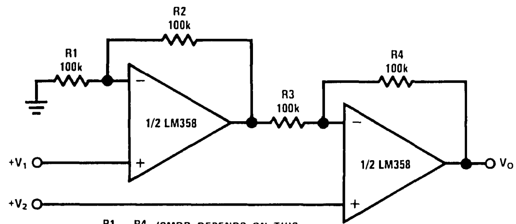
DC Summing Amplifier
(V_{IN}'S ≥ 0 V_{DC} AND V_O ≥ 0 V_{DC})



Where: $V_O = V_1 + V_2$ V_3 V_4
($V_1 + V_2$) ≥ ($V_3 + V_4$) to keep V_O > 0 V_{DC}

typical single-supply applications (con't) ($V^+ = 5.0\ V_{DC}$)

High Input Z, DC Differential Amplifier

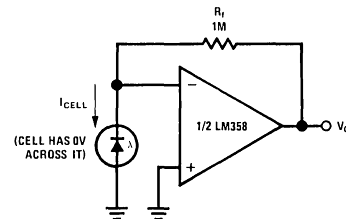


FOR $\frac{R1}{R2} = \frac{R4}{R3}$ (CMRR DEPENDS ON THIS RESISTOR RATIO MATCH)

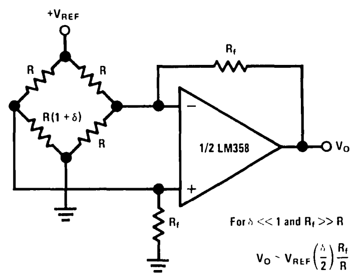
$V_O = \left(1 + \frac{R4}{R3}\right)(V_2 - V_1)$

AS SHOWN: $V_O = 2(V_2 - V_1)$

Photo Voltaic-Cell Amplifier



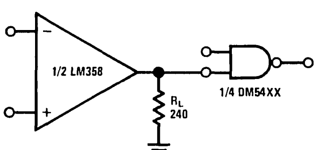
Bridge Current Amplifier



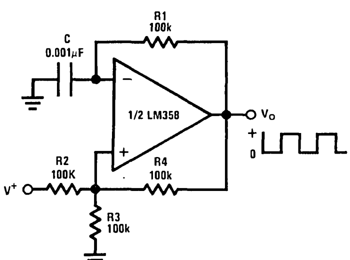
For $\delta << 1$ and $R_f >> R$

$V_O \approx V_{REF}\left(\frac{\delta}{2}\right)\frac{R_f}{R}$

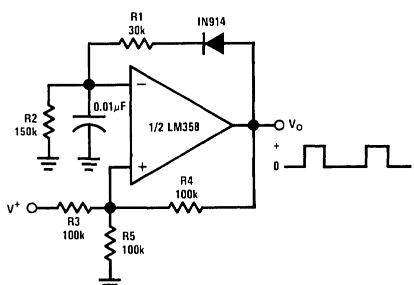
Driving TTL



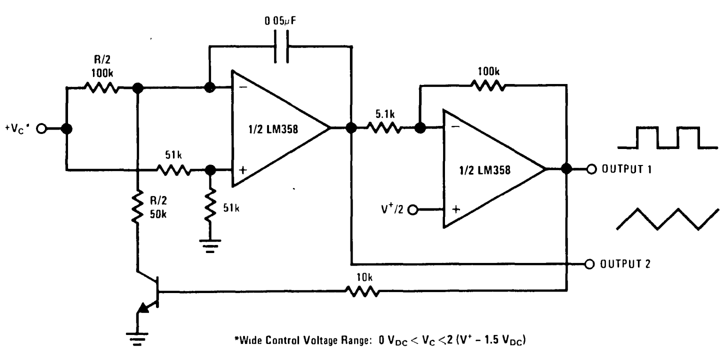
Squarewave Oscillator



Pulse Generator



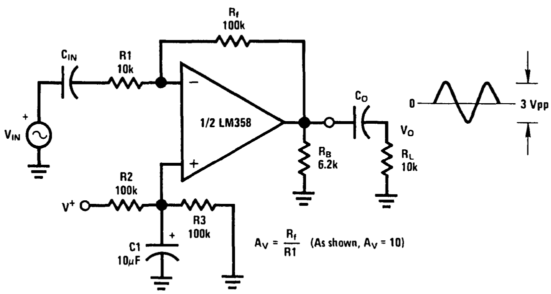
Voltage Controlled Oscillator (VCO)



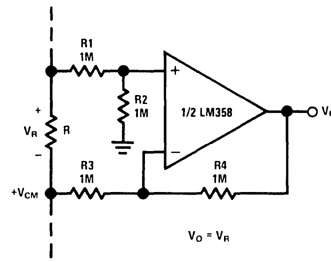
*Wide Control Voltage Range: $0\ V_{DC} < V_C < 2\ (V^+ - 1.5\ V_{DC})$

typical single-supply applications (con't) ($V^+ = 5.0\ V_{DC}$)

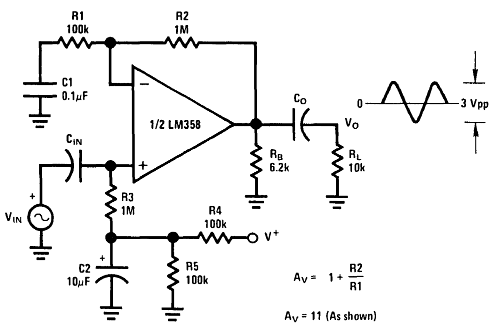
AC Coupled Inverting Amplifier



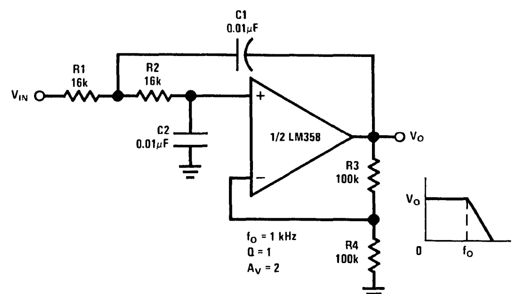
Ground Referencing A Differential Input Signal



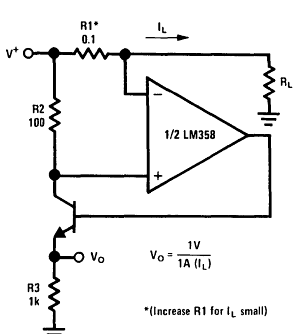
AC Coupled Non-Inverting Amplifier



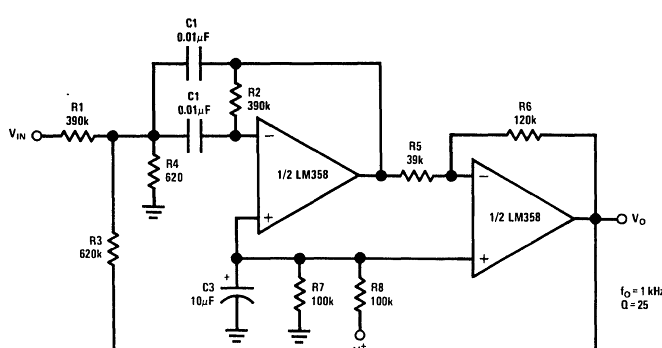
DC Coupled Low-Pass RC Active Filter



Current Monitor

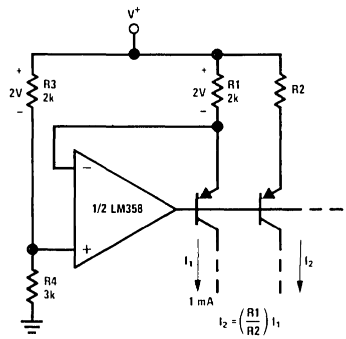


Bandpass Active Filter

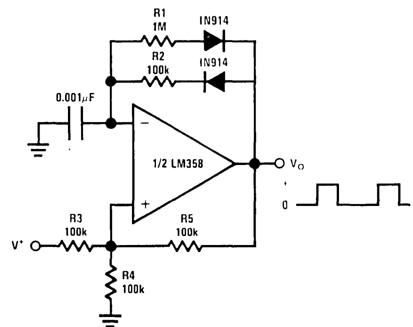


typical single-supply applications (con't) ($V^+ = 5.0\ V_{DC}$)

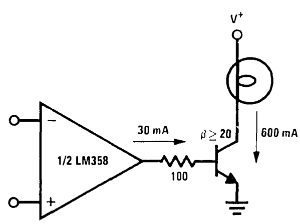
Fixed Current Source



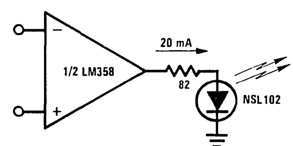
Pulse Generator



Lamp Driver



LED Driver



2

Operational Amplifiers

LM709 operational amplifier

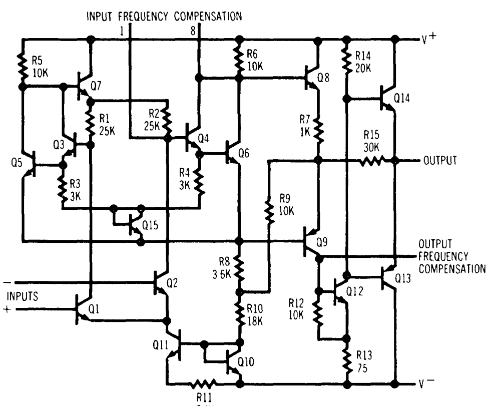
general description

The LM709 is a monolithic operational amplifier intended for general-purpose applications. Operation is completely specified over the range of voltages commonly used for these devices. The design, in addition to providing high gain, minimizes both offset voltage and bias currents. Further, the class-B output stage gives a large output capability with minimum power drain.

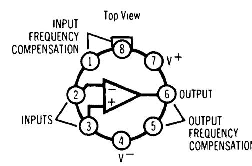
External components are used to frequency compensate the amplifier. Although the unity-gain compensation network specified will make the amplifier unconditionally stable in all feedback configurations, compensation can be tailored to optimize high-frequency performance for any gain setting.

The fact that the amplifier is built on a single silicon chip provides low offset and temperature drift at minimum cost. It also ensures negligible drift due to temperature gradients in the vicinity of the amplifier.

schematic and connection diagrams



Metal Can

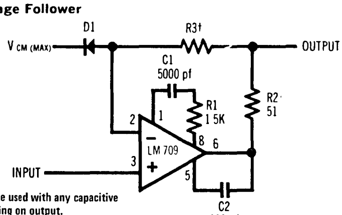


Note: Pin 4 connected to case.

Order Number LM709H
See Package 11

typical applications*

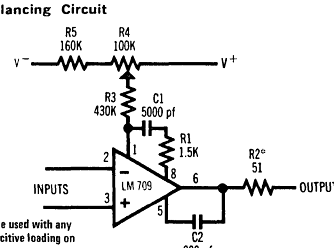
Voltage Follower



*To be used with any capacitive loading on output.

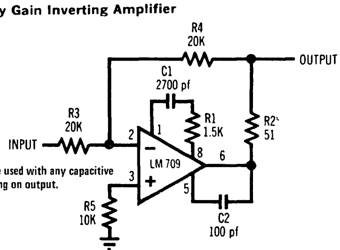
†Should be equal to dc source resistance on input.

Offset Balancing Circuit



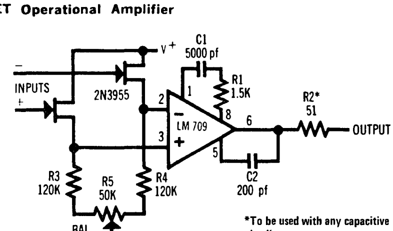
*To be used with any capacitive loading on output.

Unity Gain Inverting Amplifier



*To be used with any capacitive loading on output.

FET Operational Amplifier



*To be used with any capacitive loading on output.

* Pin connections shown are for Metal Can package.

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	300 mW
Differential Input Voltage	±5V
Input Voltage	±10V
Output Short-Circuit Duration ($T_A = 25°C$)	5 sec
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	−55°C to +125°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 2)

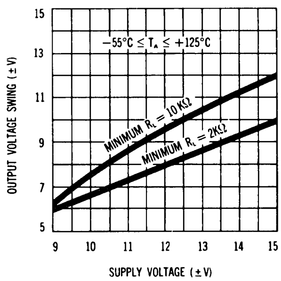
PARAMETER	CONDITION	MIN.	TYP.	MAX.	UNITS
Input Offset Voltage	$T_A = 25°C$, $R_S \leq 10\ k\Omega$		1.0	5.0	mV
Input Bias Current	$T_A = 25°C$		200	500	nA
Input Offset Current	$T_A = 25°C$		50	200	nA
Input Resistance	$T_A = 25°C$	150	400		kΩ
Output Resistance	$T_A = 25°C$		150		Ω
Supply Current	$T_A = 25°C$, $V_S = \pm 15V$		2.6	5.5	mA
Transient Response	$V_{IN} = 20\ mV$, $C_L \leq 100\ pF$				
Risetime	$T_A = 25°C$		0.3	1.0	µS
Overshoot			10	30	%
Slewing Rate	$T_A = 25°C$		0.25		V/µS
Input Offset Voltage	$R_S \leq 10\ k\Omega$			6.0	mV
Average Temperature Coefficient of Input Offset Voltage	$R_S = 50\ \Omega$		3.0		µV/°C
	$R_S = 10\ k\Omega$		6.0		µV/°C
Large-Signal Voltage Gain	$V_S = \pm 15V$, $R_L \geq 2\ k\Omega$, $V_{OUT} = \pm 10V$	25,000	45,000	70,000	
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10\ k\Omega$	±12	±14		V
	$V_S = \pm 15V$, $R_L = 2\ k\Omega$	±10	±13		V
Input Voltage Range	$V_S = \pm 15V$	±8.0	±10		V
Common Mode Rejection Ratio	$R_S \leq 10\ k\Omega$	70	90		db
Supply Voltage Rejection Ratio	$R_S \leq 10\ k\Omega$		25	150	µV/V
Input Offset Current	$T_A = +125°C$		20	200	nA
	$T_A = -55°C$		100	500	nA
Input Bias Current	$T_A = -55°C$		0.5	1.5	µA
Input Resistance	$T_A = -55°C$	40	100		kΩ

Note 1: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case for the metal-can package. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick, epoxy-glass board with ten, 0.03-inch-wide, 2-ounce copper conductors (see curve).

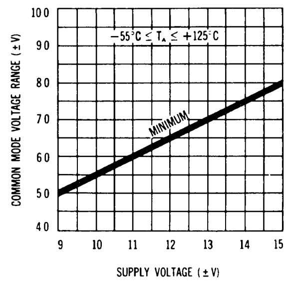
Note 2: These specifications apply for $-55°C \leq T_A \leq +125°C$, $\pm 9V \leq V_S \leq \pm 15V$, $C_1 = 5000\ pF$, $R_1 = 1.5K$, $C_2 = 200\ pF$ and $R_2 = 51\Omega$ unless otherwise specified.

guaranteed performance characteristics

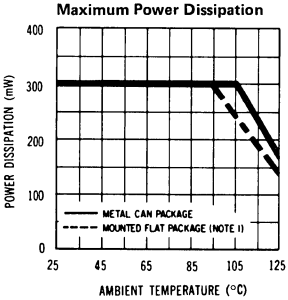
Output Voltage Swing



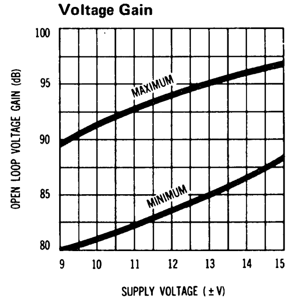
Input Common Mode Voltage Range



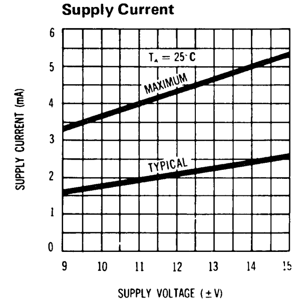
Maximum Power Dissipation



Voltage Gain

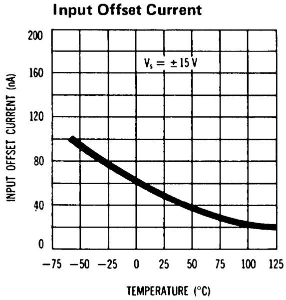


Supply Current

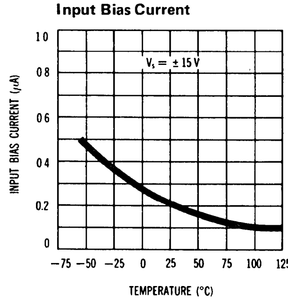


typical performance characteristics

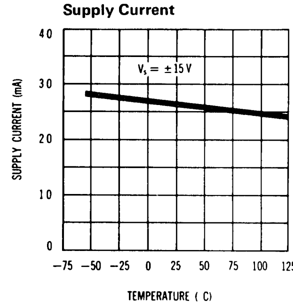
Input Offset Current



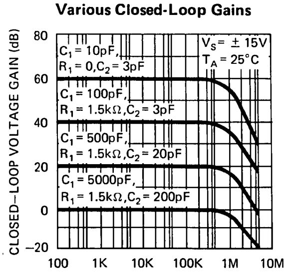
Input Bias Current



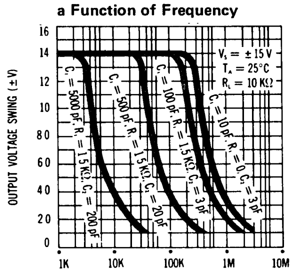
Supply Current



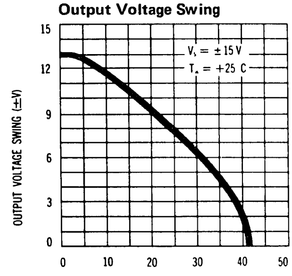
Frequency Responce For Various Closed-Loop Gains



Output Voltage Swing as a Function of Frequency



Output Voltage Swing



Operational Amplifiers

LM709A operational amplifier

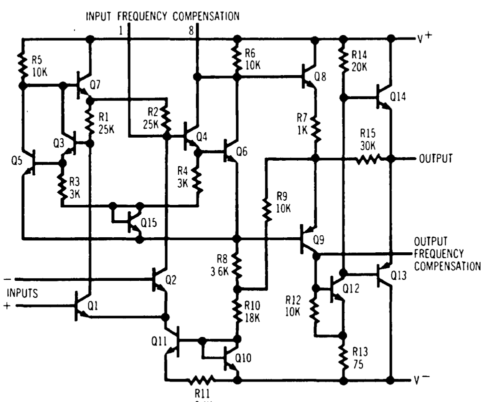
general description

The LM709A is a monolithic operational amplifier intended for general-purpose applications. Operation is completely specified over the range of voltages commonly used for these devices. The design, in addition to providing high gain, minimizes both offset voltage and bias currents. Further, the class-B output stage gives a large output capability with minimum power drain.

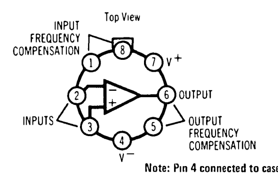
External components are used to frequency compensate the amplifier. Although the unity-gain compensation network specified will make the amplifier unconditionally stable in all feedback configurations, compensation can be tailored to optimize high-frequency performance for any gain setting.

The fact that the amplifier is built on a single silicon chip provides low offset and temperature drift at minimum cost. It also ensures negligible drift due to temperature gradients in the vicinity of the amplifier.

schematic and connection diagrams



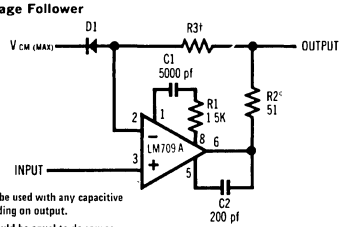
Metal Can



Order Number LM709AH
See Package 11

typical applications

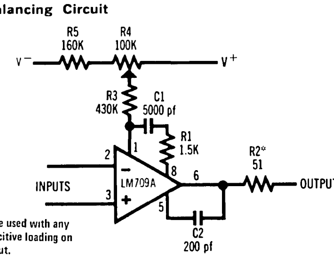
Voltage Follower



*To be used with any capacitive loading on output.

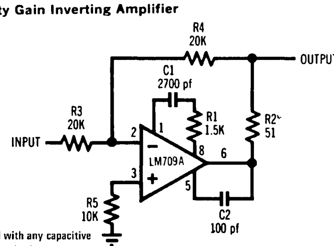
†Should be equal to dc source resistance on input.

Offset Balancing Circuit



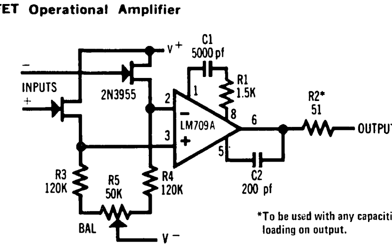
*To be used with any capacitive loading on output.

Unity Gain Inverting Amplifier



*To be used with any capacitive loading on output.

FET Operational Amplifier



*To be used with any capacitive loading on output.

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	300 mW
Differential Input Voltage	±5V
Input Voltage	±10V
Output Short-Circuit Duration (T_A = 25°C)	5 sec
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	−55°C to +125°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 2)

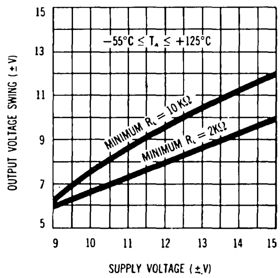
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	T_A = 25°C, $R_S \leq$ 10 kΩ		0.6	2.0	mV
Input Bias Current	T_A = 25°C		100	200	nA
Input Offset Current	T_A = 25°C		10	50	nA
Input Resistance	T_A = 25°C	350	700		kΩ
Output Resistance	T_A = 25°C		150		Ω
Supply Current	T_A = 25°C, V_S = ±15V		2.5	3.6	mA
Transient Response	V_{IN} = 20 mV, $C_L \leq$ 100 pF				
Risetime	T_A = 25°C			1.5	µs
Overshoot				30	%
Slewing Rate	T_A = 25°C		0.25		V/µs
Input Offset Voltage	$R_S \leq$ 10 kΩ			3.0	mV
Average Temperature Coefficient of Input Offset Voltage	R_S = 50Ω, T_A = 25°C to +125°C		1.8	10	µV/°C
	R_S = 50Ω, T_A = 25°C to −55°C		1.8	10	µV/°C
	R_S = 10 kΩ, T_A = 25°C to +125°C		2.0	15	µV/°C
	R_S = 10 kΩ, T_A = 25°C to −55°C		4.8	25	µV/°C
Large-Signal Voltage Gain	V_S = ±15V, $R_L \geq$ 2 kΩ, V_{OUT} = ±10V	25,000		70,000	
Output Voltage Swing	V_S = ±15V, R_L = 10 kΩ	±12	±14		V
	V_S = ±15V, R_L = 2 kΩ	±10	±13		V
Input Voltage Range	V_S = ±15V	±8.0			V
Common Mode Rejection Ratio	$R_S \leq$ 10 kΩ	80	110		dB
Supply Voltage Rejection Ratio	$R_S \leq$ 10 kΩ		40	100	µV/V
Input Offset Current	T_A = +125°C		3.5	50	nA
	T_A = −55°C		40	250	nA
Input Bias Current	T_A = −55°C		300	600	nA
Input Resistance	T_A = −55°C	85	170		kΩ

Note 1: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case for the metal can package.

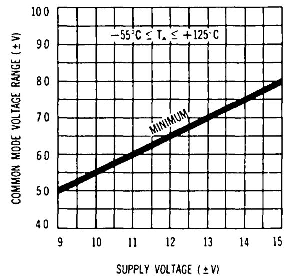
Note 2: These specifications apply for −55°C ≤ T_A ≤ +125°C, ±9V ≤ V_S ≤ ±15V, C_1 = 5000 pF, R_1 = 1.5K, C_2 = 200 pF and R_2 = 51Ω unless otherwise specified.

guaranteed performance characteristics

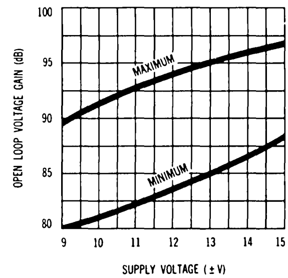
Output Voltage Swing



Input Common Mode Voltage Range

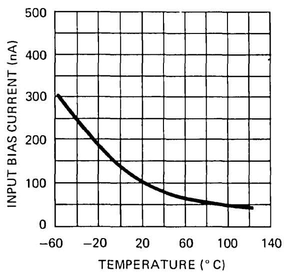


Voltage Gain

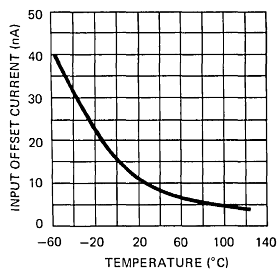


typical performance characteristics

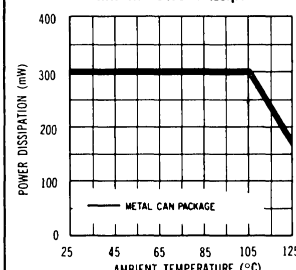
Input Bias Current as a Function of Ambient Temperature



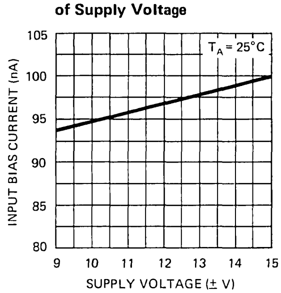
Input Offset Current as a Function of Ambient Temperature



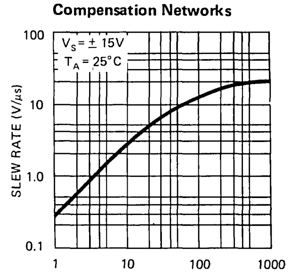
Maximum Power Dissipation



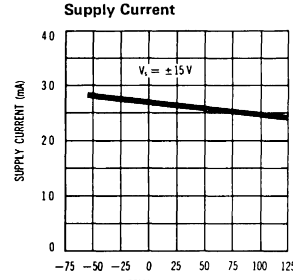
Input Bias Current as a Function of Supply Voltage



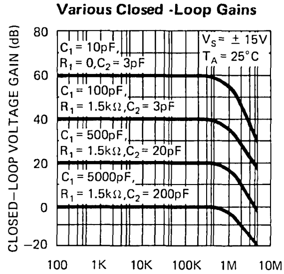
Slew Rate as a Function of Closed-Loop Gain Using Recommended Compensation Networks



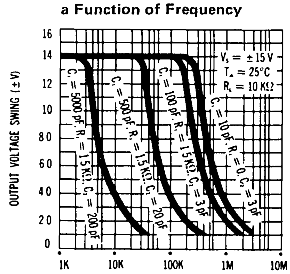
Supply Current



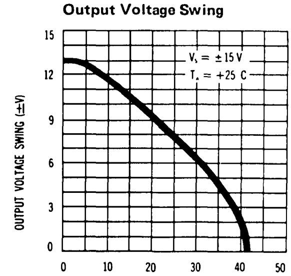
Frequency Responce For Various Closed -Loop Gains



Output Voltage Swing as a Function of Frequency



Output Voltage Swing



2

Operational Amplifiers

LM709C operational amplifier

general description

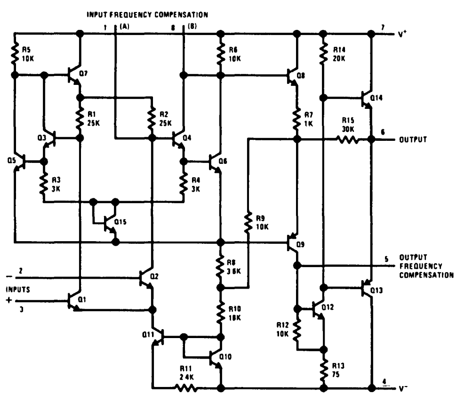
The LM709C is a monolithic operational amplifier intended for general-purpose applications. Operation is completely specified over the range of voltages commonly used for these devices. The design, in addition to providing high gain, minimizes both offset voltage and bias currents. Further, the class-B output stage gives a large output capability with minimum power drain.

External components are used to frequency compensate the amplifier. Although the unity-gain compensation network specified will make the amplifier unconditionally stable in all feedback configurations, compensation can be tailored to optimize high-frequency performance for any gain setting.

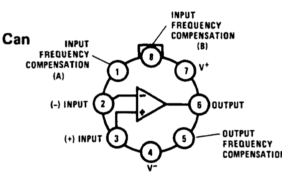
The fact that the amplifier is built on a single silicon ship provides low offset and temperature drift at minimum cost. It also ensures negligible drift due to temperature gradients in the vicinity of the amplifier.

The LM709C is commercial-industrial version of the LM709. It is identical to the LM709 except that it is specified for operation from 0°C to 70°C.

schematic** and connection diagrams



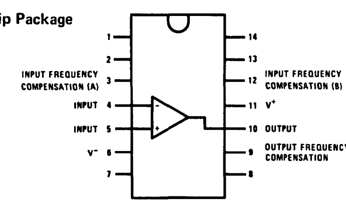
Metal Can



Note: Pin 4 connected to case.

Order Number LM709CH
See Package 11

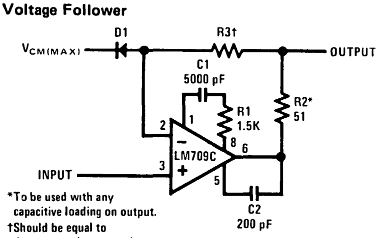
Dip Package



Order Number LM709CN
See Package 22

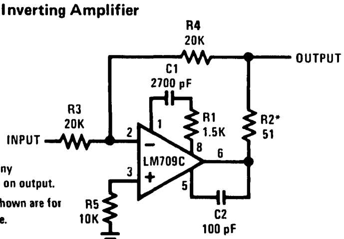
typical applications**

Voltage Follower



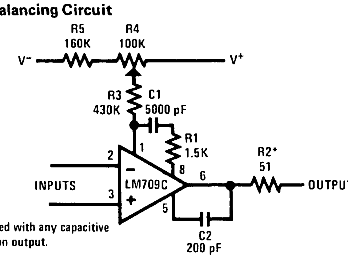
*To be used with any capacitive loading on output.
†Should be equal to dc source resistance on input.

Unity Gain Inverting Amplifier



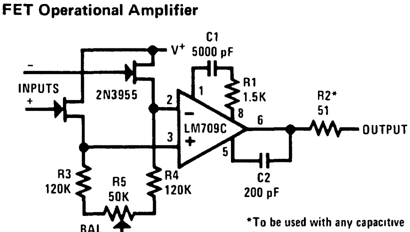
*To be used with any capacitive loading on output.
**Pin connections shown are for metal can package.

Offset Balancing Circuit



*To be used with any capacitive loading on output.

FET Operational Amplifier



*To be used with any capacitive loading on output.

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	250 mW
Differential Input Voltage	±5V
Input Voltage	±10V
Output Short-Circuit Duration (T_A = 25°C)	5 sec
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	0°C to +70°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 2)

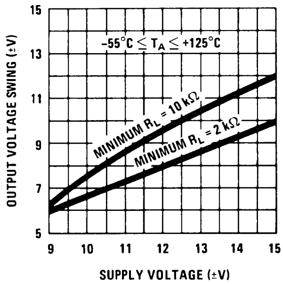
PARAMETER	CONDITION	MIN	TYP	MAX	UNITS
Input Offset Voltage	T_A = 25°C, $R_S \leq$ 10 kΩ		2.0	7.5	mV
Input Offset Current	T_A = 25°C		100	500	nA
Input Bias Current	T_A = 25°C		0.3	1.5	μA
Input Resistance	T_A = 25°C	50	250		kΩ
Output Resistance	T_A = 25°C		150		Ω
Supply Current	T_A = 25°C, V_S = ±15V		2.6	6.6	mA
Transient Response	V_{IN} = 20 mV, $C_L \leq$ 100 pF				
Risetime	T_A = 25°C		0.3	1.0	μs
Overshoot			10	30	%
Slewing Rate	T_A = 25°C		0.25		V/μs
Input Offset Voltage	$R_S \leq$ 10 kΩ			10	mV
Average Temperature Coefficient of Input Offset Voltage	R_S = 50Ω		6.0		μV/°C
	R_S = 10 kΩ		12		μV/°C
Large-Signal Voltage Gain	V_S = ±15V, $R_L \geq$ 2 kΩ, V_{OUT} = ±10V	15,000	45,000		
Output Voltage Swing	V_S = ±15V, R_L = 10 kΩ	±12	±14		V
	V_S = ±15V, R_L = 2 kΩ	±10	±13		V
Input Voltage Range	V_S = ±15V	±8.0	±10		V
Common Mode Rejection Ratio	$R_S \leq$ 10 kΩ	65	90		dB
Supply Voltage Rejection Ratio	$R_S \leq$ 10 kΩ		25	200	μV/V
Input Offset Current	T_A = +70°C		75	400	nA
	T_A = 0°C		125	750	nA
Input Bias Current	T_A = 0°C		0.36	2.0	μA

Note 1: For operating at elevated temperatures, the device must be derated based on a 100°C maximum junction temperature and a thermal resistance of 45°C/W junction to case or 150°C/W junction to ambient for the metal can package. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick, epoxy-glass board with ten, 0.03-inch-wide, 2-ounce copper conductors.

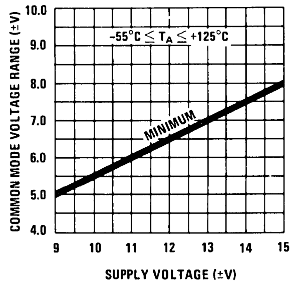
Note 2: These specifications apply for 0°C $\leq T_A \leq$ +70°C, ±9V $\leq V_S \leq$ ±15V, C_1 = 5000 pF, R_1 = 1.5K, C_2 = 200 pF and R_2 = 51Ω unless otherwise specified.

guaranteed performance characteristics

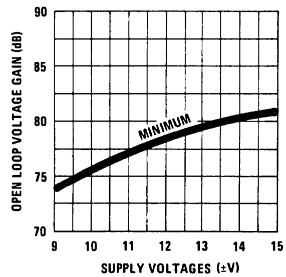
Output Voltage Swing



Input Common Mode Voltage Range

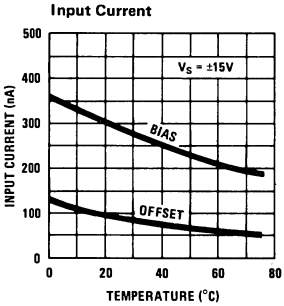


Voltage Gain

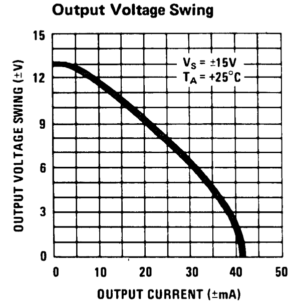


typical performance characteristics

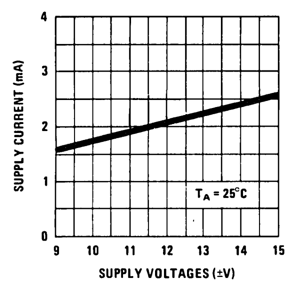
Input Current



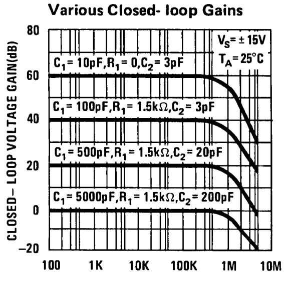
Output Voltage Swing



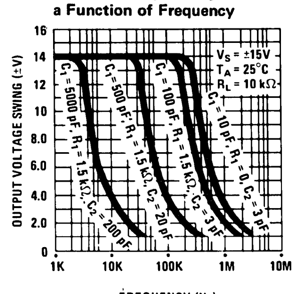
Supply Current



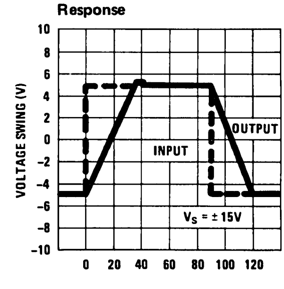
Frequency Responce For Various Closed- loop Gains



Output Voltage Swing as a Function of Frequency



Voltage Follower Pulse Response



Operational Amplifiers

LM725A/LM725/LM725C instrumentation operational amplifier

general description

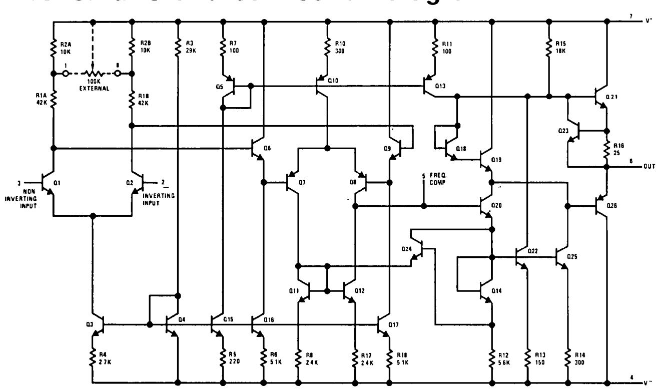
The LM725A/LM725/LM725C are operational amplifiers featuring superior performance in applications where low noise, low drift, and accurate closed-loop gain are required. With high common mode rejection and offset null capability, it is especially suited for low level instrumentation applications over a wide supply voltage range.

The LM725A has tightened electrical performance with higher input accuracy and like the LM725, is guaranteed over a −55°C to +125°C temperature range. The LM725C has slightly relaxed specifications and has its performance guaranteed over a 0°C to 70°C temperature range.

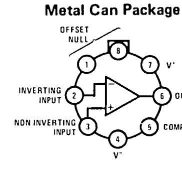
features

- High open loop gain 3,000,000
- Low input voltage drift 0.6 μV/°C
- High common mode rejection 120 dB
- Low input noise current 0.15 pA/$\sqrt{Hz}$
- Low input offset current 2 nA
- High input voltage range ±14V
- Wide power supply range ±3V to ±22V
- Offset null capability
- Output short circuit protection

schematic and connection diagrams

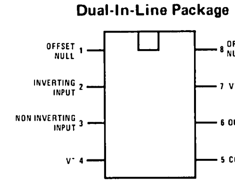


Metal Can Package



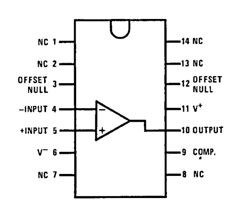
Order Number LM725H or LM725AH or LM725CH
See Package 11

Dual-In-Line Package



Order Number LM725CN
See Package 20

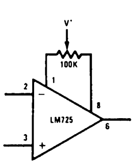
Dual-In-Line Package



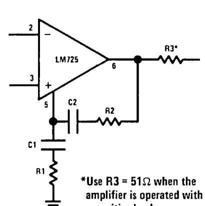
Order Number LM725D
See Package 1

auxiliary circuits

Voltage Offset Null Circuit



Frequency Compensation Circuit



*Use R3 = 51Ω when the amplifier is operated with capacitive load.

Compensation Component Values

A_{VCL}	R1 (Ω)	C1 (μF)	R2 (Ω)	C2 (μF)
10,000	10K	50 pF	–	–
1,000	470	.001	–	–
100	47	.01	–	–
10	27	05	270	0015
1	10	05	39	02

LM725A

absolute maximum ratings

Supply Voltage	±22V
Internal Power Dissipation (Note 1)	500 mW
Differential Input Voltage	±5V
Input Voltage (Note 2)	±22V
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	−55°C to +125°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage (Without External Trim)	T_A = 25°C, $R_S \leq$ 10 kΩ			0.5	mV
Input Offset Current	T_A = 25°C		2.0	5.0	nA
Input Bias Current	T_A = 25°C		42	80	nA
Input Noise Voltage	T_A = 25°C, f_o = 10 Hz f_o = 100 Hz f_o = 1 kHz		15 9.0 8.0		nV/$\sqrt{Hz}$ nV/$\sqrt{Hz}$ nV/$\sqrt{Hz}$
Input Noise Current	T_A = 25°C, f_o = 10 Hz f_o = 100 Hz f_o = 1 kHz		1.0 0.3 0.15		pA/$\sqrt{Hz}$ pA/$\sqrt{Hz}$ pA/$\sqrt{Hz}$
Input Resistance	T_A = 25°C		1.5		MΩ
Input Voltage Range	T_A = 25°C	±13.5	±14		V
Large Signal Voltage Gain	T_A = 25°C, $R_L \geq$ 2 kΩ, V_{OUT} = ±10V	1,000,000	3,000,000		
Common Mode Rejection Ratio	T_A = 25°C, $R_S \leq$ 10 kΩ	120			dB
Power Supply Rejection Ratio	T_A = 25°C, $R_S \leq$ 10 kΩ		2.0	5.0	μV/V
Output Voltage Swing	T_A = 25°C, $R_L \geq$ 10 kΩ $R_L \geq$ 2 kΩ	±12.5 ±12.0	±13.5 ±13.5		V V
Power Consumption	T_A = 25°C		80	105	mW
Input Offset Voltage (Without External Trim)	$R_S \leq$ 10 kΩ			0.7	mV
Average Input Offset Voltage Drift (Without External Trim)	R_S = 50Ω			2.0	μV/°C
Average Input Offset Voltage Drift (With External Trim)	R_S = 50Ω		0.6	1.0	μV/°C
Input Offset Current	T_A = +125°C T_A = −55°C		1.2 7.5	4.0 18.0	nA nA
Average Input Offset Current Drift			35	90	pA/°C
Input Bias Current	T_A = +125°C T_A = −55°C		20 80	70 180	nA nA
Large Signal Voltage Gain	$R_L \geq$ 2 kΩ, T_A = +125°C $R_L \geq$ 2 kΩ, T_A = −55°C	1,000,000 500,000			
Common Mode Rejection Ratio	$R_S \leq$ 10 kΩ	110			dB
Power Supply Rejection Ratio	$R_S \leq$ 10 kΩ			8.0	μV/V
Output Voltage Swing	$R_L \geq$ 2 kΩ	±12			V

Note 1: Derate at 150°C/W for operation at ambient temperatures above 75°C.

Note 2: For supply voltages less than ±22V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: These specifications apply for V_S = ±15V unless otherwise specified.

LM725

absolute maximum ratings

Supply Voltage	±22V
Internal Power Dissipation (Note 1)	500 mW
Differential Input Voltage	±5V
Input Voltage (Note 2)	±22V
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	−55°C to +125°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage (Without External Trim)	$T_A = 25°C$, $R_S \leq 10\ k\Omega$		0.5	1.0	mV
Input Offset Current	$T_A = 25°C$		2.0	20	nA
Input Bias Current	$T_A = 25°C$		42	100	nA
Input Noise Voltage	$T_A = 25°C$, $f_o = 10\ Hz$		15		$nV/\sqrt{Hz}$
	$f_o = 100\ Hz$		9.0		$nV/\sqrt{Hz}$
	$f_o = 1\ kHz$		8.0		$nV/\sqrt{Hz}$
Input Noise Current	$T_A = 25°C$, $f_o = 10\ Hz$		1.0		$pA/\sqrt{Hz}$
	$f_o = 100\ Hz$		0.3		$pA/\sqrt{Hz}$
	$f_o = 1\ kHz$		0.15		$pA/\sqrt{Hz}$
Input Resistance	$T_A = 25°C$		1.5		MΩ
Input Voltage Range	$T_A = 25°C$	±13.5	±14		V
Large Signal Voltage Gain	$T_A = 25°C$, $R_L \geq 2\ k\Omega$, $V_{OUT} = \pm 10V$	1,000,000	3,000,000		
Common Mode Rejection Ratio	$T_A = 25°C$, $R_S \leq 10\ k\Omega$	110	120		dB
Power Supply Rejection Ratio	$T_A = 25°C$, $R_S \leq 10\ k\Omega$		2.0	10	μV/V
Output Voltage Swing	$T_A = 25°C$, $R_L \geq 10\ k\Omega$	±12	±13.5		V
	$R_L \geq 2\ k\Omega$	±10	±13.5		V
Power Consumption	$T_A = 25°C$		80	105	mW
Input Offset Voltage (Without External Trim)	$R_S \leq 10\ k\Omega$			1.5	mV
Average Input Offset Voltage Drift (Without External Trim)	$R_S = 50\Omega$		2.0	5.0	μV/°C
Average Input Offset Voltage Drift (With External Trim)	$R_S = 50\Omega$		0.6		μV/°C
Input Offset Current	$T_A = +125°C$		1.2	20	nA
	$T_A = -55°C$		7.5	40	nA
Average Input Offset Current Drift			35	150	pA/°C
Input Bias Current	$T_A = +125°C$		20	100	nA
	$T_A = -55°C$		80	200	nA
Large Signal Voltage Gain	$R_L \geq 2\ k\Omega$, $T_A = +125°C$	1,000,000			
	$R_L \geq 2\ k\Omega$, $T_A = -55°C$	250,000			
Common Mode Rejection Ratio	$R_S \leq 10\ k\Omega$	100			dB
Power Supply Rejection Ratio	$R_S \leq 10\ k\Omega$			20	μV/V
Output Voltage Swing	$R_L \geq 2\ k\Omega$	±10			V

Note 1: Derate at 150°C/W for operation at ambient temperatures above 75°C.

Note 2: For supply voltages less than ±22V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: These specifications apply for $V_S = \pm 15V$ unless otherwise specified.

LM725C

absolute maximum ratings

Supply Voltage	±22V
Internal Power Dissipation (Note 1)	500 mV
Differential Input Voltage	±5V
Input Voltage (Note 2)	±22V
Storage Temperature Range	-65°C to +150°C
Operating Temperature Range	0°C to +70°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage (Without External Trim)	$T_A = 25°C$, $R_S \leq 10\ k\Omega$		0.5	2.5	mV
Input Offset Current	$T_A = 25°C$		2.0	35	nA
Input Bias Current	$T_A = 25°C$		42	125	nA
Input Noise Voltage	$T_A = 25°C$, $f_o = 10\ Hz$		15		$nV/\sqrt{Hz}$
	$f_o = 100\ Hz$		9.0		$nV/\sqrt{Hz}$
	$f_o = 1\ kHz$		8.0		$nV/\sqrt{Hz}$
Input Noise Current	$T_A = 25°C$, $f_o = 10\ Hz$		1.0		$pA/\sqrt{Hz}$
	$f_o = 100\ Hz$		0.3		$pA/\sqrt{Hz}$
	$f_o = 1\ kHz$		0.15		$pA/\sqrt{Hz}$
Input Resistance	$T_A = 25°C$		1.5		MΩ
Input Voltage Range	$T_A = 25°C$	±13.5	±14		V
Large Signal Voltage Gain	$T_A = 25°C$, $R_L \geq 2\ k\Omega$, $V_{OUT} = \pm 10V$	250,000	3,000,000		
Common Mode Rejection Ratio	$T_A = 25°C$, $R_S \leq 10\ k\Omega$	94	120		dB
Power Supply Rejection Ratio	$T_A = 25°C$, $R_S \leq 10\ k\Omega$		2.0	35	μV/V
Output Voltage Swing	$T_A = 25°C$, $R_L \geq 10\ k\Omega$	±12	±13.5		V
	$R_L \geq 2\ k\Omega$	±10	±13.5		V
Power Consumption	$T_A = 25°C$		80	150	mW
Input Offset Voltage (Without External Trim)	$R_S \leq 10\ k\Omega$			3.5	mV
Average Input Offset Voltage Drift (Without External Trim)	$R_S = 50\Omega$		2.0		μV/°C
Average Input Offset Voltage Drift (With External Trim)	$R_S = 50\Omega$		0.6		μV/°C
Input Offset Current	$T_A = +70°C$		1.2	35	nA
	$T_A = 0°C$		4.0	50	nA
Average Input Offset Current Drift			10		pA/°C
Input Bias Current	$T_A = +70°C$			125	nA
	$T_A = 0°C$			250	nA
Large Signal Voltage Gain	$R_L \geq 2\ k\Omega$, $T_A = +70°C$	125,000			
	$R_L \geq 2\ k\Omega$, $T_A = 0°C$	125,000			
Common Mode Rejection Ratio	$R_S \leq 10\ k\Omega$		115		dB
Power Supply Rejection Ratio	$R_S \leq 10\ k\Omega$		20		μV/V
Output Voltage Swing	$R_L \geq 2\ k\Omega$	±10			V

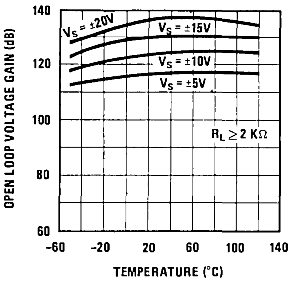
Note 1: Rating applies for case temperature to 70°C.

Note 2: For supply voltages less than ±22V, the absolute maximum input voltage is equal to the supply voltage.

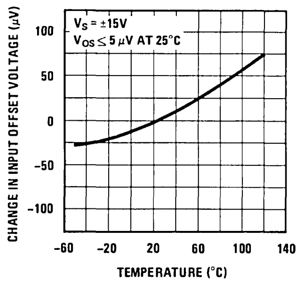
Note 3: These specifications apply for $V_S = \pm 15V$ unless otherwise specified.

typical performance characteristics

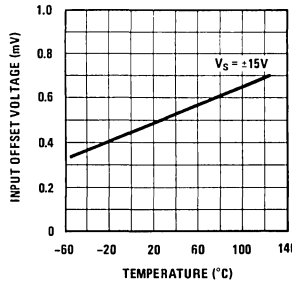
Open Loop Voltage Gain vs Temperature for Various Supply Voltages



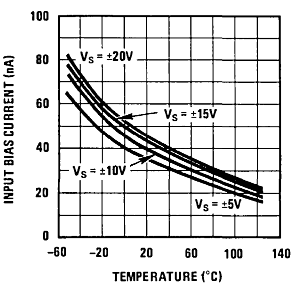
Nulled Input Offset Voltage vs Temperature



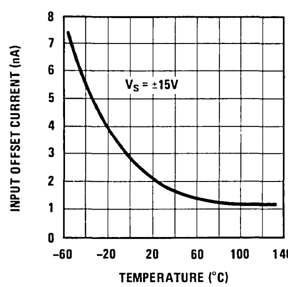
Unnulled Input Offset Voltage vs Temperature



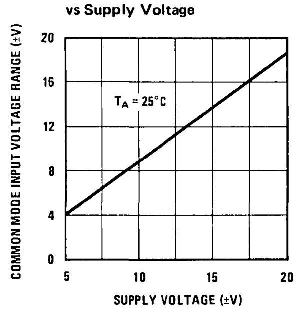
Input Bias Current vs Temperature



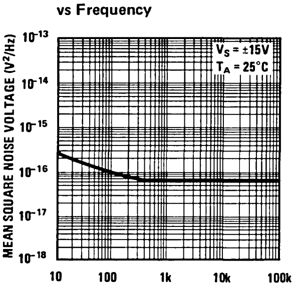
Input Offset Current vs Temperature



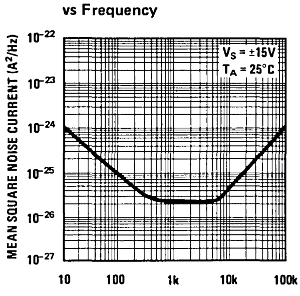
Common Mode Input Voltage vs Supply Voltage



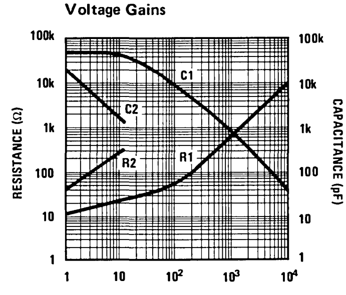
Input Noise Voltage vs Frequency



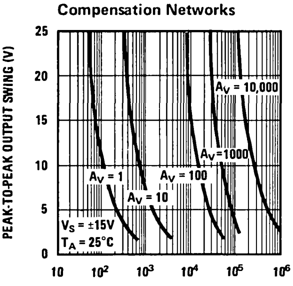
Input Noise Current vs Frequency



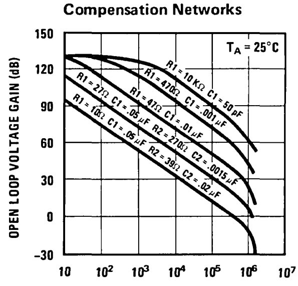
Values for Suggested Compensation Networks for Various Closed Loop Voltage Gains



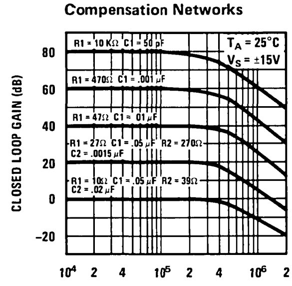
Output Voltage Swing vs Frequency for Recommended Compensation Networks



Open Loop Voltage Gain vs Frequency Using Recommended Compensation Networks



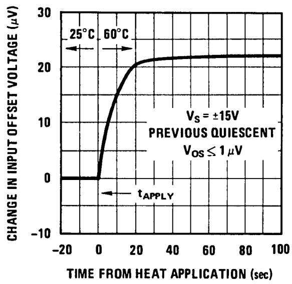
Frequency Response for Various Closed-Loop Gains Using Recommended Compensation Networks



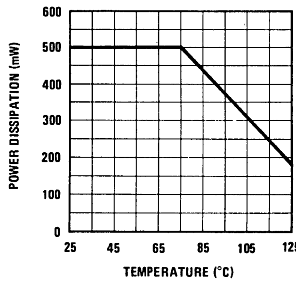
2

typical performance characteristics (con't)

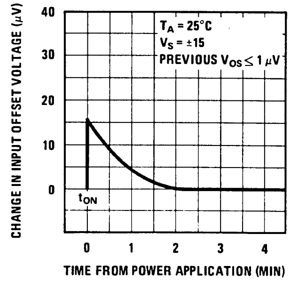
Change in Input Offset Voltage Due to Thermal Shock vs Time



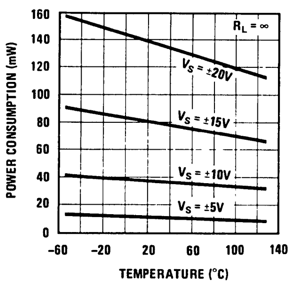
Absolute Maximum Power Dissipation vs Ambient Temperature



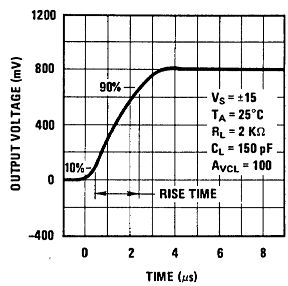
Stabilization Time of Input Offset Voltage from Power Turn-On



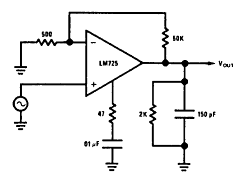
Power Consumption vs Temperature



Transient Response



Transient Response Test Circuit



Operational Amplifiers

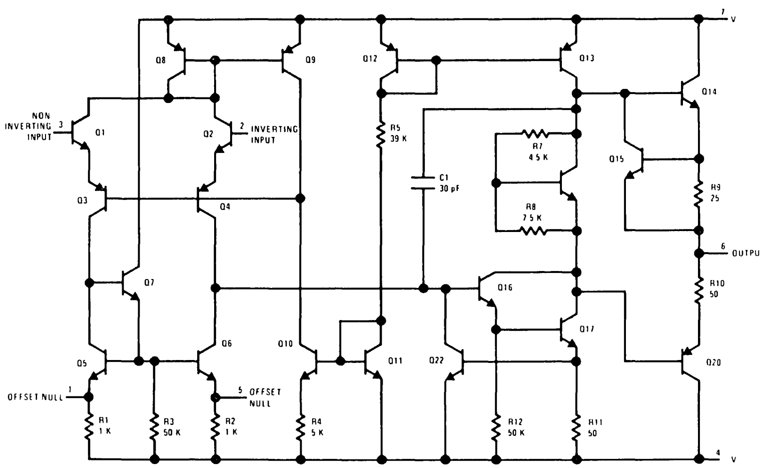
LM741/LM741C operational amplifier general description

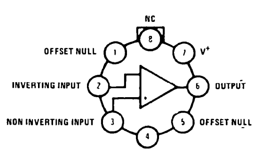
The LM741 and LM741C are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications.

The offset voltage and offset current are guaranteed over the entire common mode range. The amplifiers also offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

The LM741C is identical to the LM741 except that the LM741C has its performance guaranteed over a 0°C to 70°C temperature range, instead of -55°C to 125°C.

schematic and connection diagrams

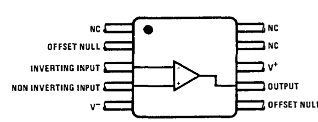




Note: Pin 4 connected to case.

TOP VIEW

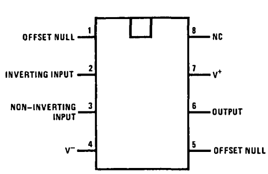
Order Number LM741H or LM741CH
See Package 11



Note: Pin 5 connected to bottom of package.

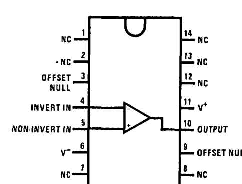
TOP VIEW

Order Number LM741F
See Package 3



TOP VIEW

Order Number LM741CN
See Package 20



TOP VIEW

Order Number LM741CD
See Package 1
Order Number LM741CN-14
See Package 22

absolute maximum ratings

Supply Voltage LM741	±22V
LM741C	±18V
Power Dissipation (Note 1)	500 mW
Differential Input Voltage	±30V
Input Voltage (Note 2)	±15V
Output Short-Circuit Duration	Indefinite
Operating Temperature Range LM741	−55°C to 125°C
LM741C	0°C to 70°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	LM741			LM741C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$, $R_S \leq 10\ k\Omega$		1.0	5.0		1.0	6.0	mV
Input Offset Current	$T_A = 25°C$		30	200		30	200	nA
Input Bias Current	$T_A = 25°C$		200	500		200	500	nA
Input Resistance	$T_A = 25°C$	0.3	1.0		0.3	1.0		MΩ
Supply Current	$T_A = 25°C$, $V_S = \pm15V$		1.7	2.8		1.7	2.8	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm15V$ $V_{OUT} = \pm10V$, $R_L \geq 2\ k\Omega$	50	160		25	160		V/mV
Input Offset Voltage	$R_S \leq 10\ k\Omega$			6.0			7.5	mV
Input Offset Current				500			300	nA
Input Bias Current				1.5			0.8	μA
Large Signal Voltage Gain	$V_S = \pm15V$, $V_{OUT} = \pm10V$ $R_L \geq 2\ k\Omega$	25			15			V/mV
Output Voltage Swing	$V_S = \pm15V$, $R_L = 10\ k\Omega$ $R_L = 2\ k\Omega$	±12 ±10	±14 ±13		±12 ±10	±14 ±13		V V
Input Voltage Range	$V_S = \pm15V$	±12			±12			V
Common Mode Rejection Ratio	$R_S \leq 10\ k\Omega$	70	90		70	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 10\ k\Omega$	77	96		77	96		dB

Note 1: The maximum junction temperature of the LM741 is 150°C, while that of the LM741C is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to case.

Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: These specifications apply for $V_S = \pm15V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise specified. With the LM741C, however, all specifications are limited to $0°C \leq T_A \leq 70°C$ and $V_S = \pm15V$.

Operational Amplifiers

LM747/LM747C dual operational amplifier

general description

The LM747 and the LM747C are general purpose dual operational amplifiers. The two amplifiers share a common bias network and power supply leads. Otherwise, their operation is completely independent.

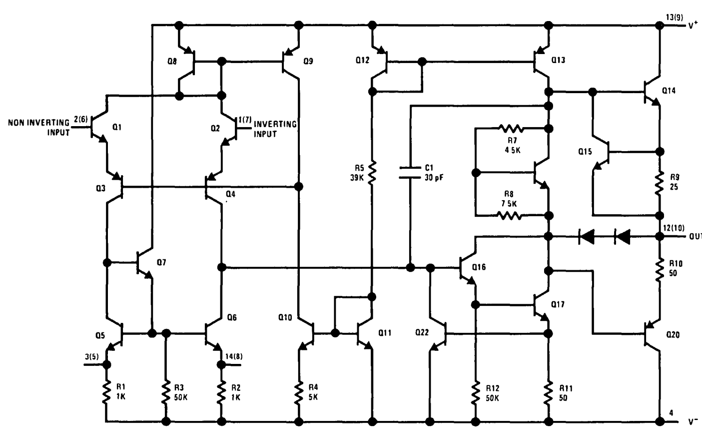
features

- No frequency compensation required
- Short-circuit protection
- Wide common-mode and differential voltage ranges
- Low-power consumption
- No latch-up
- Balanced offset null

Additional features of the LM747 and LM747C are: no latch-up when input common mode range is exceeded, freedom from oscillations, and package flexibility.

The LM747C is identical to the LM747 except that the LM747C has its specifications guaranteed over the temperature range from 0°C to 70°C instead of −55°C to +125°C.

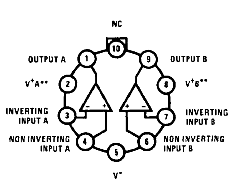
schematic diagram (each amplifier)



Note: Numbers In Parentheses Are Pin Numbers for Amplifier B DIP Only

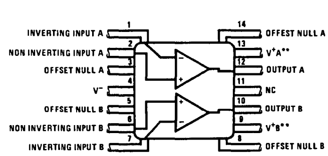
connection diagrams

Metal Can Package



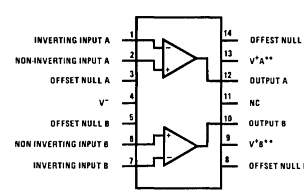
Order Number LM747H or LM747CH
See Package 14

Flat Package



Order Number LM747F or LM747CF
See Package 4

Dual-In-Line Packages



Order Number LM747D or LM747CD
See Package 1
Order Number LM747CN
See Package 22

**V^+A and V^+B are internally connected.

absolute maximum ratings

Supply Voltage LM747	±22V
LM747C	±18V
Power Dissipation (Note 1)	800 mW
Differential Input Voltage	±30V
Input Voltage (Note 2)	±15V
Output Short-Circuit Duration	Indefinite
Operating Temperature Range LM747	−55°C to 125°C
LM747C	0°C to 70°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	LM747			LM747C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$, $R_S \leq 10\ k\Omega$		1.0	5.0		1.0	6.0	mV
Input Offset Current	$T_A = 25°C$		80	200		80	200	nA
Input Bias Current	$T_A = 25°C$		200	500		200	500	nA
Input Resistance	$T_A = 25°C$	0.3	1.0		0.3	1.0		MΩ
Supply Current Both Amplifiers	$T_A = 25°C$, $V_S = \pm 15V$		3.0	5.6		3.0	5.6	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm 15V$ $V_{OUT} = \pm 10V$, $R_L \geq 2\ k\Omega$	50	160		50	160		V/mV
Input Offset Voltage	$R_S \leq 10\ k\Omega$			6.0			7.5	mV
Input Offset Current				500			300	nA
Input Bias Current				1.5			0.8	μA
Large Signal Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \geq 2\ k\Omega$	25			25			V/mV
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10\ k\Omega$	±12	±14		±12	±14		V
	$R_L = 2\ k\Omega$	±10	±13		±10	±13		V
Input Voltage Range	$V_S = \pm 15V$	±12			±12			V
Common Mode Rejection Ratio	$R_S \leq 10\ k\Omega$	70	90		70	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 10\ k\Omega$	77	96		77	96		dB

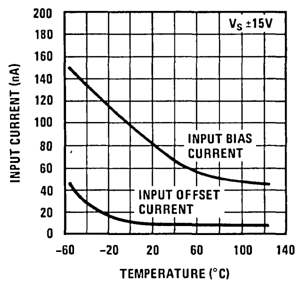
Note 1: The maximum junction temperature of the LM747 is 150°C, while that of the LM747C is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

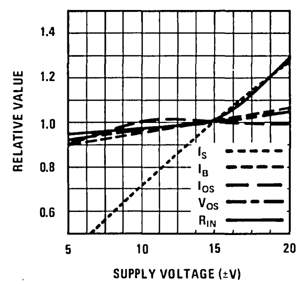
Note 3: These specifications apply for $V_S = \pm 15V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise specified. With the LM747C, however, all specifications are limited to $0°C \leq T_A \leq 70°C$ $V_S = \pm 15V$.

typical performance characteristics

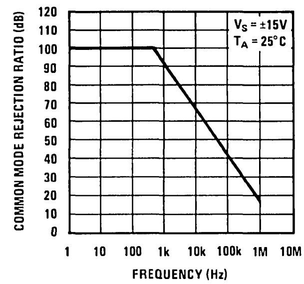
Input Bias and Offset Currents vs Ambient Temperature



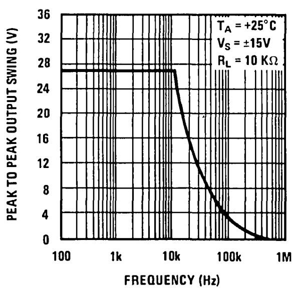
DC Parameters vs Supply Voltage



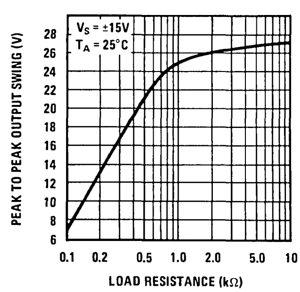
Common Mode Rejection Ratio vs Frequency



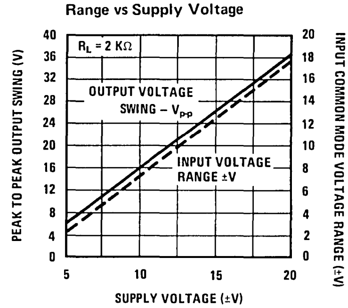
Output Voltage Swing vs Frequency



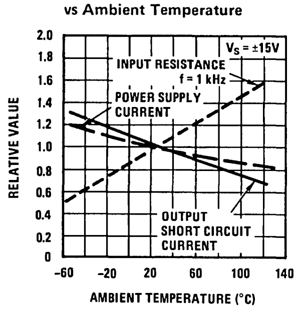
Output Voltage Swing vs Load Resistance



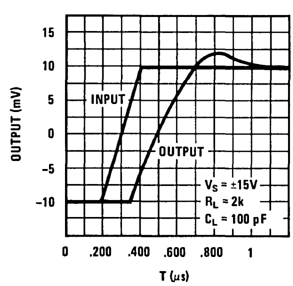
Output Swing and Input Range vs Supply Voltage



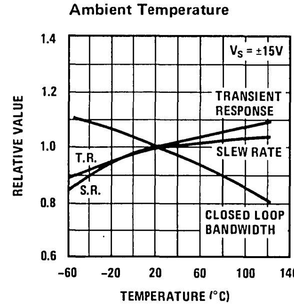
Normalized DC Parameters vs Ambient Temperature



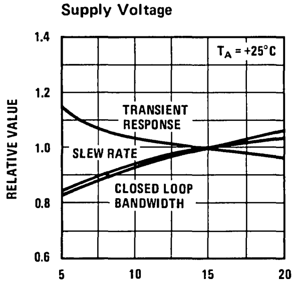
Transient Response



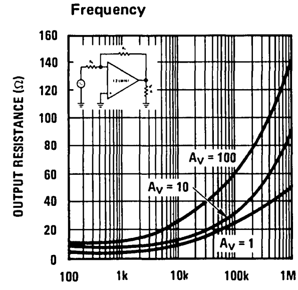
Frequency Characteristics vs Ambient Temperature



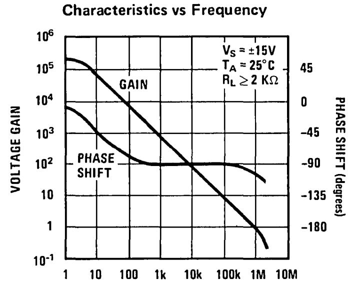
Frequency Characteristics vs Supply Voltage



Output Resistance vs Frequency



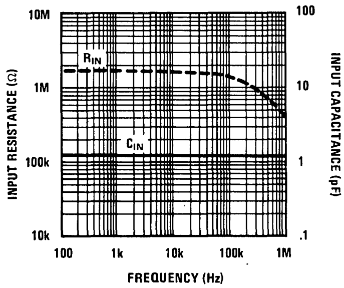
Open Loop Transfer Characteristics vs Frequency



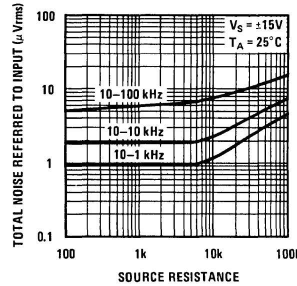
2

typical performance characteristics (con't)

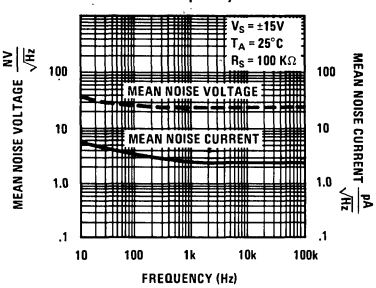
Input Resistance and Input Capacitance vs Frequency



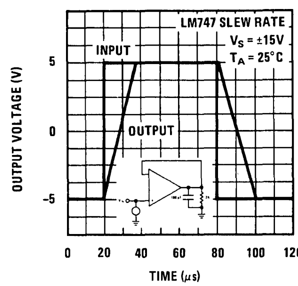
Broadband Noise for Various Bandwidths



Input Noise Voltage and Current vs Frequency



Voltage Follower Large Signal Pulse Response



Operational Amplifiers

LM748/LM748C operational amplifier

general description

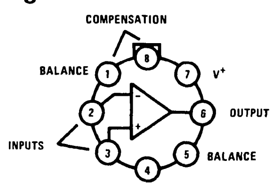
The LM748/LM748C is a general purpose operational amplifier built on a single silicon chip. The resulting close match and tight thermal coupling gives low offsets and temperature drift as well as fast recovery from thermal transients. In addition, the device features:

- Frequency compensation with a single 30 pF capacitor
- Operation from ±5V to ±20V
- Low current drain: 1.8 mA at ±20V
- Continuous short-circuit protection
- Operation as a comparator with differential inputs as high as ±30V
- No latch-up when common mode range is exceeded.
- Same pin configuration as the LM101.

The unity-gain compensation specified makes the circuit stable for all feedback configurations, even with capacitive loads. However, it is possible to optimize compensation for best high frequency performance at any gain. As a comparator, the output can be clamped at any desired level to make it compatible with logic circuits.

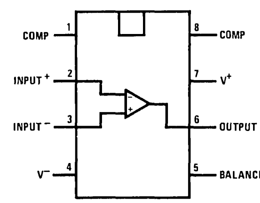
The LM748 is specified for operation over the −55°C to +125°C military temperature range. The LM748C is specified for operation over the 0°C to +70°C temperature range.

connection diagrams



Note: Pin 4 connected to case.

Order Number LM748H or LM748CH
See Package 11

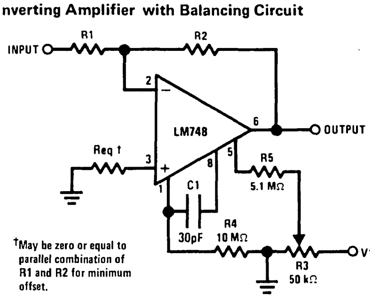


TOP VIEW

Order Number LM748CN
See Package 20

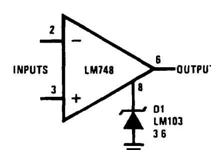
typical applications

Inverting Amplifier with Balancing Circuit

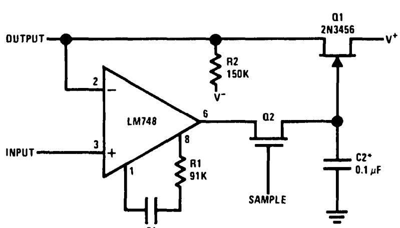


†May be zero or equal to parallel combination of R1 and R2 for minimum offset.

Voltage Comparator for Driving DTL or TTL Integrated Circuits

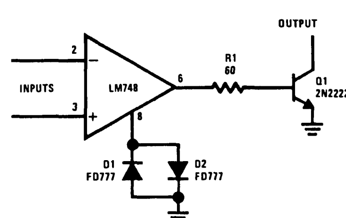


Low Drift Sample and Hold



*Polycarbonate-dielectric capacitor.

Voltage Comparator for Driving RTL Logic or High Current Driver



2

absolute maximum ratings

Supply Voltage	±22V
Power Dissipation (Note 1)	500 mW
Differential Input Voltage	±30V
Input Voltage (Note 2)	±15V
Output Short-Circuit Duration (Note 3)	Indefinite
Operating Temperature Range: LM748	−55°C to +125°C
LM748C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$, $R_S \le 10\ k\Omega$		1.0	5.0	mV
Input Offset Current	$T_A = 25°C$		40	200	nA
Input Bias Current	$T_A = 25°C$		120	500	nA
Input Resistance	$T_A = 25°C$	300	800		kΩ
Supply Current	$T_A = 25°C$, $V_S = \pm 15V$		1.8	2.8	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm 15V$ $V_{OUT} = \pm 10V$, $R_L \ge 2\ k\Omega$	50	160		V/mV
Input Offset Voltage	$R_S \le 10\ k\Omega$			6.0	mV
Average Temperature Coefficient of Input Offset Voltage	$R_S \le 50\Omega$ $R_S \le 10\ k\Omega$		3.0 6.0		μV/°C μV/°C
Input Offset Current	$T_A = 0°C$ to $70°C$ $T_A = -55°C$ to $125°C$			300 500	nA nA
Input Bias Current	$T_A = 0°C$ to $70°C$ $T_A = -55°C$ to $125°C$			0.8 1.5	μA μA
Supply Current	$T_A = +125°C$, $V_S = \pm 15V$ $T_A = -55°C$ to $125°C$		1.2 1.9	2.25 3.3	mA mA
Large Signal Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \ge 2\ K\Omega$	25			V/mV
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10\Omega$ $R_L = 2\ k\Omega$	±12 ±10	±14 ±13		V V
Input Voltage Range	$V_S = \pm 15V$	±12			V
Common Mode Rejection Ratio	$R_S \le 10\ k\Omega$	70	90		dB
Supply Voltage Rejection Ratio	$R_S \le 10\ k\Omega$	77	90		dB

Note 1: For operating at elevated temperatures the devices must be derated based on a maximum junction to case thermal resistance of 45°C per watt, or 150°C per watt junction to ambient. (See Curves).

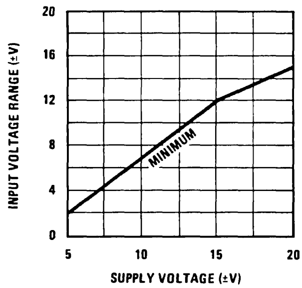
Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: Continuous short circuit is allowed for case temperatures to +125°C and ambient temperatures to +70°C.

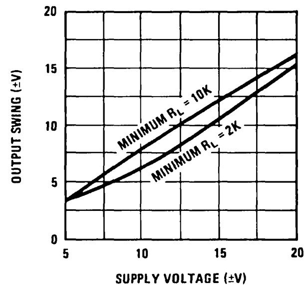
Note 4: These specifications apply for $\pm 5V \le V_S \le +15V$ and $-55°C \le T_A \le 125°C$, unless otherwise specified. With the LM748C, however, all temperature specifications are limited to $0°C \le T_A \le 70°C$.

guaranteed performance characteristics (Note 4)

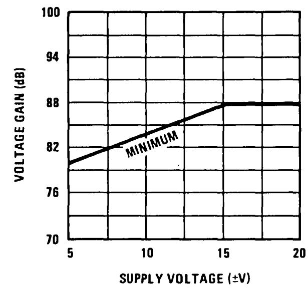
Input Voltage Range



Output Swing

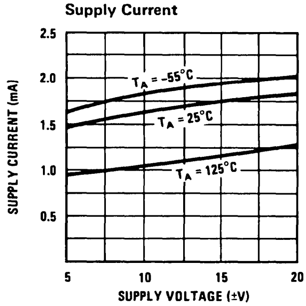


Voltage Gain

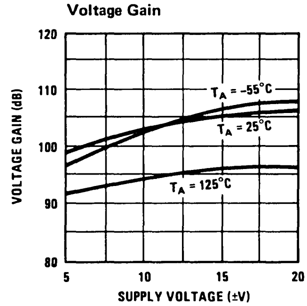


typical performance characteristics

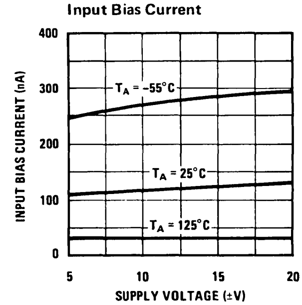
Supply Current



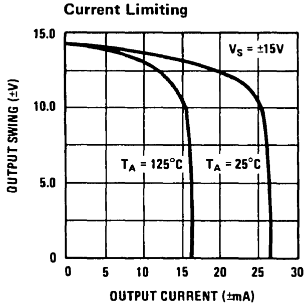
Voltage Gain



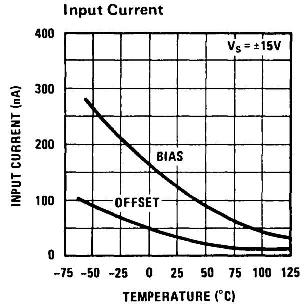
Input Bias Current



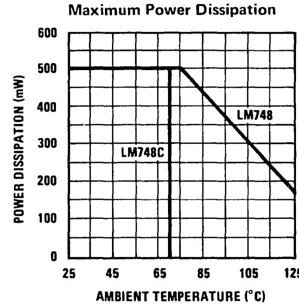
Current Limiting



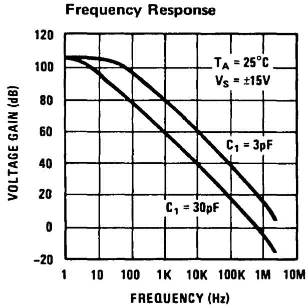
Input Current



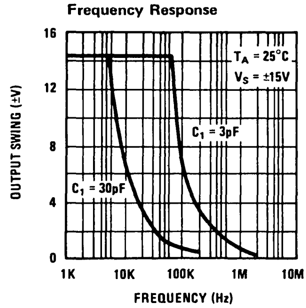
Maximum Power Dissipation



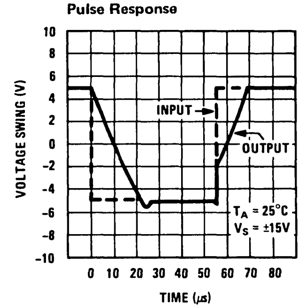
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



Operational Amplifiers

LM1558/LM1458 dual operational amplifier

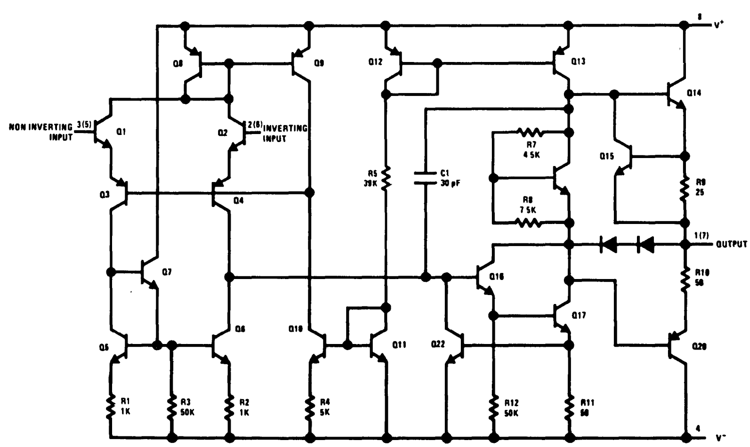
general description

The LM1558 and the LM1458 are general purpose dual operational amplifiers. The two amplifiers share a common bias network and power supply leads. Otherwise, their operation is completely independent. Features include:

- No frequency compensation required
- Short-circuit protection
- Wide common-mode and differential voltage ranges
- Low-power consumption
- 8-lead TO-5 and 8-lead mini DIP
- No latch up when input common mode range is exceeded

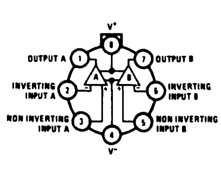
The LM1458 is identical to the LM1558 except that the LM1458 has its specifications guaranteed over the temperature range from 0°C to 70°C instead of −55°C to +125°C.

schematic and connection diagrams



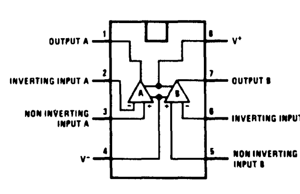
Note: Numbers in parentheses are pin numbers for amplifier B.

Metal Can Package



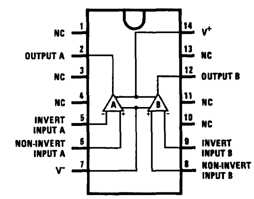
Order Number LM1458H or LM1558H
See Package 11

Dual-In-Line Package



Order Number LM1458N
See Package 20

Dual-In-Line Package



Order Number LM1458-14
See Package 22

absolute maximum ratings

Supply Voltage LM1558	±22V	Output Short-Circuit Duration	Indefinite
LM1458	±18V	Operating Temperature Range LM1558	−55°C to 125°C
Power Dissipation (Note 1) LM1558H/LM1458H	500 mW	LM1458	0°C to 70°C
LM1458N	400 mW	Storage Temperature Range	−65°C to 150°C
Differential Input Voltage	±30V	Lead Temperature (Soldering, 10 sec)	300°C
Input Voltage (Note 2)	±15V		

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	LM1558 MIN	LM1558 TYP	LM1558 MAX	LM1458 MIN	LM1458 TYP	LM1458 MAX	UNITS
Input Offset Voltage	$T_A = 25°C$, $R_S \leq 10\ k\Omega$		1.0	5.0		1.0	6.0	mV
Input Offset Current	$T_A = 25°C$		80	200		80	200	nA
Input Bias Current	$T_A = 25°C$		200	500		200	500	nA
Input Resistance	$T_A = 25°C$	0.3	1.0		0.3	1.0		MΩ
Supply Current Both Amplifiers	$T_A = 25°C$, $V_S = \pm 15V$		3.0	5.0		3.0	5.6	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm 15V$ $V_{OUT} = \pm 10V$, $R_L \geq 2\ k\Omega$	50	160		20	160		V/mV
Input Offset Voltage	$R_S \leq 10\ k\Omega$			6.0			7.5	mV
Input Offset Current				500			300	nA
Input Bias Current				1.5			0.8	μA
Large Signal Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \geq 2\ k\Omega$	25			15			V/mV
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10\ k\Omega$	±12	±14		±12	±14		V
	$R_L = 2\ k\Omega$	±10	±13		±10	±13		V
Input Voltage Range	$V_S = \pm 15V$	±12			±12			V
Common Mode Rejection Ratio	$R_S \leq 10\ k\Omega$	70	90		70	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 10\ k\Omega$	77	96		77	96		dB

Note 1: The maximum junction temperature of the LM1558 is 150°C, while that of the LM1458 is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient or 45°C/W, junction to case. For the DIP the device must be derated based on a thermal resistance of 187°C/W, junction to ambient.

Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: These specifications apply for $V_S = \pm 15V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise specified. With the LM1458, however, all specifications are limited to $0°C \leq T_A \leq 70°C$ and $V_S = \pm 15V$.

Operational Amplifiers

LM2900 quad amplifier

general description

The LM2900 consists of four independent, dual input, internally compensated amplifiers which were designed specifically for automotive and industrial applications. They operate off a single power supply voltage and provide a large output voltage swing. These amplifiers make use of a current mirror to achieve the non-inverting input function.

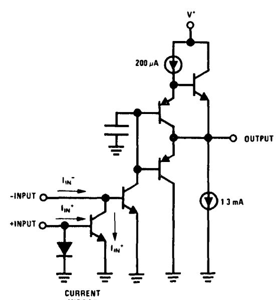
Applications include: AC amplifiers, RC active filters; low frequency triangle, squarewave and pulse waveform generation circuits; tachometers and low speed, high voltage digital logic gates.

For additional information, see Application Note 72, "The LM3900 – A New Current-Differencing Quad of ± Input Amplifiers."

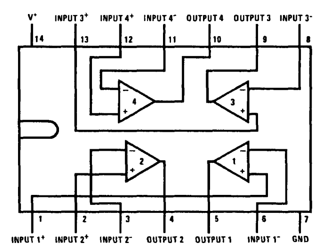
features

- Wide single supply voltage range 4 V_{DC} to 36 V_{DC}
- Supply current drain independent of supply voltage
- Low input biasing current 30 nA
- High open-loop gain 70 dB
- Wide bandwidth 2.5 MHz (Unity Gain)
- Larger gain-bandwidth product in non-inverting mode (A_V = 100 @ f = 1 MHz)
- Large output voltage swing (V^+ −1) $V_{p\text{-}p}$
- Internally frequency compensated for unity gain
- Output short-circuit protection
- Eliminates need for dual supplies
- Reduces package count

schematic and connection diagrams

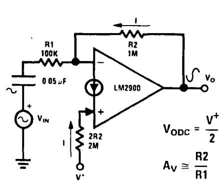


Dual-In-Line Package

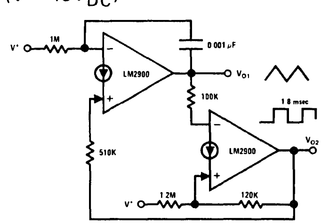


Order Number LM2900N
See Package 22

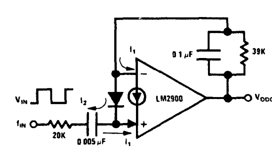
typical applications (V^+= 15V_{DC})



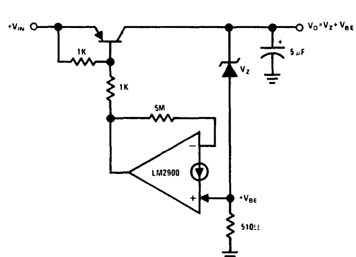
Inverting Amplifier



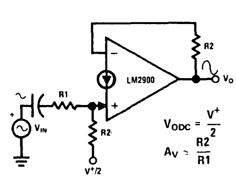
Triangle/Square Generator



Frequency-Doubling Tachometer

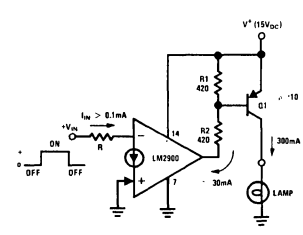


Low V_{IN}–V_{OUT} Voltage Regulator



High gain-bandwidth example:
A_V = 100 @ 1 MHz
(See note 2, page 2)

Non-Inverting Amplifier



Boosting to 300 mA Loads

absolute maximum ratings

Supply Voltage	+36 V_{DC} ±18 V_{DC}
Power Dissipation (T_A = 25°C) (Note 1)	570 mW
Input Currents, $I_{IN}+$ or $I_{IN}-$	20 mA DC
Output Short Circuit Duration – One Amplifier T_A = 25°C (See Application Hints)	Continuous
Operating Temperature Range	–40°C to +85°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (V^+ = +15 V_{DC} and T_A = 25°C unless otherwise noted)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Open Loop					
Voltage Gain	f = 100 Hz	1200	2800		V/V
Input Resistance	Inverting Input		1		MΩ
Output Resistance			8		kΩ
Unity Gain Bandwidth	Inverting Input (Note 2)		2.5		MHz
Input Bias Current	Inverting Input		30	200	nA
Slew Rate	Positive Output Swing		0.5		V/µs
	Negative Output Swing		20		V/µs
Supply Current	R_L = ∞ On All Amplifiers		6.2	10	mA DC
Output Voltage Swing	R_L = 5.1k				
V_{OUT} High	$I_{IN}-$ = 0, $I_{IN}+$ = 0	13.5	14.2		V_{DC}
V_{OUT} Low	$I_{IN}-$ = 10 µA, $I_{IN}+$ = 0		0.09	0.2	V_{DC}
Output Current Capability					
Source		3	18		mA DC
Sink	(Note 3)	0.5	1.3		mA DC
Power Supply Rejection	f = 100 Hz		70		dB
Mirror Gain	$I_{IN}+$ = 200 µA (Note 4)	0.90	1	1.1	µA/µA
Mirror Current	(Note 5)		10	500	µA DC
Negative Input Current	(Note 6)		1.0		mA DC

Note 1: For operating at high temperatures, the device must be derated based on a 125°C maximum junction temperature and a thermal resistance of 175°C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient.

Note 2: When used as a "non-inverting amplifier" (see bottom of page 1) the gain-bandwidth product is not limited to 2.5 MHz. The isolation provided by the "current mirror" allows a constant unity voltage gain feedback for the main inverting amplifier. This means that large values of gain can be achieved at high frequencies and the dominate limit is due to the slew rate of the amplifier. For example: a voltage gain of 100 is easily obtained at 1 MHz and an output voltage swing of 160 mVp-p can be achieved prior to slew rate limiting. This operational mode is useful for signal frequencies in the 50 kHz to 1 MHz range as would be encountered in IF or carrier frequency applications.

Note 3: The output current sink capability can be increased for large signal conditions by overdriving the inverting input. This is shown in the section on Typical Characteristics.

Note 4: This spec indicates the current gain of the current mirror which is used as the non-inverting input.

Note 5: Input V_{BE} match between the non-inverting and the inverting inputs occurs for a mirror current (non-inverting input current) of approximately 10 µA. This is therefore a typical design center for many of the application circuits.

Note 6: Clamp transistors are included on the IC to prevent the input voltages from swinging below ground more than approximately –0.3 V_{DC}. The negative input currents which may result from large signal overdrive with capacitance input coupling need to be externally limited 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. This maximum current applies to any one of the input terminals. If more than one of the input terminals are simultaneously driven negative smaller maximum currents are allowed. Common-mode current biasing can be used to prevent negative input voltages; for example, see the "Differentiator Circuit" in the applications section.

Operational Amplifiers

LM2902 quad op amp

general description

The LM2902 consists of four independent, high gain, internally frequency compensated operational amplifiers which were designed specifically for automotive and industrial control systems. They operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

unique characteristics

- In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage.
- The unity gain-cross frequency is temperature compensated.
- The input bias current is also temperature compensated.

Application areas include transducer amplifiers, DC gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM2902 can be directly operated off of the standard $+5V_{DC}$ power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional $\pm 15V_{DC}$ power supplies.

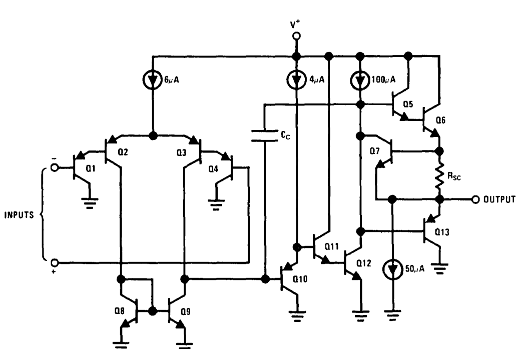
advantages

- Eliminates need for dual supplies
- Four internally compensated op amps in a single package
- Allows directly sensing near GND and V_{OUT} also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation

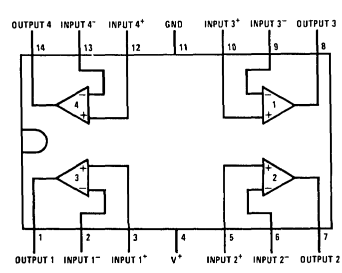
features

- Internally frequency compensated for unity gain
- Large DC voltage gain — 100 dB
- Wide bandwidth (unity gain) (temperature compensated) — 1 MHz
- Wide power supply range
  - Single supply — $3\ V_{DC}$ to $26\ V_{DC}$
  - or dual supplies — $\pm 1.5\ V_{DC}$ to $\pm 13\ V_{DC}$
- Very low supply current drain ($800\mu A$) — essentially independent of supply voltage (1 mW/op amp at $+5V_{DC}$)
- Low input biasing current (temperature compensated) — $45\ nA_{DC}$
- Low input offset voltage — $2\ mV_{DC}$ and offset current — $5\ nA_{DC}$
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Large output voltage swing — $0V_{DC}$ to $V^+ - 1.5V_{DC}$

schematic and connection diagrams



Dual-In-Line Package



Order Number LM2902N
See Package 22

absolute maximum ratings

Supply Voltage, V^+	32 V_{DC} or ±13 V_{DC}
Differential Input Voltage	26 V_{DC}
Input Voltage	−0.3 V_{DC} to +26 V_{DC}
Power Dissipation (Note 1)	570 mW
Output Short-Circuit to GND (Note 2) $V^+ \leq 15\ V_{DC}$ and $T_A = 25°C$	Continuous
Operating Temperature Range	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 60 sec)	300°C

electrical characteristics ($V^+ = +5V_{DC}$ and $T_A = 25°C$ unless otherwise noted)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$R_S = 0\Omega$		2	10	mV_{DC}
Input Bias Current (Note 3)	$I_{IN(+)}$ or $I_{IN(-)}$		45	500	nA_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$		±5	±50	nA_{DC}
Input Common-Mode Voltage Range (Note 4)		0		$V^+-1.5$	V_{DC}
Supply Current	$R_L = \infty$ On All Op Amps		0.8	2	mA_{DC}
Large Signal Voltage Gain	$R_L \geq 2\ k\Omega$		100		V/mV
Output Voltage Swing	$R_L = 2\ k\Omega$	0		$V^+-1.5$	V_{DC}
Common Mode Rejection Ratio	DC		85		dB
Power Supply Rejection Ratio	DC		100		dB
Amplifier-to-Amplifier Coupling	f = 1 kHz to 20 kHz (Input Referred)		−120		dB
Output Current Source	$V_{IN}^+ = +1\ V_{DC}$, $V_{IN}^- = 0\ V_{DC}$	20	40		mA_{DC}
Output Current Sink	$V_{IN}^- = +1\ V_{DC}$, $V_{IN}^+ = 0\ V_{DC}$	8	20		mA_{DC}

Note 1: For operating at high temperatures, the LM2902 must be derated based on a +125°C maximum junction temperature and a thermal resistance of 175°C/W which applies for the device soldered in a printed circuit board operating in a still air ambient.

Note 2: Short circuits from the output to V^+ can cause excessive heating and eventual destruction. The maximum output current is approximately 40 mA independent of the magnitude of V^+. At values of supply voltage in excess of $+15V_{DC}$, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction.

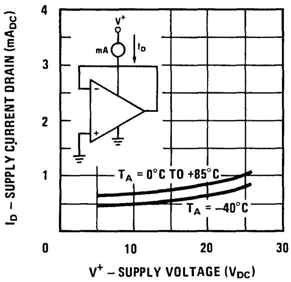
Note 3: The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.

Note 4: The input common-mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3V. The upper end of the common-mode voltage range is $V^+ - 1.5V$, but either or both inputs can go to $+26V_{DC}$ without damage.

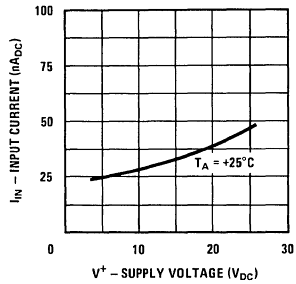
2

typical performance characteristics

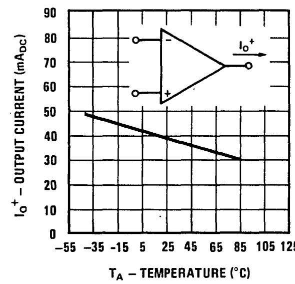
Supply Current



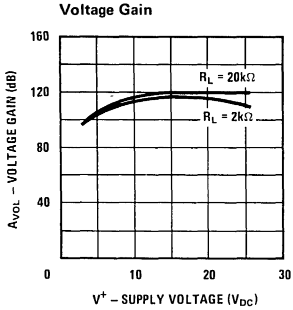
Input Current



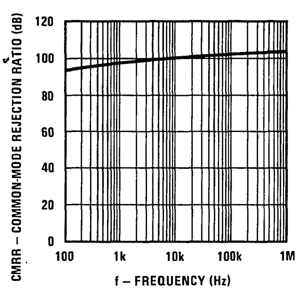
Current Limiting



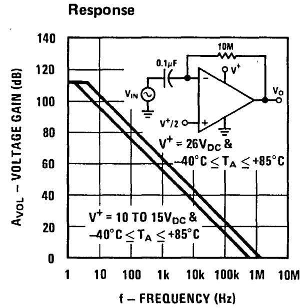
Voltage Gain



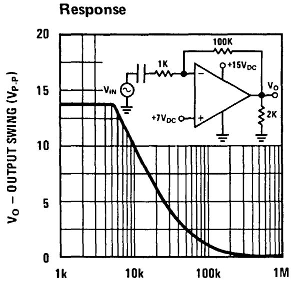
Common-Mode Rejection Ratio



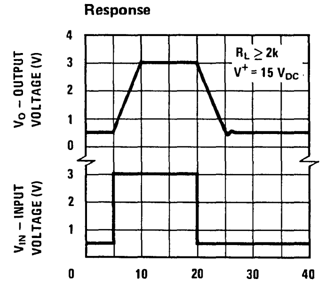
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



application hints

The LM2902 op amps operate with only a single power supply voltage, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of $0V_{DC}$. These amplifiers operate over a wide range of power supply voltage with little change in performance characteristics. At 25°C amplifier operation is possible down to a minimum supply voltage of $2.3V_{DC}$.

The pinouts of the package have been designed to simplify PC board layouts. Inverting inputs are adjacent to outputs for all of the amplifiers and the outputs have also been placed at the corners of the package (pins 1, 7, 8, and 14).

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a test socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Large differential input voltages can be easily accommodated and, as input differential voltage protection diodes are not needed, no large input currents result from large differential input voltages. The differential input voltage may be larger than V^+ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than $-0.3V_{DC}$ (at 25°C). An input clamp consisting of a diode-connected NPN transistor (C-B short) can be used.

To reduce the power supply current drain, the amplifiers have a class A output stage for small signal levels which converts to class B in a large signal mode. This allows the amplifiers to both source and sink large output currents. Therefore both NPN and PNP external current boost transistors can be used to extend the power capability of the basic amplifiers. The output voltage needs to raise approximately 1 diode drop above ground to bias the on-chip vertical PNP transistor for output current sinking applications.

For AC applications, where the load is capacitively coupled to the output of the amplifier, a resistor should be used, from the output of the amplifier to ground to increase the class A bias current and prevent crossover distortion. Where the load is directly coupled, as in DC applications, there is no crossover distortion.

Capacitive loads which are applied directly to the output of the amplifier reduce the loop stability margin. Values of 50 pF can be accommodated using the worst-case non-inverting unity gain connection. Large closed loop gains or resistive isolation should be used if larger load capacitance must be driven by the amplifier.

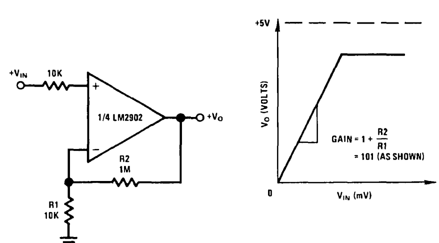
The bias network of the LM2902 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from $3V_{DC}$ to $26V_{DC}$.

Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperatures. Putting direct short-circuits on more than one amplifier at a time will increase the total IC power dissipation to destructive levels, if not properly protected with external dissipation limiting resistors in series with the output leads of the amplifiers. The larger value of output source current which is available at 25°C provides a larger output current capability at elevated temperatures (see typical performance characteristics) than a standard IC op amp.

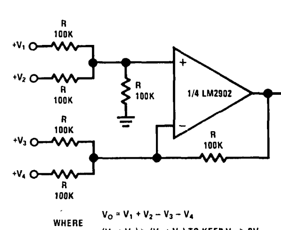
The circuits presented in the section on typical applications emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op amp circuits can be used. In general, introducing a pseudo-ground (a bias voltage reference of $V^+/2$) will allow operation above and below this value in single power supply systems. Many application circuits are shown which take advantage of the wide input common-mode voltage range which includes ground. In most cases, input biasing is not required and input voltages which range to ground can easily be accommodated.

typical single-supply applications ($V^+ = 5\ V_{DC}$)

Non-Inverting DC Gain (0V Input = 0V Output)

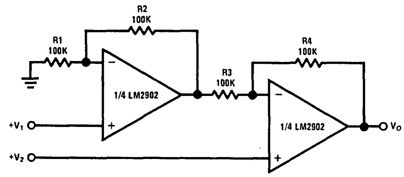


DC Summing Amplifier
(V_{IN}'S $\geq 0V_{DC}$ AND $V_O \geq 0V_{DC}$)



typical single-supply applications (con't) ($V^+ = 5\ V_{DC}$)

High Input Z, DC Differential Amplifier

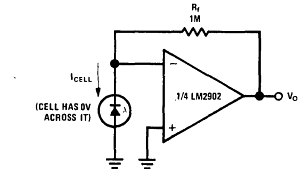


FOR $\frac{R1}{R2} = \frac{R4}{R3}$ (CMRR DEPENDS ON THIS RESISTOR RATIO MATCH)

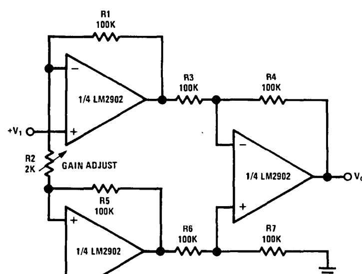
$$V_O = \left(1 + \frac{R4}{R3}\right)(V_2 - V_1)$$

AS SHOWN $V_O = 2(V_2 - V_1)$

Photo Voltaic-Cell Amplifier



High Input Z Adjustable-Gain DC Instrumentation Amplifier

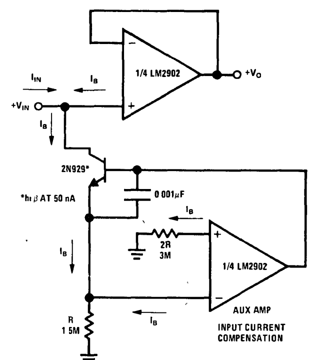


IF R1 = R5 & R3 = R4 = R6 = R7 (CMRR DEPENDS ON MATCH)

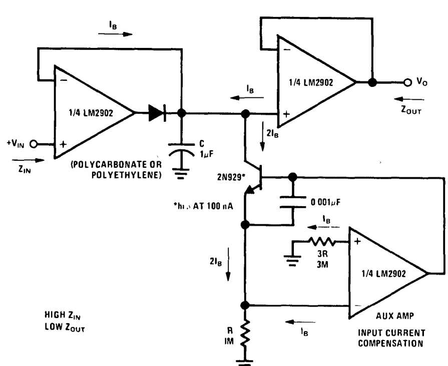
$$V_O = 1 + \frac{2\,R1}{R2}(V_2 - V_1)$$

AS SHOWN $V_O = 101\,(V_2 - V_1)$

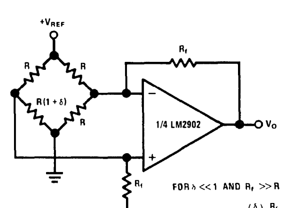
Using Symmetrical Amplifiers to Reduce Input Current (General Concept)



Low Drift Peak Detector



Bridge Current Amplifier

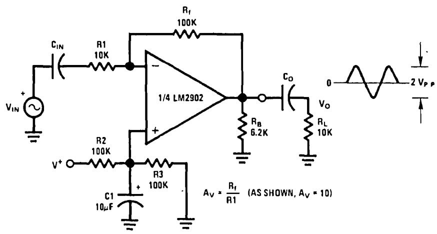


FOR $\delta << 1$ AND $R_f >> R$

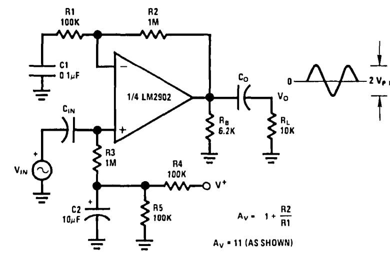
$$V_O \approx V_{REF}\left(\frac{\delta}{2}\right)\frac{R_f}{R}$$

typical single-supply applications (con't) ($V^+ = 5\ V_{DC}$)

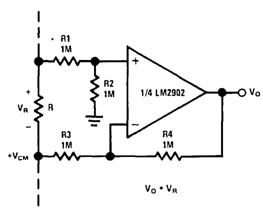
AC Coupled Inverting Amplifier



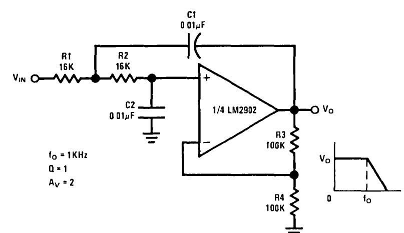
AC Coupled Non-Inverting Amplifier



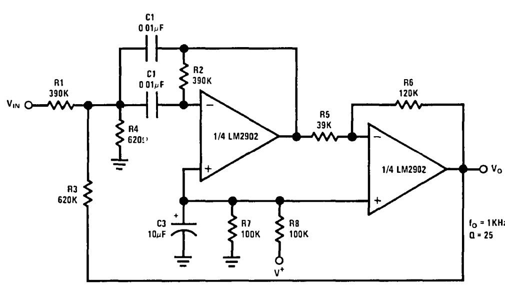
Ground Referencing A Differential Input Signal



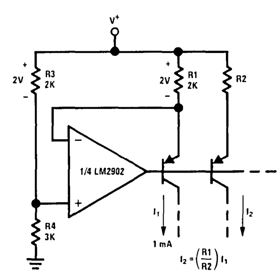
DC Coupled Low-Pass RC Active Filter



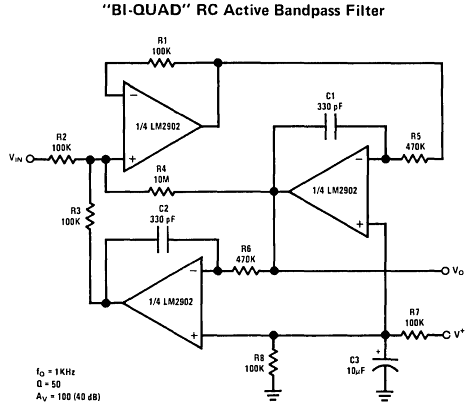
Bandpass Active Filter



Fixed Current Sources



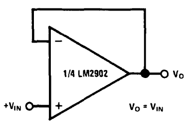
"BI-QUAD" RC Active Bandpass Filter



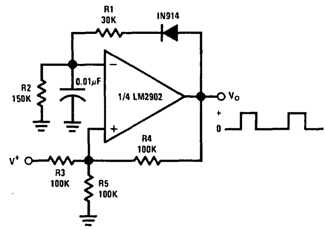
2

typical single-supply applications (con't) ($V^+ = 5\ V_{DC}$)

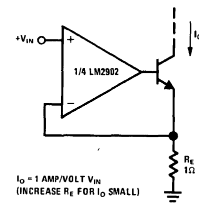
Voltage Follower



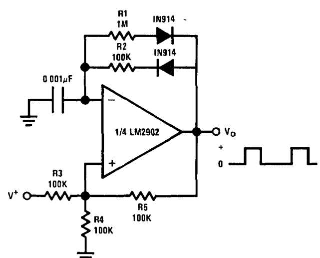
Pulse Generator



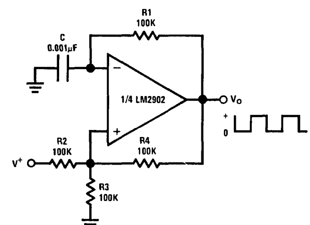
High Compliance Current Sink



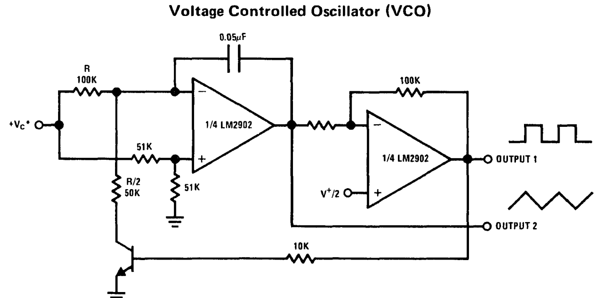
Pulse Generator



Squarewave Oscillator

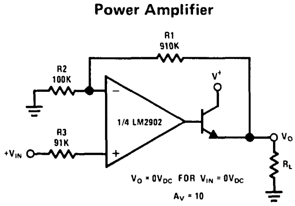


Voltage Controlled Oscillator (VCO)

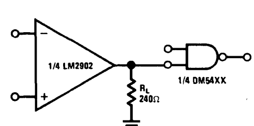


*WIDE CONTROL VOLTAGE RANGE: $0\ V_{DC} \leq V_C \leq 2\ (V^+ - 1.5\ V_{DC})$

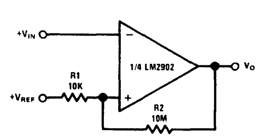
Power Amplifier



Driving TTL

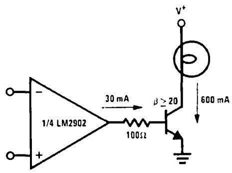


Comparator With Hysteresis

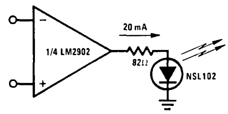


typical single-supply applications (con't) ($V^+ = 5\ V_{DC}$)

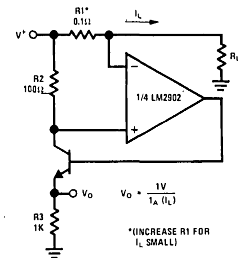
Lamp Driver



LED Driver



Current Monitor



Operational Amplifiers

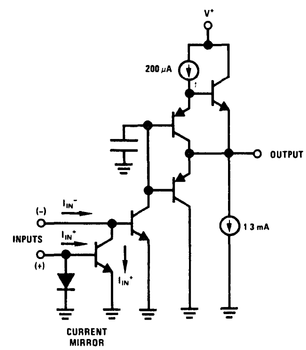
LM3900 quad amplifier general description

The LM3900 consists of four independent, dual input, internally compensated amplifiers which were designed specifically to operate off of a single power supply voltage and to provide a large output voltage swing. These amplifiers make use of a current mirror to achieve the non-inverting input function. Application areas include: AC amplifiers, RC active filters; low frequency triangle, squarewave and pulse waveform generation circuits, tachometers and low speed, high voltage digital logic gates.

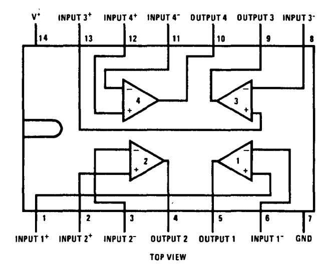
features

- Wide single supply voltage range $4\ V_{DC}$ to $36\ V_{DC}$ or dual supplies $\pm 2\ V_{DC}$ to $\pm 18\ V_{DC}$
- Supply current drain independent of supply voltage
- Low input biasing current 30 nA
- High open-loop gain 70 dB
- Wide bandwidth 2.5 MHz (Unity Gain)
- Large output voltage swing $(V^+ -1)\ V_{p\text{-}p}$
- Internally frequency compensated for unity gain
- Output short-circuit protection

schematic and connection diagrams

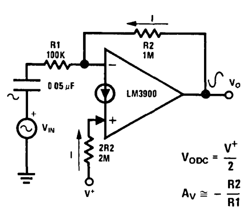


Dual-In-Line Package

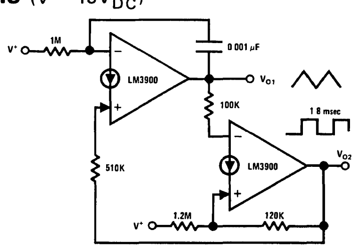


Order Number LM3900N
See Package 22

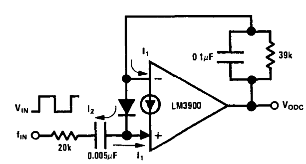
typical applications $(V^+ = 15V_{DC})$



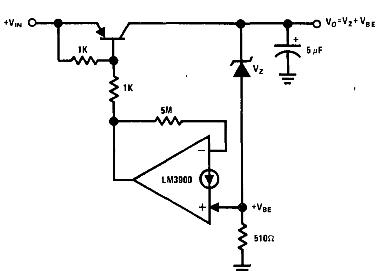
Inverting Amplifier



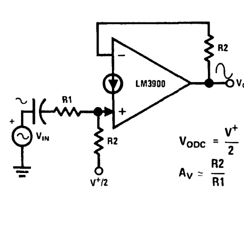
Triangle/Square Generator



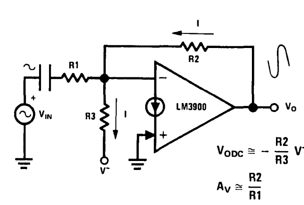
Frequency-Doubling Tachometer



Low V_{IN}–V_{OUT} Voltage Regulator



Non-Inverting Amplifier



Negative Supply Biasing

absolute maximum ratings

Supply Voltage	+32 VDC ±18 VDC
Power Dissipation (T_A = 25°C) (Note 1)	570 mW
Input Currents, $I_{IN}+$ or $I_{IN}-$	20 mA DC
Output Short Circuit Duration – One Amplifier T_A = 25°C (See Application Hints)	Continuous
Operating Temperature Range	0°C to +70°C
Storage Temperature Range	–65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (V^+ = +15 VDC and T_A = 25°C unless otherwise noted)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Open Loop					
Voltage Gain	f = 100 Hz	1200	2800		V/V
Input Resistance	Inverting Input		1		MΩ
Output Resistance			8		kΩ
Unity Gain Bandwidth	Inverting Input		2.5		MHz
Input Bias Current	Inverting Input		30	200	nA
Slew Rate	Positive Output Swing		0.5		V/μs
	Negative Output Swing		20		V/μs
Supply Current	R_L = ∞ On All Amplifiers		6.2	10	mA DC
Output Voltage Swing	R_L = 5.1k				
V_{OUT} High	$I_{IN}-$ = 0, $I_{IN}+$ = 0	13.5	14.2		VDC
V_{OUT} Low	$I_{IN}-$ = 10 μA, $I_{IN}+$ = 0		0.09	0.2	VDC
Output Current Capability					
Source		3	18		mA DC
Sink	(Note 2)	0.5	1.3		mA DC
Power Supply Rejection	f = 100 Hz		70		dB
Mirror Gain	$I_{IN}+$ = 200 μA (Note 3)	0.9	1	1.1	μA/μA
Mirror Current	(Note 4)		10	500	μA DC
Negative Input Current	(Note 5)		1.0		mA DC

Note 1: For operating at high temperatures, the device must be derated based on a 125°C maximum junction temperature and a thermal resistance of 175°C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient.

Note 2: The output current sink capability can be increased for large signal conditions by overdriving the inverting input. This is shown in the section on Typical Characteristics.

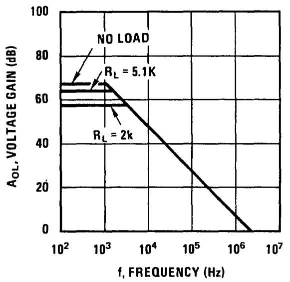
Note 3: This spec indicates the current gain of the current mirror which is used as the non-inverting input.

Note 4: Input V_{BE} match between the non-inverting and the inverting inputs occurs for a mirror current (non-inverting input current) of approximately 10 μA. This is therefore a typical design center for many of the application circuits.

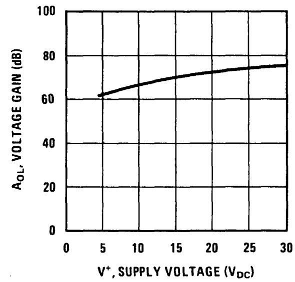
Note 5: Clamp transistors are included on the IC to prevent the input voltages from swinging below ground more than approximately –0.3 VDC. The negative input currents which may result from large signal overdrive with capacitance input coupling need to be externally limited to values of approximately 1 mA. Negative input currents in excess of 4 mA will cause the output voltage to drop to a low voltage. This maximum current applies to any one of the input terminals. If more than one of the input terminals are simultaneously driven negative smaller maximum currents are allowed. Common-mode current biasing can be used to prevent negative input voltages; see for example the "Differentiator Circuit" in the applications section.

typical performance characteristics

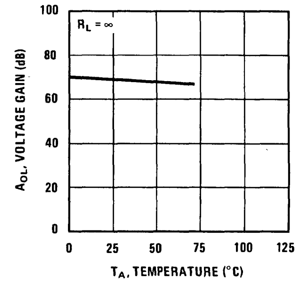
Open-Loop Gain



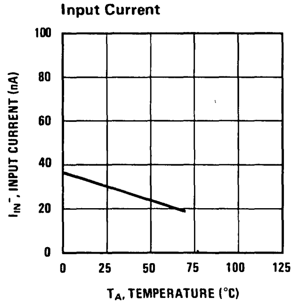
Voltage Gain



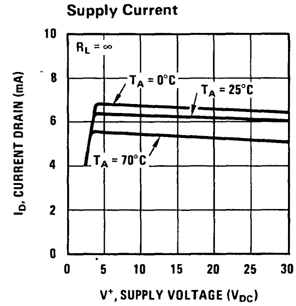
Voltage Gain



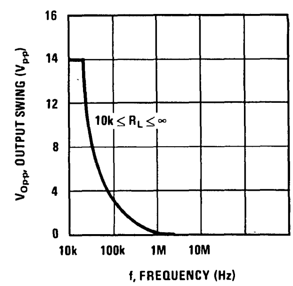
Input Current



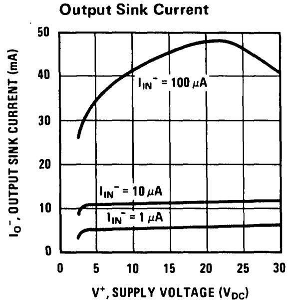
Supply Current



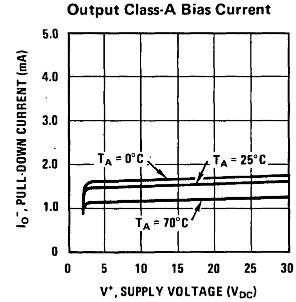
Large Signal Frequency Response



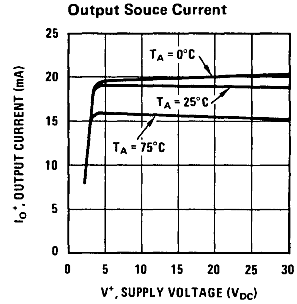
Output Sink Current



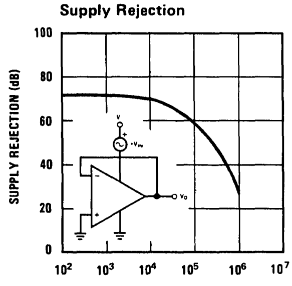
Output Class-A Bias Current



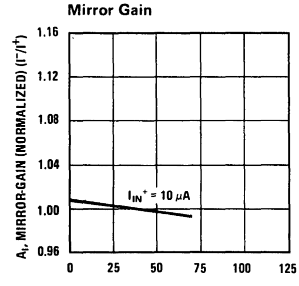
Output Souce Current



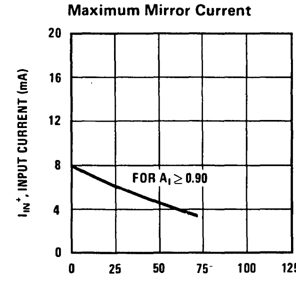
Supply Rejection



Mirror Gain



Maximum Mirror Current



application hints

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. Currents as large as 20 mA will not damage the device, but the current mirror on the non-inverting input will saturate and cause a loss of mirror gain at mA current levels – especially at high operating temperatures.

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a test socket as an unlimited current surge through the resulting forward diode within the IC could cause fuzing of the internal conductors and result in a destroyed unit.

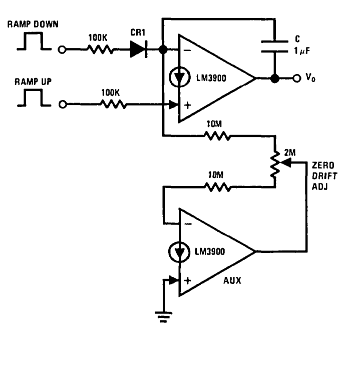
Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fuzing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperatures. For example, when operating from a well-regulated +15 VDC power supply at T_A = 25°C with a 100 kΩ shunt-feedback resistor (from the output to the inverting input) a short directly to the power supply will not cause catastrophic failure but the current magnitude will be approximately 50 mA and the junction temperature will be above T_J max. Larger feedback resistors will reduce the current, 11 MΩ provides approximately 30 mA, an open circuit provides 1.3 mA, and a direct connection from the output to the non-inverting input will result in catastrophic failure when the output is shorted to V^+ as this then places the base-emitter junction of the input transistor directly across the power supply. Short-circuits to ground will have magnitudes of approximately 30 mA and will not cause catastrophic failure at T_A = 25°C.

Unintentional signal coupling from the output to the non-inverting input can cause oscillations. This is likely only in breadboard hook-ups with long component leads and can be prevented by a more careful lead dress or by locating the non-inverting input biasing resistor close to the IC. A quick check of this condition is to bypass the non-inverting input to ground with a capacitor. High impedance biasing resistors used in the non-inverting input circuit make this input lead highly susceptible to unintentional AC signal pickup.

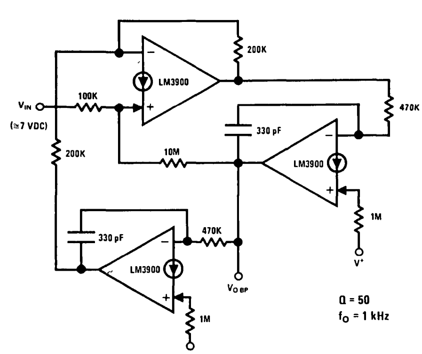
Operation of this amplifier can be best understood by noticing that input currents are differenced at the inverting-input terminal and this difference current then flows through the external feedback resistor to produce the output voltage. Common mode current biasing is generally useful to allow operating with signal levels near ground or even negative as this maintains the inputs biased at $+V_{BE}$. Internal clamp transistors (see note 5) catch negative input voltages at approximately –0.3 VDC 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 μA.

This new "Norton" current-differencing amplifier can be used in most of the applications of a standard IC op amp. Performance as a DC amplifier using only a single supply is not as precise as a standard IC op amp operating with split supplies but is adequate in many less critical applications. New functions are made possible with this amplifier which are useful in single power supply systems. For example, biasing can be designed separately from the AC gain as was shown in the "inverting amplifier", the "difference integrator" allows controlling the charging and the discharging of the integrating capacitor using only positive voltages, and the "frequency doubling tachometer" provides a simple circuit which reduces the ripple voltage on a tachometer output DC voltage.

typical applications (con't)

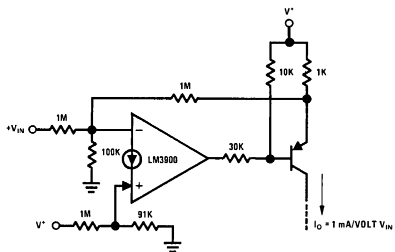


Low-Drift Ramp & Hold Circuit

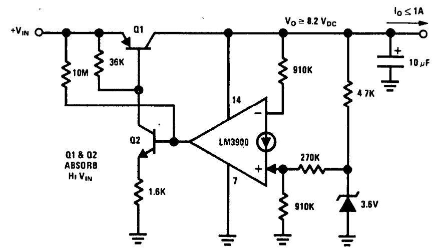


Bi-Quad Active Filter
(2nd Degree State-Variable Network)

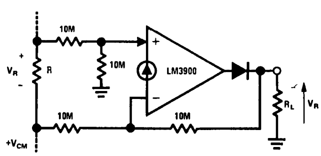
typical applications (con't)



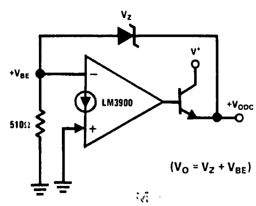
Voltage-Controlled Current Source (Transconductance Amplifier)



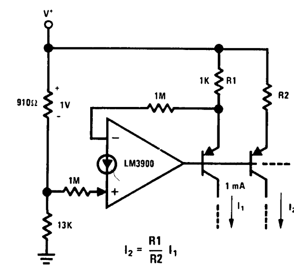
Hi V_{IN}, Lo (V_{IN}−V_O) Self-Regulator



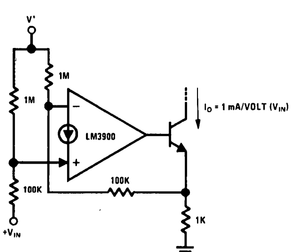
Ground-Referencing a Differential Input Signal



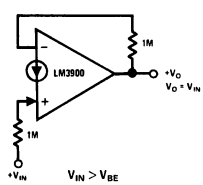
Voltage Regulator



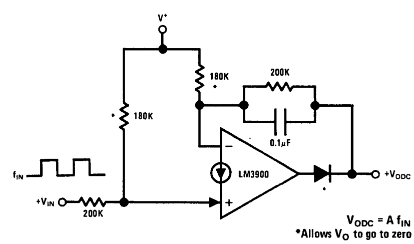
Fixed Current Sources



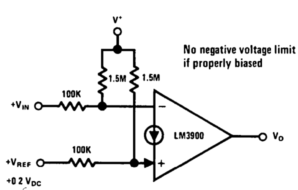
Voltage-Controlled Current Sink (Transconductance Amplifier)



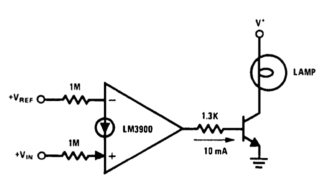
Buffer Amplifier



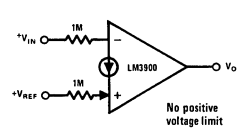
Tachometer



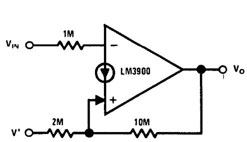
Low-Voltage Comparator



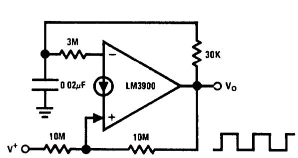
Power Comparator



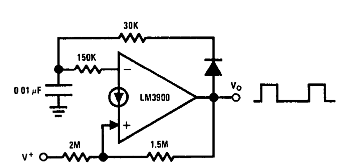
Comparator



Schmitt-Trigger

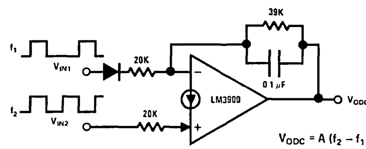


Square-Wave Oscillator

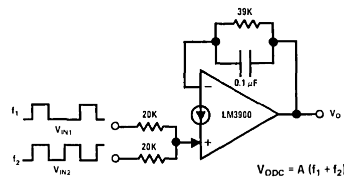


Pulse Generator

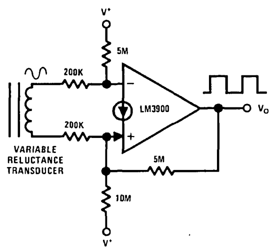
typical applications (con't)



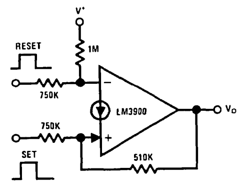
Frequency Differencing Tachometer



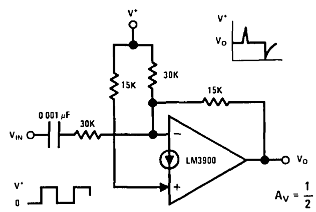
Frequency Averaging Tachometer



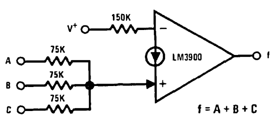
Squaring Amplifier (W/Hysteresis)



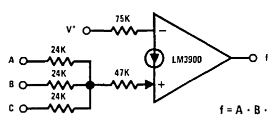
Bi-Stable Multivibrator



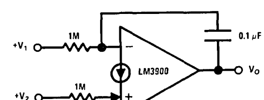
Differentiator (Common-Mode Biasing Keeps Input at $+V_{BE}$)



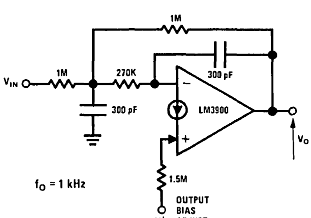
"OR" Gate



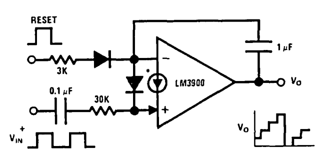
"AND" Gate



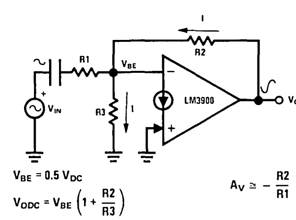
Difference Integrator



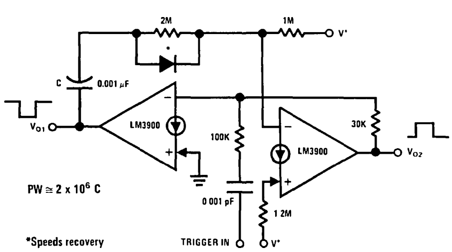
Low Pass Active Filter



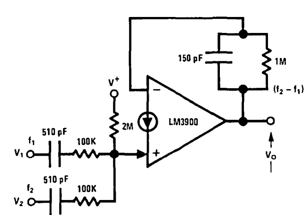
Staircase Generator



V_{BE} Biasing

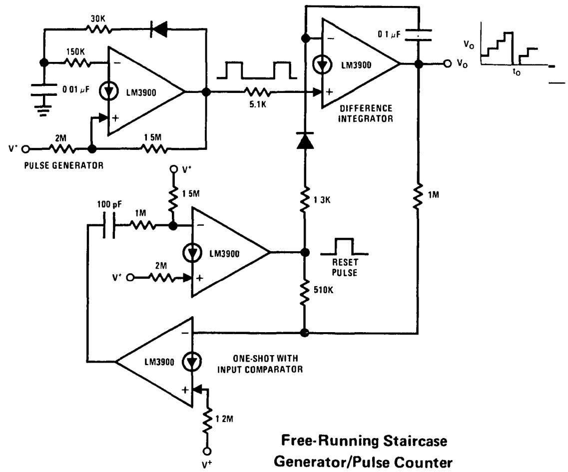


One-Shot Multivibrator

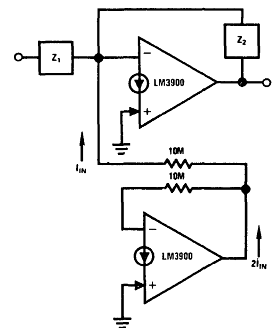


Low-Frequency Mixer

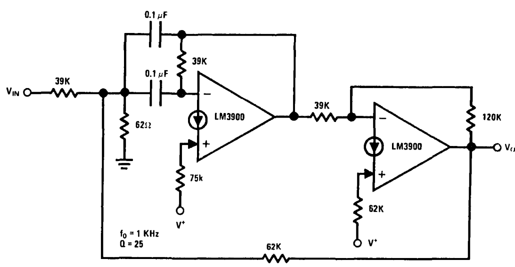
typical applications (con't)



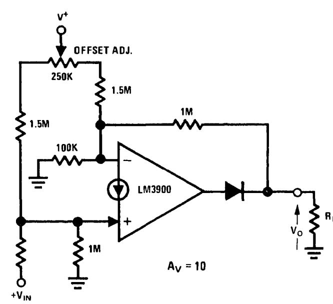
Free-Running Staircase Generator/Pulse Counter



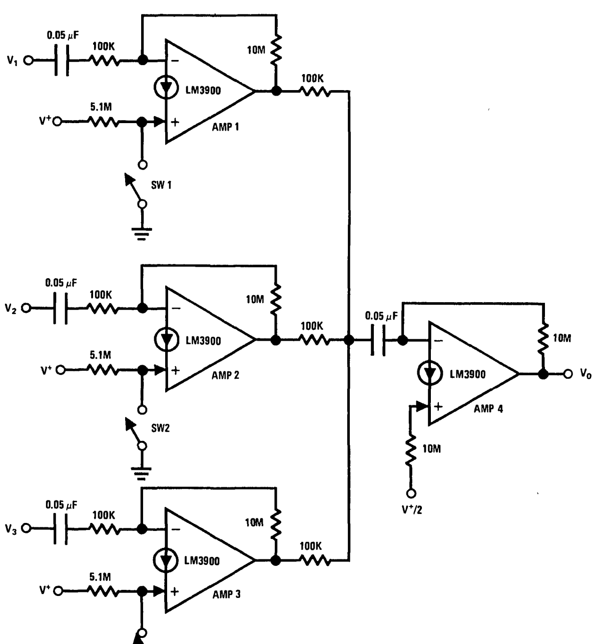
Supplying I_{IN} with Aux. Amp (to Allow High Z Feedback Networks)

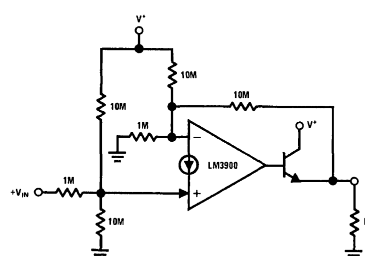


Bandpass Active Filter



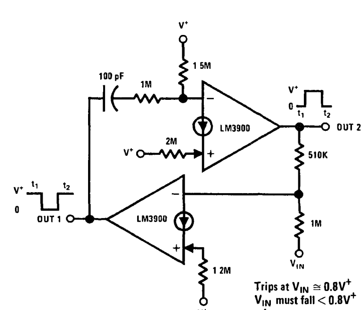
Non-Inverting DC Gain to (0,0)





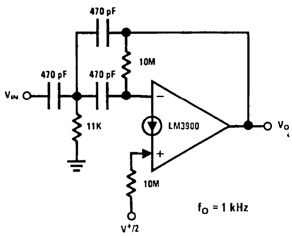
Power Amplifier

Channel Selection by DC Control (or Audio Mixer)

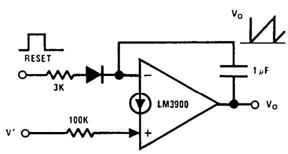


One-Shot w/ DC Input Comparator

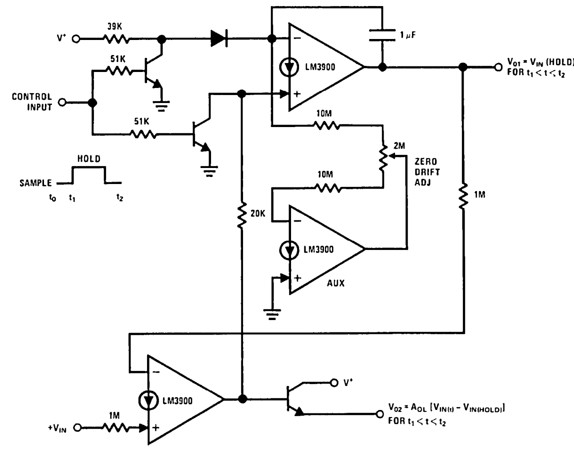
typical applications (con't)



High Pass Active Filter

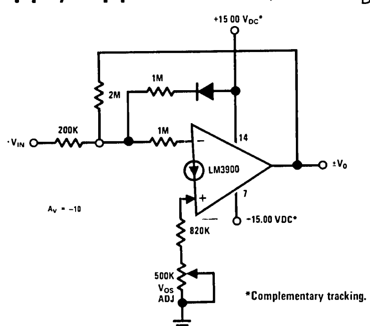


Sawtooth Generator

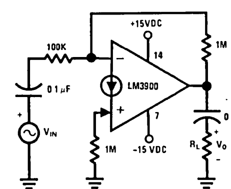


Sample-Hold & Compare with New $+V_{IN}$

split-supply applications ($V^+ = +15V_{DC}$ & $V^- = -15V_{DC}$)



Inverting DC Gain



AC Amplifier

Operational Amplifiers

LM4250/LM4250C programmable operational amplifier

general description

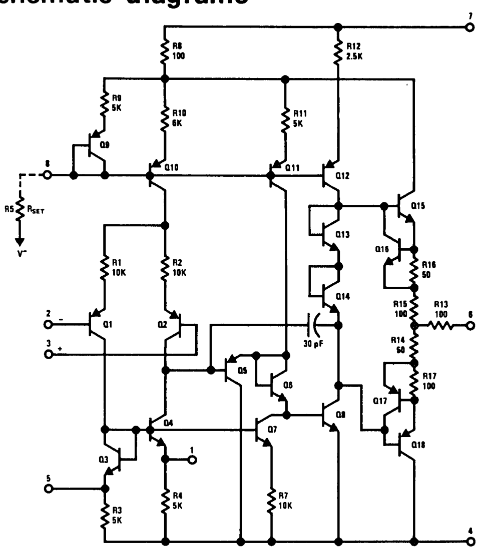
The LM4250 and LM4250C are extremely versatile programmable monolithic operational amplifiers. A single external master bias current setting resistor programs the input bias current, input offset current, quiescent power consumption, slew rate, input noise, and the gain-bandwidth product. The device is a truly general purpose operational amplifier.

features

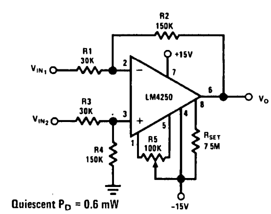
- ±1V to ±18V power supply operation
- 3 nA input offset current
- Standby power consumption as low as 500 nW
- No frequency compensation required
- Programmable electrical characteristics
- Offset Voltage nulling capability
- Can be powered by two flashlight batteries
- Short circuit protection

The LM4250C is identical to the LM4250 except that the LM4250C has its performance guaranteed over a 0°C to 70°C temperature range instead of the −55°C to +125°C temperature range of the LM4250.

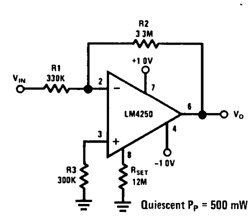
schematic diagrams



typical applications



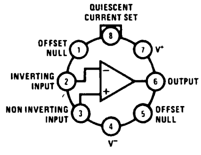
X5 Difference Amplifier



500 Nano-Watt X10 Amplifier

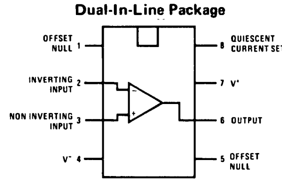
connection diagrams

Metal Can Package



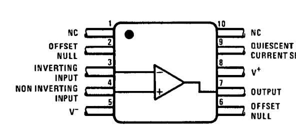
Order Number LM4250H or LM4250CH
See Package 11

Dual-In-Line Package



Order Number LM4250CN
See Package 20

Flat Package



Order Number LM4250F
See Package 3

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Differential Input Voltage	±30V
Input Voltage (Note 2)	±15V
I_{SET} Current	150 μA
Output Short-Circuit Duration	Indefinite
Operating Temperature Range LM4250	$-55°C \leq T_A \leq 125°C$
LM4250C	$0°C \leq T_A \leq 70°C$
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics LM4250 ($-55°C \leq T_A \leq 125°C$ unless otherwise specified)

PARAMETERS	CONDITIONS	V_S = ±1.5V			
		I_{SET} = 1 μA		I_{SET} = 10 μA	
		MIN	MAX	MIN	MAX
V_{OS}	T_A = 25° $R_S \leq$ 100 kΩ		3 mV		5 mV
I_{OS}	T_A = 25°		3 nA		10 nA
I_{bias}	T_A = 25°		7.5 nA		50 nA
Large Signal Voltage Gain	T_A = 25° R_L = 100 kΩ	40k			
	V_O = ±0.6, R_L = 10 kΩ			50k	
Supply Current	T_A = 25°C		7.5 μA		80 μA
Power Consumption	T_A = 25°C		23 μW		240 μW
V_{OS}	$R_S \leq$ 100 kΩ		4 mV		6 mV
I_{OS}	T_A = 125°C		5 nA		10 nA
	T_A = −55°C		3 nA		10 nA
I_{bias}			7.5 nA		50 nA
Input Voltage Range		±0.7V		±0.7V	
Large Signal Voltage Gain	V_O = ±0.6V R_L = 100 kΩ	30k			
	R_L = 10 kΩ			30k	
Output Voltage Swing	R_L = 100 kΩ	±0.6V			
	R_L = 10 kΩ			±0.6V	
Common Mode Rejection Ratio	$R_S \leq$ 10 kΩ	70 dB		70 dB	
Supply Voltage Rejection Ratio	$R_S \leq$ 10 kΩ	76 dB		76 dB	
Supply Current			8 μA		90 μA
Power Consumption			24 μW		270 μW

PARAMETERS	CONDITIONS	V_S = ±15V			
		I_{SET} = 1 μA		I_{SET} = 10 μA	
		MIN	MAX	MIN	MAX
V_{OS}	T_A = 25°C $R_S \leq$ 100 kΩ		3 mV		5 mV
I_{OS}	T_A = 25°C		3 nA		10 nA
I_{bias}	T_A = 25°C		7.5 nA		50 nA
Large Signal Voltage Gain	T_A = 25°C R_L = 100 kΩ	100k			
	V_O = ±10V R_L = 10 kΩ			100k	
Supply Current	T_A = 25°C		10 μA		90 μA
Power Consumption	T_A = 25°C		300 μW		2.7 mW
V_{OS}	$R_S \leq$ 100 kΩ		4 mV		6 mV
I_{OS}	T_A = 125°C		25 nA		25 nA
	T_A = −55°C		3 nA		10 nA
I_{bias}			7.5 nA		50 nA
Input Voltage Range		±13.5V		±13.5V	
Large Signal Voltage Gain	V_O = ±10V R_L = 100 kΩ	50k			
	R_L = 10 kΩ			50k	
Output Voltage Swing	R_L = 100 kΩ	±12V			
	R_L = 10 kΩ			±12V	
Common Mode Rejection Ratio	$R_S \leq$ 10 kΩ	70 dB		70 dB	
Supply Voltage Rejection Ratio	$R_S \leq$ 10 kΩ	76 dB		76 dB	
Supply Current			11 μA		100 μA
Power Consumption			330 μW		3 mW

Note 1: The maximum junction temperature of the LM4250 is 150°C, while that of the LM4250C is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W junction to ambient, or 45°C/W junction to case. The thermal resistance of the dual-in-line package is 125°C/W.

Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

electrical characteristics LM4250C ($0°C \leq T_A \leq 70°C$ unless otherwise specified)

PARAMETERS	CONDITIONS	$V_S = \pm1.5V$			
		$I_{SET} = 1\ \mu A$		$I_{SET} = 10\ \mu A$	
		MIN	MAX	MIN	MAX
V_{OS}	$T_A = 25°C$ $R_S \leq 100\ k\Omega$		5 mV		6 mV
I_{OS}	$T_A = 25°C$		6 nA		20 nA
I_{bias}	$T_A = 25°C$		10 nA		75 nA
Large Signal Voltage Gain	$T_A = 25°C$ $R_L = 100\ k\Omega$	25k			
	$V_O = \pm0.6V$ $R_L = 10\ k\Omega$			25k	
Supply Current	$T_A = 25°C$		8 µA		90 µA
Power Consumption	$T_A = 25°C$		24 µW		270 µW
V_{OS}	$R_S \leq 10\ k\Omega$		6.5 mV		7.5 mV
I_{OS}			8 nA		25 nA
I_{bias}			10 nA		80 nA
Input Voltage Range		±0.6V		±0.6V	
Large Signal Voltage Gain	$V_O = \pm0.6V$ $R_L = 100\ k\Omega$	25k			
	$R_L = 10\ k\Omega$			25k	
Output Voltage Swing	$R_L = 100\ k\Omega$	±0.6V			
	$R_L = 10\ k\Omega$			±0.6V	
Common Mode Rejection Ratio	$R_S \leq 10\ k\Omega$	70 dB		70 dB	
Supply Voltage Rejection Ratio	$R_S \leq 10\ k\Omega$	74 dB		74 dB	
Supply Current			8 µA		90 uA
Power Consumption			24 µW		270 uW

PARAMETERS	CONDITIONS	$V_S = \pm15V$			
		$I_{SET} = 1\ \mu A$		$I_{SET} = 10\ \mu A$	
		MIN	MAX	MIN	MAX
V_{OS}	$T_A = 25°C$ $R_S \leq 100\ k\Omega$		5 mV		6 mV
I_{OS}	$T_A = 25°C$		6 nA		20 nA
I_{bias}	$T_A = 25°C$		10 nA		75 nA
Large Signal Voltage Gain	$T_A = 25°C$ $R_L = 100\ k\Omega$	60k			
	$V_O = \pm10V$ $R_L = 10\ k\Omega$			60k	
Supply Current	$T_A = 25°C$		11 µA		100 µA
Power Consumption	$T_A = 25°C$		330 µW		3 mW
V_{OS}	$R_S \leq 10\ k\Omega$		6.5 mV		7.5 mV
I_{OS}			8 nA		25 nA
I_{bias}			10 nA		80 nA
Input Voltage Range		±13.5V		±13.5V	
Large Signal Voltage Gain	$V_O = \pm10V$ $R_L = 100\ k\Omega$	50k			
	$R_L = 10\ k\Omega$			50k	
Output Voltage Swing	$R_L = 100\ k\Omega$	±12V			
	$R_L = 10\ k\Omega$			±12V	
Common Mode Rejection Ratio	$R_S \leq 10\ k\Omega$	70 dB		70 dB	
Supply Voltage Rejection Ratio	$R_S \leq 10\ k\Omega$	74 dB		74 dB	
Supply Current			11 uA		100 uA
Power Consumption			300 uW		3 mW

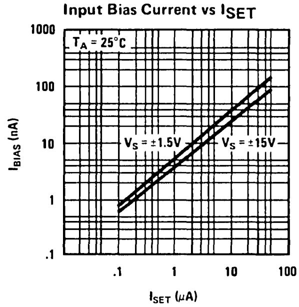
resistor biasing

Set Current Setting Resistor to V^-

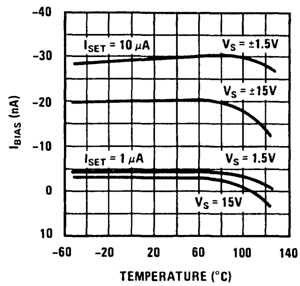
	I_{SET}				
V_S	0.1 µA	0.5 µA	1.0 µA	5 µA	10 µA
±1.5V	25.6 MΩ	5.04 MΩ	2.5 MΩ	492 kΩ	244 kΩ
±3.0V	55.6 MΩ	11.0 MΩ	5.5 MΩ	1.09 MΩ	544 kΩ
±6.0V	116 MΩ	23.0 MΩ	11.5 MΩ	2.29 MΩ	1.14 MΩ
±9.0V	176 MΩ	35.0 MΩ	17.5 MΩ	3.49 MΩ	1.74 MΩ
±12.0V	236 MΩ	47.0 MΩ	23.5 MΩ	4.69 MΩ	2.34 MΩ
±15.0V	296 MΩ	59.0 MΩ	29.5 MΩ	5.89 MΩ	2.94 MΩ

typical performance characteristics

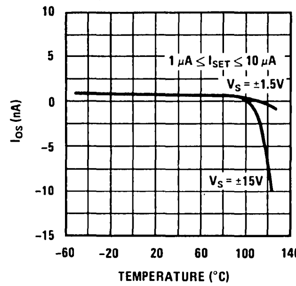
Input Bias Current vs I_{SET}



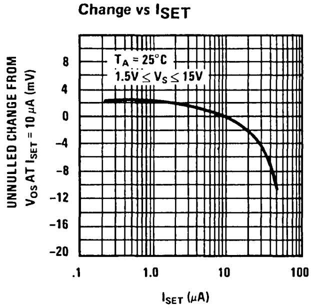
Input Bias Current vs Temperature



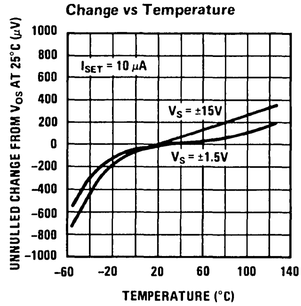
Input Offset Current vs Temperature



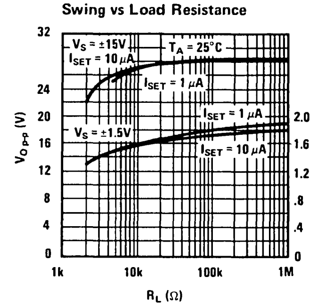
Unnulled Input Offset Voltage Change vs I_{SET}



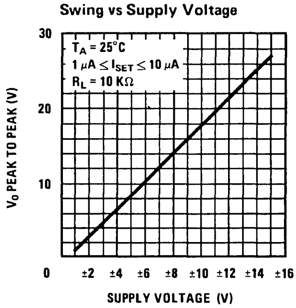
Unnulled Input Offset Voltage Change vs Temperature



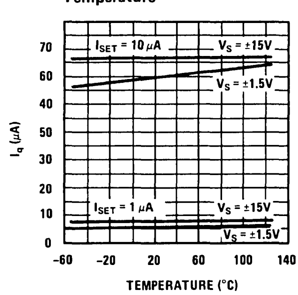
Peak to Peak Output Voltage Swing vs Load Resistance



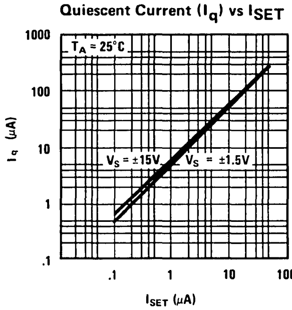
Peak to Peak Output Voltage Swing vs Supply Voltage



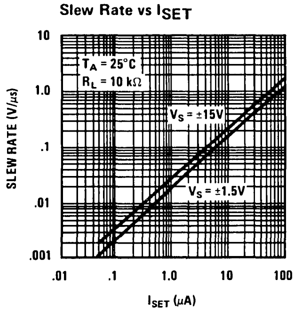
Quiescent Current (I_q) vs Temperature



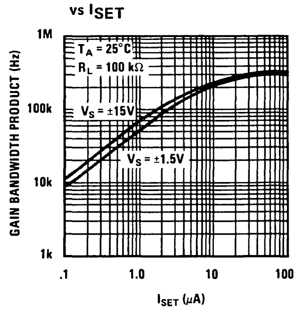
Quiescent Current (I_q) vs I_{SET}



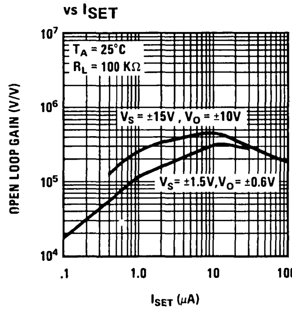
Slew Rate vs I_{SET}



Gain Bandwidth Product vs I_{SET}

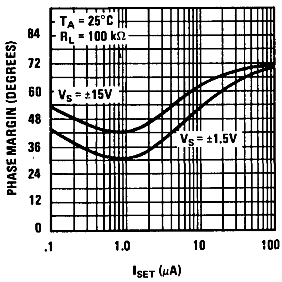


Open Loop Voltage Gain vs I_{SET}

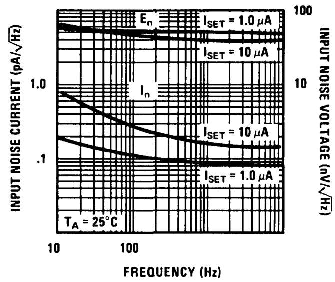


typical performance characteristics (con't)

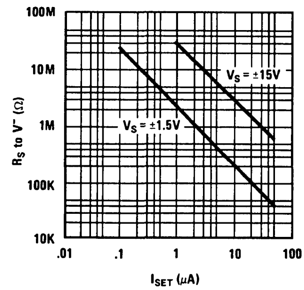
Phase Margin vs I_{SET}



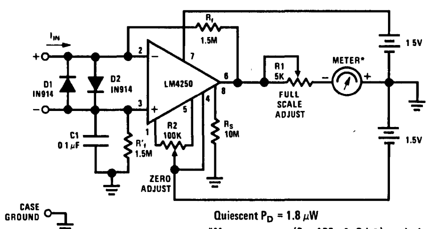
Input Noise Current (I_n) and Voltage (E_n) vs Frequency



R_{SET} vs I_{SET}



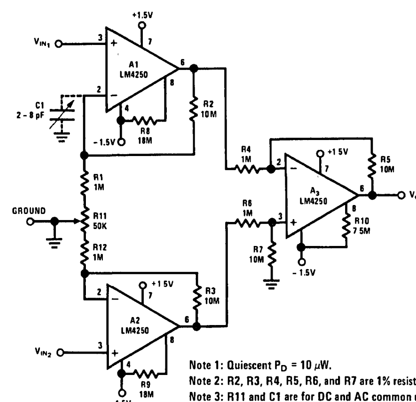
typical applications (con't)



Quiescent P_D = 1.8 μW

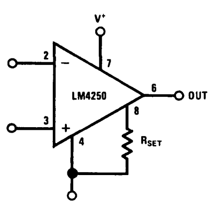
*Meter movement (0 – 100 μA, 2 kΩ) marked for 0 – 100 nA full scale.

Floating Input Meter Amplifier
100 Nano-Ampere Full Scale

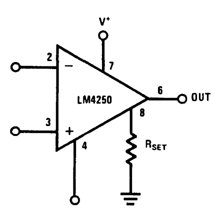


Note 1: Quiescent P_D = 10 μW.
Note 2: R2, R3, R4, R5, R6, and R7 are 1% resistors.
Note 3: R11 and C1 are for DC and AC common mode rejection adjustments.

X100 Instrumentation Amplifier 10 μW



R_{SET} Connected to V⁻

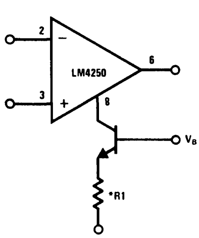


R_{SET} Connected to Ground

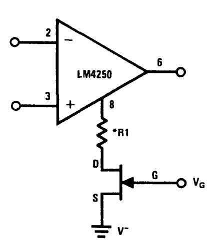
I_{SET} EQUATIONS:

$I_{SET} \approx \frac{V^+ + |V^-| - 0.5}{R_{SET}}$ where R_{SET} is connected to V^-.

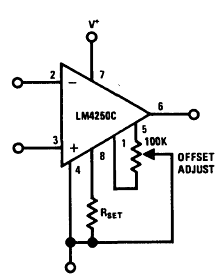
$I_{SET} \approx \frac{V^+ - 0.5}{R_{SET}}$ where R_{SET} is connected to ground.



Transistor Current Source Biasing



FET Current Source Biasing



Offset Null Circuit

*R1 limits I_{SET} maximum

Voltage Comparators/Buffers

LF111/LF211/LF311 voltage comparators

general description

The LF111, LF211 and LF311 are FET input voltage comparators that virtually eliminate input current errors. Designed to operate over a 5.0V to ±15V range the LF111 can be used in the most critical applications.

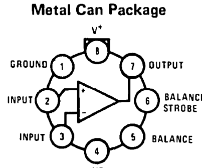
The extremely low input currents of the LF111 allows the use of a simple comparator in applications usually requiring input current buffering. Leakage testing, long time delay circuits, charge measurements, and high source impedance voltage comparisons are easily done. Further, the LF111 can be used in place of the LM111 eliminating errors due to input currents.

advantages

- Eliminates input current errors
- Interchangeable with LM111
- No need for input current buffering

connection diagrams*

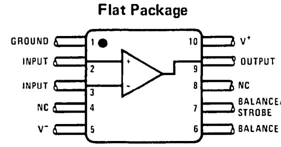
Metal Can Package



NOTE: Pin 4 connected to case.
TOP VIEW

Order Number LF111H, LF211H or LF311H
See Package 11

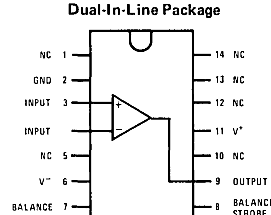
Flat Package



NOTE: Pin 5 connected to bottom of package.
TOP VIEW

Order Number LF111F, LF211F or LF311F
See Package 3

Dual-In-Line Package

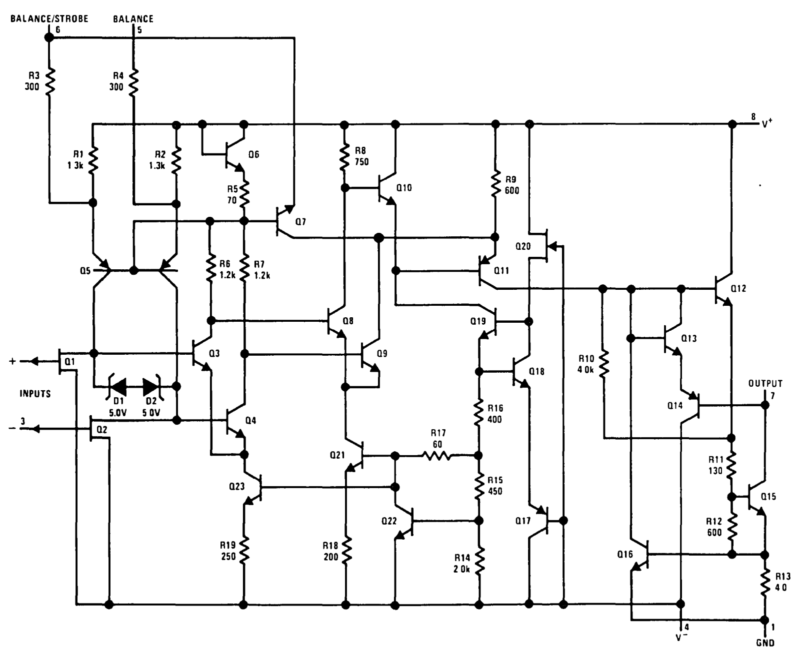


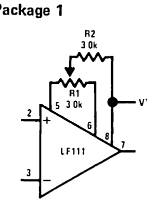
Note: Pin 6 connected to bottom of package.
TOP VIEW

Order Number LF111D, LF211D or LF311D
See Package 1

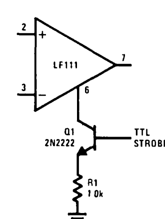
*Pin connections shown on schematic diagram and typical applications are for TO-5 package.

schematic diagram and auxiliary circuits

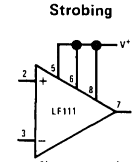




Offset Balancing



Strobing



*Increases typical common mode slew from 7.0V/μs to 18V/μs.

Increasing Input Stage Current*

absolute maximum ratings

	LF111/LF211	LF311
Total Supply Voltage (V_{84})	36V	36V
Output to Negative Supply Voltage (V_{74})	50V	40V
Ground to Negative Supply Voltage (V_{14})	30V	30V
Differential Input Voltage	±30V	±30V
Input Voltage (Note 1)	±15V	±15V
Power Dissipation (Note 2)	500 mW	500 mW
Output Short Circuit Duration	10 seconds	10 seconds
Operating Temperature Range		
LF111	−55°C to +125°C	
LF211	−25°C to +85°C	
LF311		0°C to +70°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C	300°C

electrical characteristics (LF111/LF211) (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage (Note 4)	T_A = 25°C, R_S		0.7	4.0	mV
Input Offset Current (Note 4)	T_A = 25°C, V_{CM} = 0 (Note 6)		5.0	25	pA
Input Bias Current	T_A = 25°C, V_{CM} = 0 (Note 6)		20	50	pA
Voltage Gain	T_A = 25°C		200		V/mV
Response Time (Note 5)	T_A = 25°C		200		ns
Saturation Voltage	$V_{IN} \leq -5.0$ mV, I_{OUT} = 50 mA, T_A = 25°C		0.75	1.5	V
Strobe On Current	T_A = 25°C		3.0		mA
Output Leakage Current	$V_{IN} \geq 5.0$ mV, V_{OUT} = 35V, T_A = 25°C		0.2	10	nA
Input Offset Voltage (Note 4)				6.0	mV
Input Offset Current (Note 4)	V_S = ±15V, V_{CM} = 0 (Note 6)		2.0	3.0	nA
Input Bias Current	V_S = ±15V, V_{CM} = 0 (Note 6)		5.0	7.0	nA
Input Voltage Range			+14 −13.5		V V
Saturation Voltage	$V^+ \geq 4.5V$, $V^- = 0$ $V_{IN} \leq -6.0$ mV, $I_{SINK} \leq 8.0$ mA		0.23	0.4	V
Output Leakage Current	$V_{IN} \geq 5.0$ mV, V_{OUT} = 35V		0.1	0.5	µA
Positive Supply Current	T_A = 25°C		5.1	6.0	mA
Negative Supply Current	T_A = 25°C		4.1	5.0	mA

Note 1: This rating applies for ±15V supplies. The positive input voltage limit is 30V above the negative supply. The negative input voltage limit is equal to the negative supply voltage or 30V below the positive supply, whichever is less.

Note 2: The maximum junction temperature of the LF111 is +150°C, the LF211 is +110°C and the LF311 is +85°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of +150°C/W, junction to ambient, or +45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of +185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is +100°C/W, junction to ambient.

Note 3: These specifications apply for V_S = ±15V and $-55°C \leq T_A \leq +125°C$ for the LF111, unless otherwise stated. With the LF211, however, all temperature specifications are limited to $-25°C \leq T_A \leq +85°C$ and for the LF311 $0°C \leq T_A \leq +70°C$. The offset voltage, offset current and bias current specifications apply for any supply voltage from a single 5.0 mV supply up to ±15V supplies.

Note 4: The offset voltages and offset currents given are the maximum values required to drive the output within a volt of either supply with a 1.0 mA load. Thus, these parameters define an error band and take into account the worst case effects of voltage gain and input impedance.

Note 5: The response time specified (see definitions) is for a 100 mV input step with 5.0 mV overdrive.

Note 6: For input voltages greater than 15V above the negative supply the bias and offset currents will increase—see typical performance curves.

electrical characteristics (LF311) (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage (Note 4)	$T_A = 25°C$, $R_S \leq 50k$		2.0	10	mV
Input Offset Current (Note 4)	$T_A = 25°C$, $V_{CM} = 0$ (Note 6)		5.0	75	pA
Input Bias Current	$T_A = 25°C$, $V_{CM} = 0$ (Note 6)		25	150	pA
Voltage Gain	$T_A = 25°C$		200		V/mV
Response Time (Note 5)	$T_A = 25°C$		200		ns
Saturation Voltage	$V_{IN} \leq -10$ mV, $I_{OUT} = 50$ mA, $T_A = 25°C$		0.75	1.5	V
Strobe On Current	$T_A = 25°C$		3.0		mA
Output Leakage Current	$V_{IN} \geq 10$ mV, $V_{OUT} = 35V$, $T_A = 25°C$		0.2	10	nA
Input Offset Voltage (Note 4)	$R_S \leq 50k$			15	mV
Input Offset Current (Note 4)	$V_S = \pm 15V$, $V_{CM} = 0$ (Note 6)		1.0		nA
Input Bias Current	$V_S = \pm 15V$, $V_{CM} = 0$ (Note 6)		3.0		nA
Input Voltage Range			+14 −13.5		V V
Saturation Voltage	$V^+ \geq 4.5V$, $V^- = 0$ $V_{IN} \leq -10$ mV, $I_{SINK} \leq 8.0$ mA		0.23	0.4	V
Positive Supply Current	$T_A = 25°C$		5.1	7.5	mA
Negative Supply Current	$T_A = 25°C$		4.1	5.0	mA

Note 1: This rating applies for ±15V supplies. The positive input voltage limit is 30V above the negative supply. The negative input voltage limit is equal to the negative supply voltage or 30V below the positive supply, whichever is less.

Note 2: The maximum junction temperature of the LF111 is +150°C, the LF211 is +110°C and the LF311 is +85°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of +150°C/W, junction to ambient, or +45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of +185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is +100°C/W, junction to ambient.

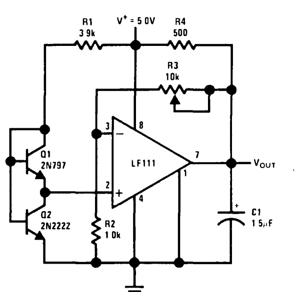
Note 3: These specifications apply for $V_S = \pm 15V$ and $-55°C \leq T_A \leq +125°C$ for the LF111, unless otherwise stated. With the LF211, however, all temperature specifications are limited to $-25°C \leq T_A \leq +85°C$ and for the LF311 $0°C \leq T_A \leq +70°C$. The offset voltage, offset current and bias current specifications apply for any supply voltage from a single 5.0 mV supply up to ±15V supplies.

Note 4: The offset voltages and offset currents given are the maximum values required to drive the output within a volt of either supply with a 1.0 mA load. Thus, these parameters define an error band and take into account the worst case effects of voltage gain and input impedance.

Note 5: The response time specified (see definitions) is for a 100 mV input step with 5.0 mV overdrive.

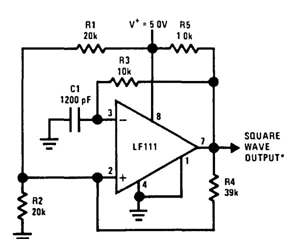
Note 6: For input voltages greater than 15V above the negative supply the bias and offset currents will increase—see typical performance curves.

typical applications



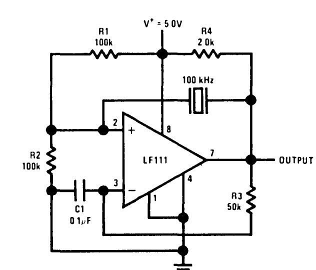
*Solid tantalum

Low Voltage Adjustable Reference Supply



*TTL or DTL fanout of two.

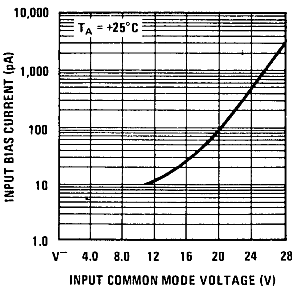
100 kHz Free Running Multivibrator



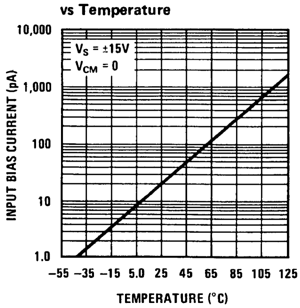
Crystal Oscillator

typical performance

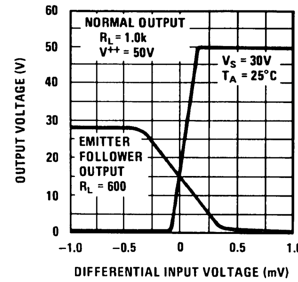
Input Bias Current vs Common Mode



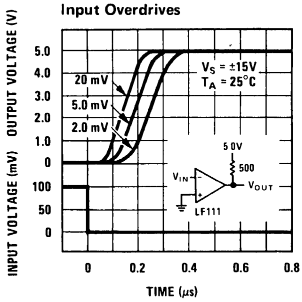
Input Bias Current vs Temperature



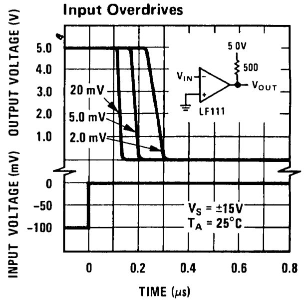
Transfer Function



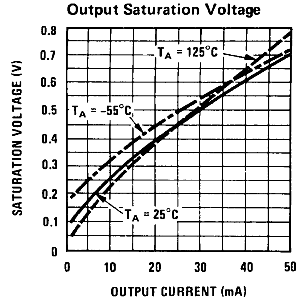
Response Time for Various Input Overdrives



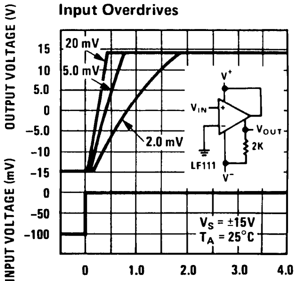
Response Time for Various Input Overdrives



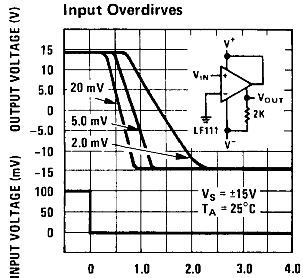
Output Saturation Voltage



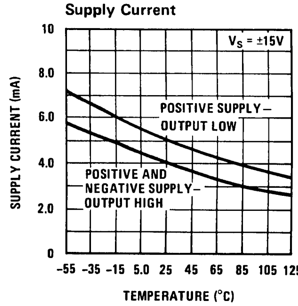
Response Time for Various Input Overdrives



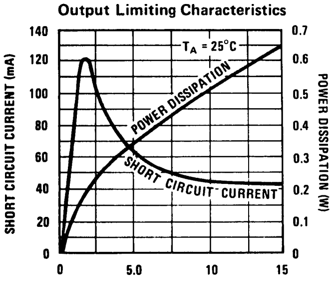
Response Time for Various Input Overdirves



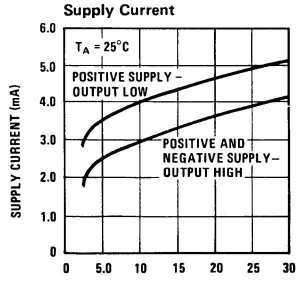
Supply Current



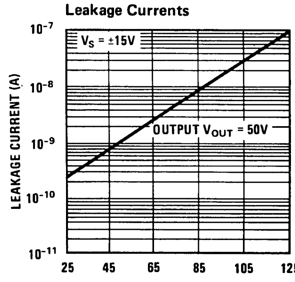
Output Limiting Characteristics



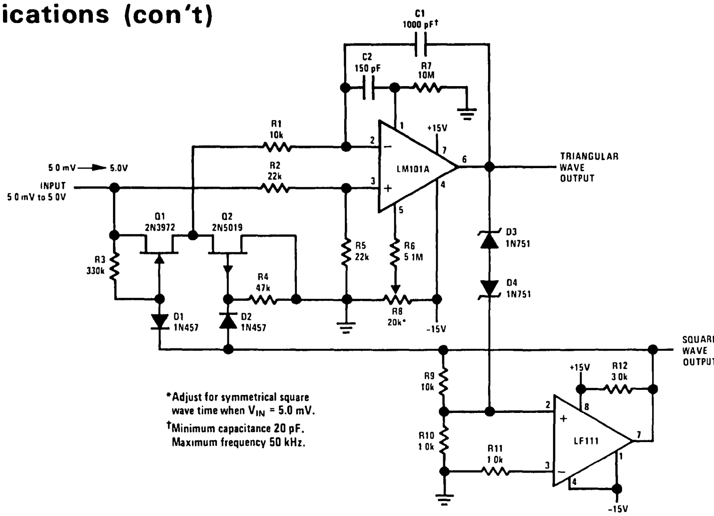
Supply Current



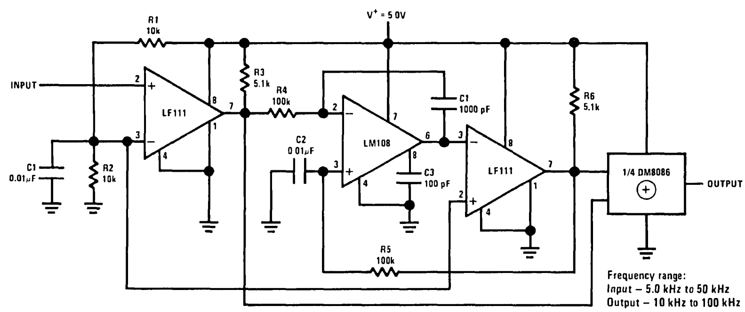
Leakage Currents



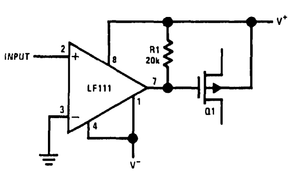
typical applications (con't)



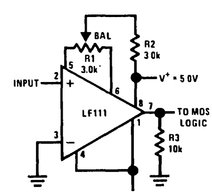
10 Hz to 10 kHz Voltage Controlled Oscillator



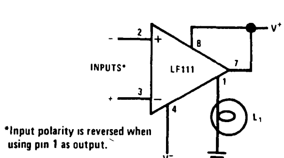
Frequency Doubler



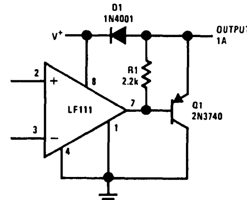
Zero Crossing Detector Driving MOS Switch



Zero Crossing Detector Driving MOS Logic



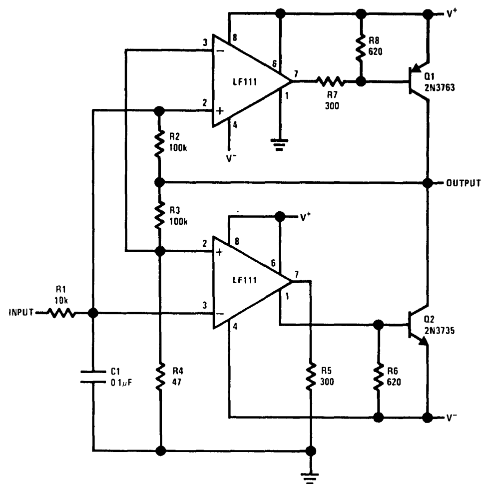
Driving Ground-Referred Load



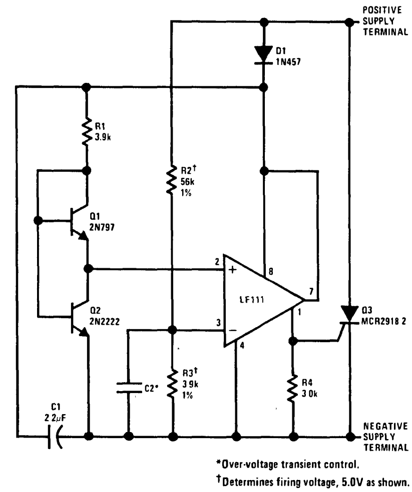
Comparator and Solenoid Driver

3

typical applications (con't)



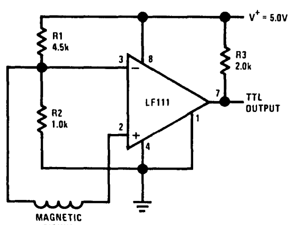
Switching Power Amplifier



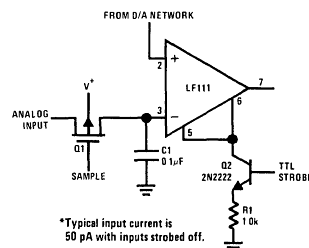
*Over-voltage transient control.

†Determines firing voltage, 5.0V as shown.

Crowbar Over-Voltage Protector

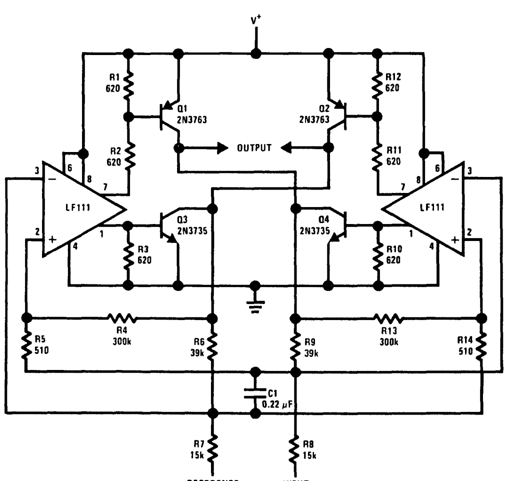


Detector for Magnetic Transducer

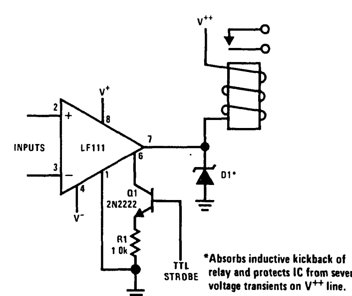


*Typical input current is 50 pA with inputs strobed off.

Strobing Off Both Input* and Output Stages



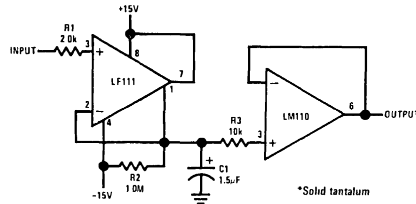
Switching Power Amplifier



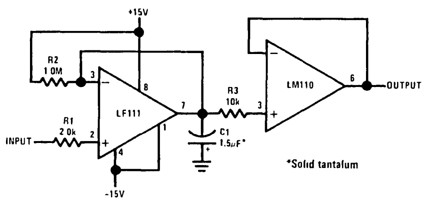
*Absorbs inductive kickback of relay and protects IC from severe voltage transients on V++ line.

Relay Driver with Strobe

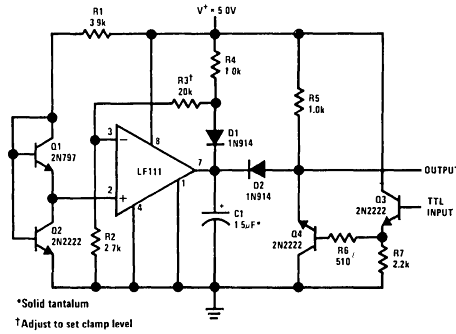
typical applications (con't)



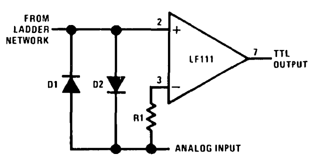
Positive Peak Detector



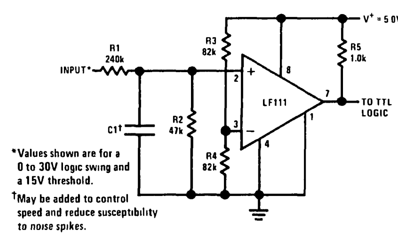
Negative Peak Detector



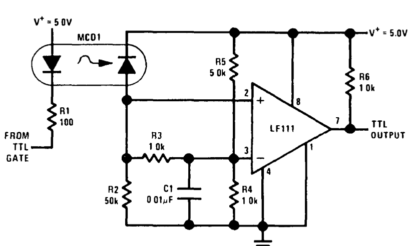
Precision Squarer



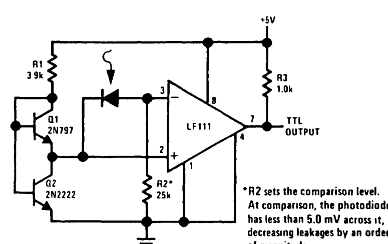
Using Clamp Diodes to Improve Response



TTL Interface with High Level Logic



Digital Transmission Isolator



Precision Photodiode Comparator

3

Voltage Comparators/Buffers

LH2111/LH2211/LH2311 dual voltage comparator

general description

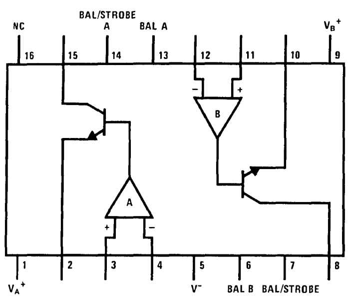
The LH2111 series of dual voltage comparators are two LM111 type comparators in a single hermetic package. Featuring all the same performance characteristics of the single, these duals offer in addition closer thermal tracking, lower weight, reduced insertion cost and smaller size than two singles. For additional information see the LM111 data sheet and National's Linear Application Handbook.

The LH2111 is specified for operation over the −55°C to +125°C military temperature range. The LH2211 is specified for operation over the −25°C to +85°C temperature range. The LH2311 is specified for operation over the 0°C to 70°C temperature range.

features

- Wide operating supply range ±15V to a single +5V
- Low input currents 6 nA
- High sensitivity 10 μV
- Wide differential input range ±30V
- High output drive 50 mA, 50V

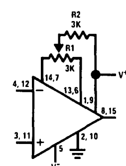
connection diagram



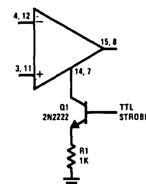
Order Number LH2111D or LH2211D or LH2311D
See Package 2

Order Number LH2111F or LH2211F or LH2311F
See Package 5

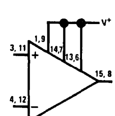
auxiliary circuits



Offset Balancing

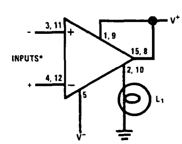


Strobing

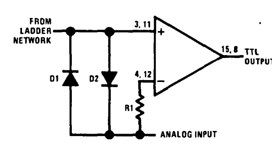


*Increases typical common mode slew from 7.0V/μs to 18V/μs.

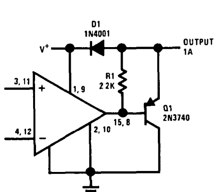
Increasing Input Stage Current*



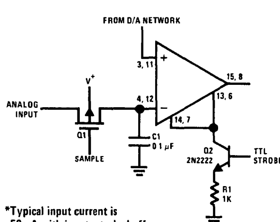
Driving Ground-Referred Load



Using Clamp Diodes to Improve Responses

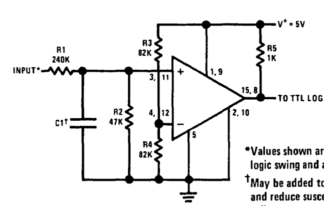


Comparator and Solenoid Driver



*Typical input current is 50 pA with inputs strobed off.

Strobing off Both Input* and Output Stages



*Values shown are for a 0 to 30V logic swing and a 15V threshold.
†May be added to control speed and reduce susceptibility to noise spikes.

TTL Interface with High Level Logic

absolute maximum ratings

Total Supply Voltage ($V^+ - V^-$)	36V
Output to Negative Supply Voltage ($V_{OUT} - V^-$)	50V
Ground to Negative Supply Voltage ($GND - V^-$)	30V
Differential Input Voltage	±30V
Input Voltage (Note 1)	±15V
Power Dissipation (Note 2)	500 mW
Output Short Circuit Duration	10 sec
Operating Temperature Range LH2111	−55°C to 125°C
LH2211	−25°C to 85°C
LH2311	0°C to 70°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics – each side (Note 3)

PARAMETER	CONDITIONS	LIMITS			UNITS
		LH2111	LH2211	LH2311	
Input Offset Voltage (Note 4)	$T_A = 25°C$, $R_S \leq 50k$	3.0	3.0	7.5	mV Max
Input Offset Current (Note 4)	$T_A = 25°C$	10	10	50	nA Max
Input Bias Current	$T_A = 25°C$	100	100	250	nA Max
Voltage Gain	$T_A = 25°C$	200	200	200	V/mV Typ
Response Time (Note 5)	$T_A = 25°C$	200	200	200	ns Typ
Saturation Voltage	$V_{IN} \leq -5$ mV, $I_{OUT} = 50$ mA $T_A = 25°C$	1.5	1.5	1.5	V Max
Strobe On Current	$T_A = 25°C$	3.0	3.0	3.0	mA Typ
Output Leakage Current	$V_{IN} \geq 5$ mV, $V_{OUT} = 35V$ $T_A = 25°C$	10	10	50	nA Max
Input Offset Voltage (Note 4)	$R_S \leq 50k$	4.0	4.0	10	mV Max
Input Offset Current (Note 4)		20	20	70	nA Max
Input Bias Current		150	150	300	nA Max
Input Voltage Range		±14	±14	±14	V Typ
Saturation Voltage	$V^+ \geq 4.5V$, $V^- = 0$ $V_{IN} \leq -5$ mV, $I_{SINK} \leq 8$ mA	0.4	0.4	0.4	V Max
Positive Supply Current	$T_A = 25°C$	6.0	6.0	7.5	mA Max
Negative Supply Current	$T_A = 25°C$	5.0	5.0	5.0	mA Max

Note 1: This rating applies for ±15V supplies. The positive input voltage limit is 30V above the negative supply. The negative input voltage limit is equal to the negative supply voltage or 30V below the positive supply, whichever is less.

Note 2: The maximum junction temperature is 150°C. For operating at elevated temperatures, devices in the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with 0.03-inch-wide, 2-ounce copper conductor. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

Note 3: These specifications apply for $V_S = \pm15V$ and $-55°C \leq T_A \leq 125°C$ for the LH2111, $-25°C \leq T_A \leq 85°C$ for the LH2211, and $0°C \leq T_A \leq 70°C$ for the LH2311, unless otherwise stated. The offset voltage, offset current and bias current specifications apply for any supply voltage from a single 5V supply up to ±15V supplies. For the LH2311, $V_{IN} = \pm10$ mV.

Note 4: The offset voltages and offset currents given are the maximum values required to drive the output within a volt of either supply with a 1 mA load. Thus, these parameters define an error band and take into account the worst case effects of voltage gain and input impedance.

Note 5: The response time specified is for a 100 mV input step with 5 mV overdrive.

Voltage Comparators/Buffers

LM106/LM206 voltage comparator/buffer

general description

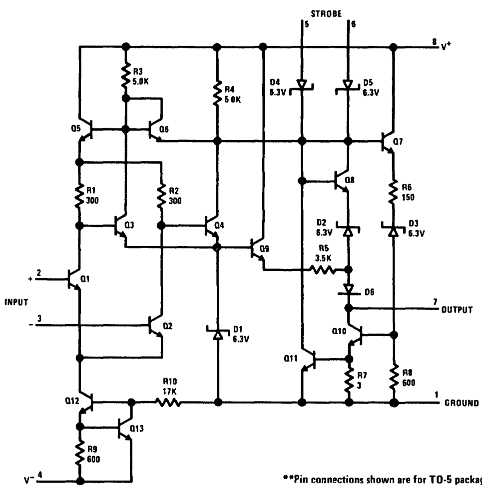
The LM106 and LM206 are high-speed voltage comparators designed to accurately detect low-level analog signals and drive a digital load. They are equivalent to an LM710, combined with a two input NAND gate and an output buffer. The circuits can drive RTL, DTL or TTL integrated circuits directly. Furthermore, their outputs can switch voltages up to 24V at currents as high as 100 mA. Other features include:

- Improved accuracy: 2 mV maximum worst case offset
- Fan-out of 10 with DTL or TTL
- Added logic or strobe capability
- Useful as a relay or lamp driver
- Plug-in replacement for the LM710
- 40 ns maximum response time

The devices have short-circuit protection which limits the inrush current when it is used to drive incandescent lamps, in addition to preventing damage from accidental shorts to the positive supply. The speed is equivalent to that of an LM710. However, they are even faster where buffers and additional logic circuitry can be eliminated by the increased flexibility of the LM106 and LM206. They can also be operated from any negative supply voltage between −3V and −12V with little effect on performance.

The LM106 is specified for operation over the −55°C to +125°C military temperature range. The LM206 is specified for operation over the −25°C to +85°C temperature range.

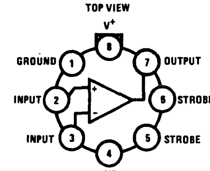
schematic and connection diagrams **



**Pin connections shown are for TO-5 package.

Metal Can

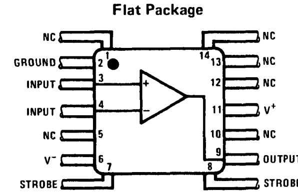
TOP VIEW



Note: Pin 4 connected to case.

Order Number LM106H or LM206H
See Package 11

Flat Package



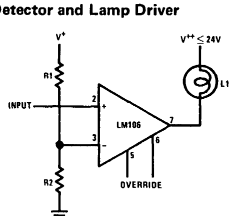
Note: Pin 6 connected to bottom of package.

TOP VIEW

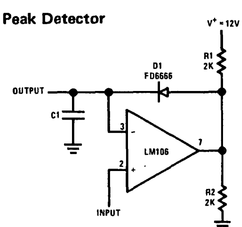
Order Number LM106F or LM206F
See Package 4

typical applications **

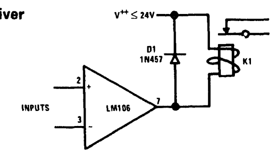
Level Detector and Lamp Driver



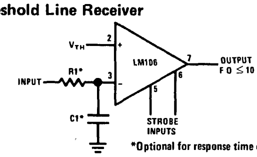
Fast Response Peak Detector



Relay Driver



Adjustable Threshold Line Receiver



*Optional for response time control.

absolute maximum ratings

Positive Supply Voltage	15V	Power Dissipation (Note 1)		600 mW
Negative Supply Voltage	−15V	Output Short Circuit Duration		10 sec
Output Voltage	24V	Operating Temperature Range	LM106	−55°C to 125°C
Output to Negative Supply Voltage	30V		LM206	−25°C to 85°C
Differential Input Voltage	±5V	Storage Temperature Range		−65°C to 150°C
Input Voltage	±7V	Lead Temperature (soldering, 10 sec)		300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	Note 3		0.5	2.0	mV
Input Offset Current	Note 3		0.7	3.0	μA
Input Bias Current			10	20	μA
Response Time	Note 4, R_L = 390Ω to +5V, C_L = 15 pF		28	40	ns
Saturation Voltage	$V_{IN} \leq -5$ mV, I_{OUT} = 100 mA		1.0	1.5	V
Output Leakage Current	$V_{IN} \geq 5$ mV, $8V \leq V_{OUT} \leq 24V$		0.02	1.0	μA

electrical characteristics

The following specifications apply for $T_L \leq T_A \leq T_H$ (Note 5)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	Note 3			3.0	mV
Average Temperature Coefficient of Input Offset Voltage			3.0	10	μV/°C
Input Offset Current	Note 3, $T_L \leq T_A \leq 25°C$		1.8	7.0	μA
	$25°C \leq T_A \leq T_H$		0.25	3.0	μA
Average Temperature Coefficient of Input Offset Current	$25°C \leq T_A \leq T_H$		5.0	25	nA/°C
	$T_L \leq T_A \leq 25°C$		15	75	nA/°C
Input Bias Current	$T_L \leq T_A \leq 25°C$			45	μA
	$25°C \leq T_A \leq T_H$			20	μA
Input Voltage Range	$-7V \geq V^- \geq -12V$	±5.0			V
Differential Input Voltage Range		±5.0			V
Saturation Voltage	$V_{IN} \leq -5$ mV, I_{OUT} = 50 mA			1.0	V
Saturation Voltage	$V_{IN} \leq -5$ mV, I_{OUT} = 16 mA			0.4	V
Positive Output Level	$V_{IN} \geq 5$ mV, I_{OUT} = −400 μA	2.5		5.5	V
Output Leakage Current	$V_{IN} \geq 5$ mV, $8V \leq V_{OUT} \leq 24V$ $T_L \leq T_A \leq 25°C$			1.0	μA
	$25°C < T_A \leq T_H$			100	μA
Strobe Current	V_{strobe} = 0.4V		−1.7	−3.2	mA
Strobe ON Voltage		0.9	1.4		V
Strobe OFF Voltage	$I_{sink} \leq 16$ mA		1.4	2.2	V
Positive Supply Current	V_{IN} = −5 mV		5.5	10	mA
Negative Supply Current			−1.5	−3.6	mA

Note 1: The maximum junction temperature of the LM106 is 150°C, while that of the LM206 is 110°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors.

Note 2: These specifications apply for $-3V \geq V^- \geq -12V$, V^+ = 12V and T_A = 25°C unless otherwise specified. All currents into device pins are considered positive.

Note 3: The offset voltages and offset currents given are the maximum values required to drive the output down to 0.5V or up to 4.4V. Thus, these parameters actually define an error band and take into account the worst-case effects of voltage gain, specified supply voltage variations, and common mode voltage variations.

Note 4: The response time specified (see definitions) is for a 100 mV input step with 5 mV overdrive.

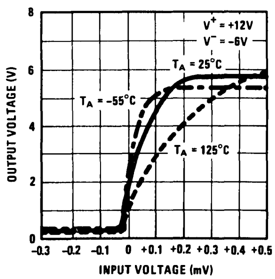
Note 5: All currents into device pins are considered positive.

	T_L	T_H
LM106	−55°C	+125°C
LM206	−25°C	+85°C

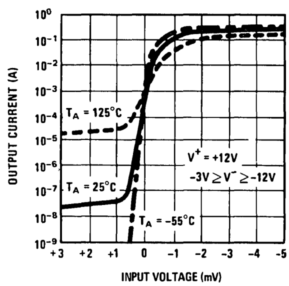
3

typical performance characteristics

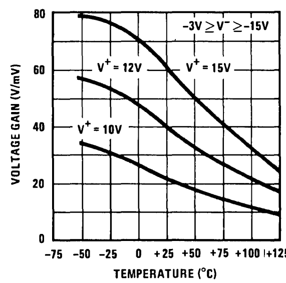
Transfer Function



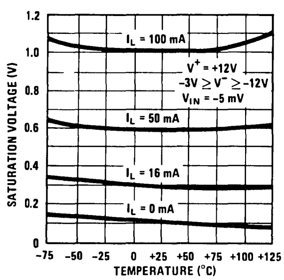
Transconductance



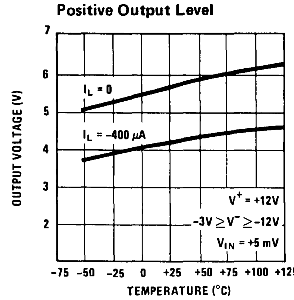
Voltage Gain



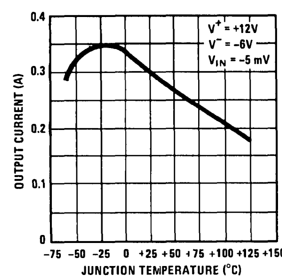
Saturation Voltage



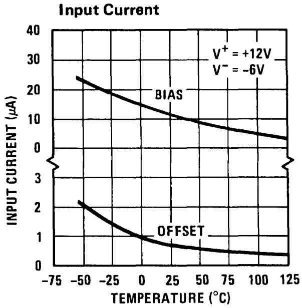
Positive Output Level



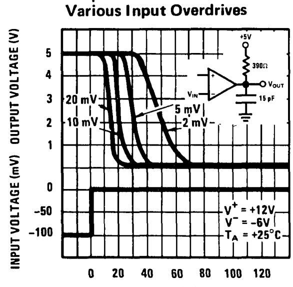
Short Circuit Output Current



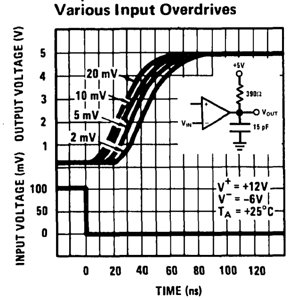
Input Current



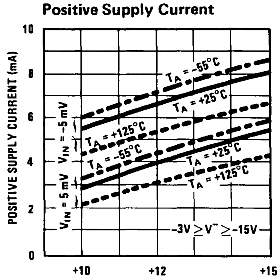
Response Time For Various Input Overdrives



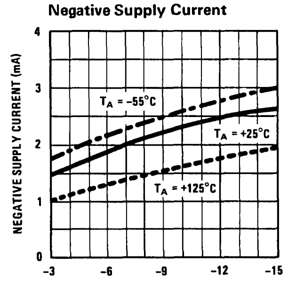
Response Time For Various Input Overdrives



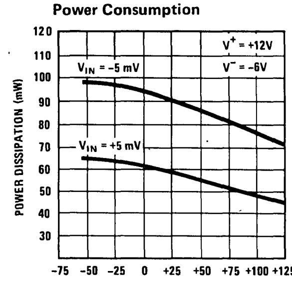
Positive Supply Current



Negative Supply Current



Power Consumption



Voltage Comparators/Buffers

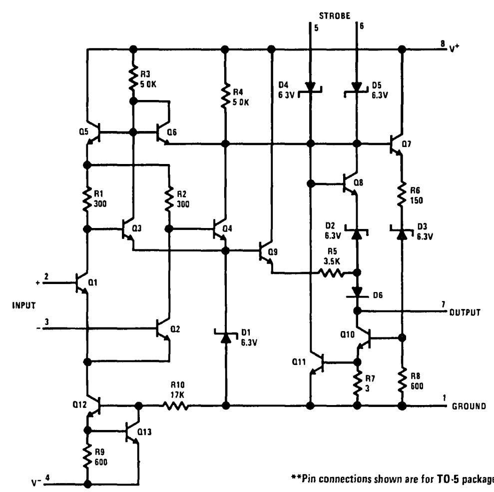
LM306 voltage comparator/buffer general description

The LM306 is a high-speed voltage comparator designed to accurately detect low-level analog signals and drive a digital load. It is equivalent to an LM710C, combined with a two input NAND gate and an output buffer. The circuit can drive RTL, DTL or TTL integrated circuits directly. Furthermore, the output can switch voltages up to 24V at currents as high as 100 mA. Other features include:

- Improved accuracy: 5 mV (max) offset
- Fan-out of 10 with DTL or TTL
- Added logic or strobe capability
- Useful as a relay or lamp driver
- Plug-in replacement for the LM710C.
- 40 ns maximum response time

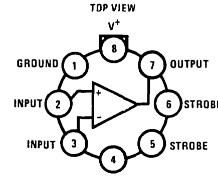
The device has short-circuit protection which limits the inrush current when it is used to drive incandescent lamps, in addition to preventing damage from accidental shorts. The speed is equivalent to that of an LM710C. However, it is even faster where buffers and additional logic circuitry can be eliminated by the increased flexibility of the LM306. It can also be operated from any negative supply voltage between −3V and −12V with little effect on performance. The LM306 is identical to the LM106, except that it is specified over a 0°C to 70°C temperature range.

schematic and connection diagrams**



**Pin connections shown are for TO-5 package.

Metal Can

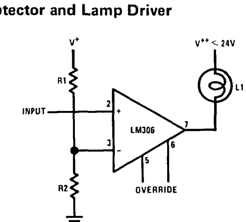


Note: Pin 4 connected to case.

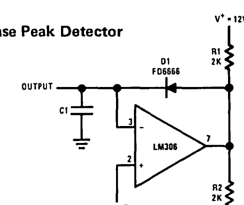
Order Number LM306H
See Package 11

typical applications**

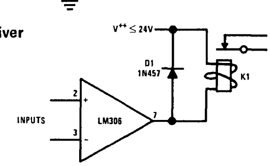
Level Detector and Lamp Driver



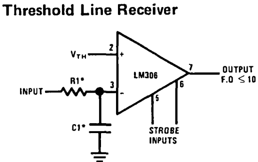
Fast Response Peak Detector



Relay Driver



Adjustable Threshold Line Receiver



*Optional for response time control.

absolute maximum ratings

Positive Supply Voltage	15V
Negative Supply Voltage	-15V
Output Voltage	24V
Output to Negative Supply Voltage	30V
Differential Input Voltage	±5V
Input Voltage	±7V
Power Dissipation (Note 1)	600 mW
Output Short Circuit Duration	10 sec
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature (soldering, 10 sec)	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	Note 3		1.6	5.0	mV
Input Offset Current	Note 3		1.8	5.0	μA
Input Bias Current			16	25	μA
Response Time	Note 4, R_L = 390Ω to +5V, C_L = 15 pF		28	40	ns
Saturation Voltage	$V_{IN} \leq -7$ mV, I_{OUT} = 100 mA		0.8	2.0	V
Output Leakage Current	$V_{IN} \geq 7$ mV, $8V \leq V_{OUT} \leq 24V$		0.02	2.0	μA

electrical characteristics

The following specifications apply for $0°C \leq T_A \leq 70°C$ (Note 5)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	Note 3			6.5	mV
Average Temperature Coefficient of Input Offset Voltage			5	20	μV/°C
Input Offset Current	Note 3, $0°C \leq T_A < 25°C$		2.4	7.5	μA
	$25°C \leq T_A \leq 70°C$			5.0	μA
Average Temperature Coefficient of Input Offset Current	$25°C \leq T_A \leq 70°C$		15	50	nA/°C
	$0°C \leq T_A \leq 25°C$		24	100	nA/°C
Input Bias Current	$0°C \leq T_A < 25°C$		25	40	μA
	$25°C \leq T_A \leq 70°C$			25	μA
Input Voltage Range	$-7V \geq V^- \geq -12V$	±5.0			V
Differential Input Voltage Range		±5.0			V
Saturation Voltage	$V_{IN} \leq -8$ mV, I_{OUT} = 50 mA			1.0	V
Saturation Voltage	$V_{IN} \leq -8$ mV, I_{OUT} = 16 mA			0.4	V
Positive Output Level	$V_{IN} \geq 8$ mV, $I_{OUT} = -400$ μA	2.5		5.5	V
Output Leakage Current	$V_{IN} \geq 8$ mV, $8V \leq V_{OUT} \leq 24V$				
	$0°C \leq T_A \leq 25°C$			2.0	μA
	$25°C < T_A \leq 70°C$			100	μA
Strobe Current	V_{strobe} = 0.4V		-1.7	-3.2	mA
Strobe ON Voltage		0.9	1.4		V
Strobe OFF Voltage	$I_{sink} \leq 16$ mA		1.4	2.2	V
Positive Supply Current	V_{IN} = -8 mV		5.5	10	mA
Negative Supply Current			-1.5	-3.6	mA

Note 1: For operating at elevated temperatures, the device must be derated based on a 85°C maximum junction temperature and a thermal resistance of 45°C/W junction to case or 150°C/W junction to ambient.

Note 2: These specifications apply for $-3V \geq V^- \geq -12V$, V^+ = 12V and T_A = 25°C unless otherwise specified. All currents into pins are considered positive.

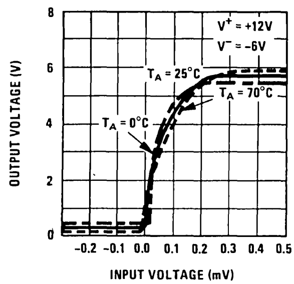
Note 3: The offset voltages and offset currents given are the maximum values required to drive the output down to 0.5V or up to 4.8V. Thus, these parameters actually define an error band and take into account the worst-case effects of voltage gain, and input impedance, specified supply voltage variations, and common mode voltage variations.

Note 4: The response time specified (see definitions) is for a 100 mV input step with 5 mV overdrive.

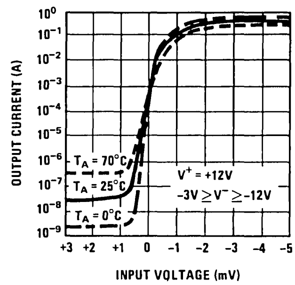
Note 5: All currents into device pins are considered positive.

typical performance characteristics

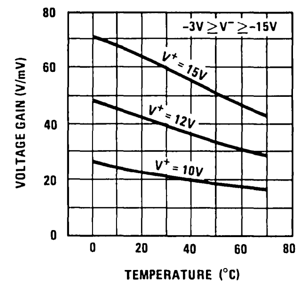
Transfer Function



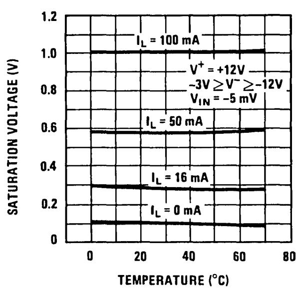
Transconductance



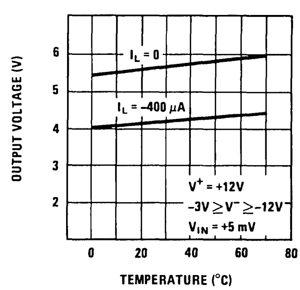
Voltage Gain



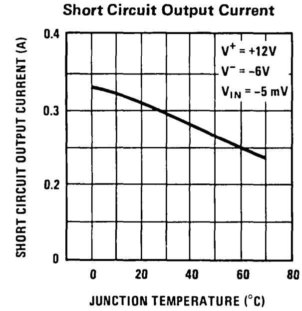
Saturation Voltage



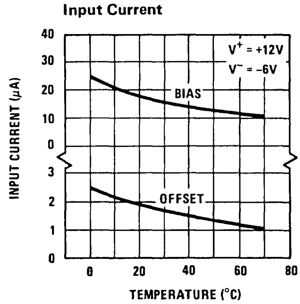
Positive Output Level



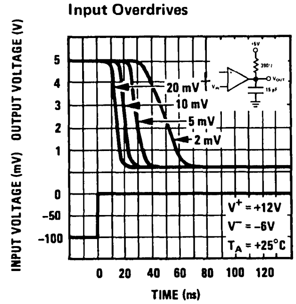
Short Circuit Output Current



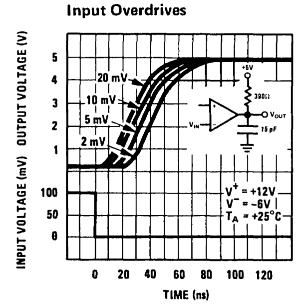
Input Current



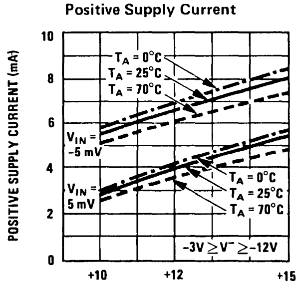
Response Time for Various Input Overdrives



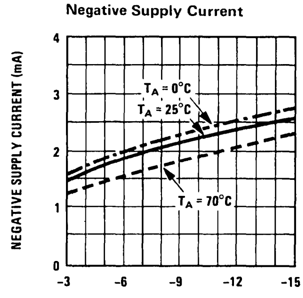
Response Time for Various Input Overdrives



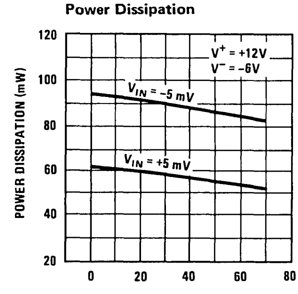
Positive Supply Current



Negative Supply Current



Power Dissipation



Voltage Comparators/Buffers

LM111/LM211 voltage comparator

general description

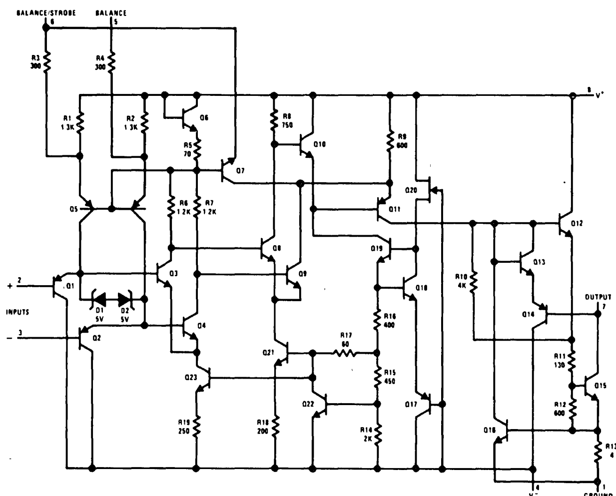
The LM111 and LM211 are voltage comparators that have input currents nearly a thousand times lower than devices like the LM106 or LM710. They are also designed to operate over a wider range of supply voltages: from standard ±15V op amp supplies down to the single 5V supply used for IC logic. Their output is compatible with RTL, DTL and TTL as well as MOS circuits. Further, they can drive lamps or relays, switching voltages up to 50V at currents as high as 50 mA. Outstanding characteristics include:

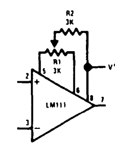
- Operates from single 5V supply
- Input current: 150 nA max. over temperature
- Offset current: 20 nA max. over temperature
- Differential input voltage range: ±30V
- Power consumption: 135 mW at ±15V

Both the inputs and the outputs of the LM111 or the LM211 can be isolated from system ground, and the output can drive loads referred to ground, the positive supply or the negative supply. Offset balancing and strobe capability are provided and outputs can be wire OR'ed. Although slower than the LM106 and LM710 (200 ns response time vs 40 ns) the devices are also much less prone to spurious oscillations. The LM111 has the same pin configuration as the LM106 and LM710.

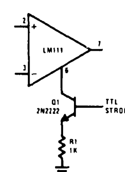
The LM211 is identical to the LM111, except that its performance is specified over a −25°C to 85°C temperature range instead of −55°C to 125°C.

schematic diagram and auxiliary circuits**

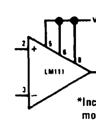




Offset Balancing



Strobing

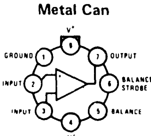


*Increases typical common mode slew from 7.0V/μs to 18V/μs.

Increasing Input Stage Current*

connection diagrams**

Metal Can

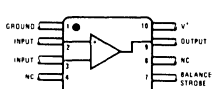


Note: Pin 4 connected to case.

TOP VIEW

Order Number LM111H or LM211H
See Package 11

Flat Package

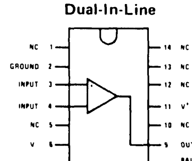


Note: Pin 5 connected to bottom of package.

TOP VIEW

Order Number LM111F or LM211F
See Package 3

Dual-In-Line

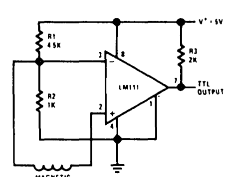


Note: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM111D or LM211D
See Package 1

typical application



Detector for Magnetic Transducer

**Pin connections shown are for metal can.

absolute maximum ratings

Total Supply Voltage (V_{84})	36V
Output to Negative Supply Voltage (V_{74})	50V
Ground to Negative Supply Voltage (V_{14})	30V
Differential Input Voltage	±30V
Input Voltage (Note 1)	±15V
Power Dissipation (Note 2)	500 mW
Output Short Circuit Duration	10 sec
Operating Temperature Range LM111	−55°C to 125°C
LM211	−25°C to 85°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (soldering, 10 sec)	300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage (Note 4)	T_A = 25°C, $R_S \leq 50k$		0.7	3.0	mV
Input Offset Current (Note 4)	T_A = 25°C		4.0	10	nA
Input Bias Current	T_A = 25°C		60	100	nA
Voltage Gain	T_A = 25°C		200		V/mV
Response Time (Note 5)	T_A = 25°C		200		ns
Saturation Voltage	$V_{IN} \leq -5$ mV, I_{OUT} = 50 mA T_A = 25°C		0.75	1.5	V
Strobe On Current	T_A = 25°C		3.0		mA
Output Leakage Current	$V_{IN} \geq 5$ mV, V_{OUT} = 35V T_A = 25°C		0.2	10	nA
Input Offset Voltage (Note 4)	$R_S \leq 50k$			4.0	mV
Input Offset Current (Note 4)				20	nA
Input Bias Current				150	nA
Input Voltage Range			±14		V
Saturation Voltage	$V^+ \geq 4.5V$, $V^- = 0$ $V_{IN} \leq -6$ mV, $I_{SINK} \leq 8$ mA		0.23	0.4	V
Output Leakage Current	$V_{IN} \geq 5$ mV, V_{OUT} = 35V		0.1	0.5	µA
Positive Supply Current	T_A = 25°C		5.1	6.0	mA
Negative Supply Current	T_A = 25°C		4.1	5.0	mA

Note 1: This rating applies for ±15V supplies. The positive input voltage limit is 30V above the negative supply. The negative input voltage limit is equal to the negative supply voltage or 30V below the positive supply, whichever is less.

Note 2: The maximum junction temperature of the LM111 is 150°C, while that of the LM211 is 110°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

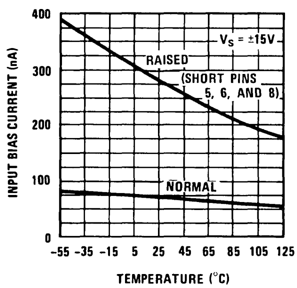
Note 3: These specifications apply for V_S = ±15V and −55°C $\leq T_A \leq$ 125°C, unless otherwise stated. With the LM211, however, all temperature specifications are limited to −25°C $\leq T_A \leq$ 85°C. The offset voltage, offset current and bias current specifications apply for any supply voltage from a single 5V supply up to ±15V supplies.

Note 4: The offset voltages and offset currents given are the maximum values required to drive the output within a volt of either supply with a 1 mA load. Thus, these parameters define an error band and take into account the worst case effects of voltage gain and input impedance.

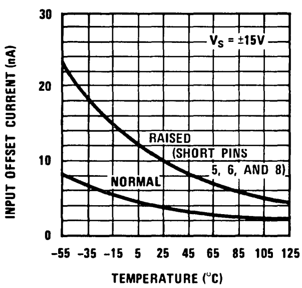
Note 5: The response time specified (see definitions) is for a 100 mV input step with 5 mV overdrive.

typical performance characteristics

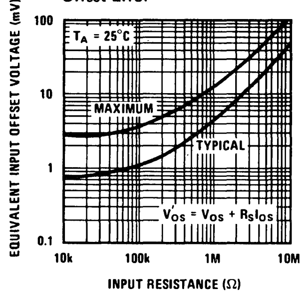
Input Bias Current



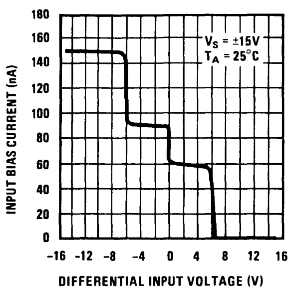
Input Offset Current



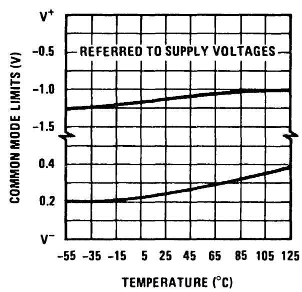
Offset Error



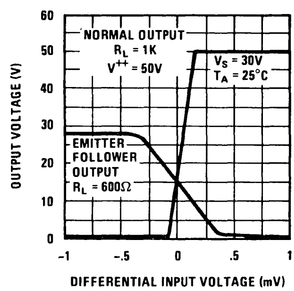
Input Characteristics



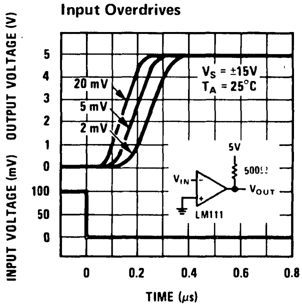
Common Mode Limits



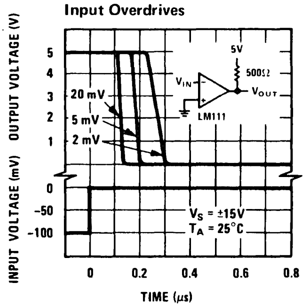
Transfer Function



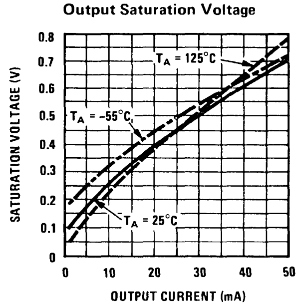
Response Time for Various Input Overdrives



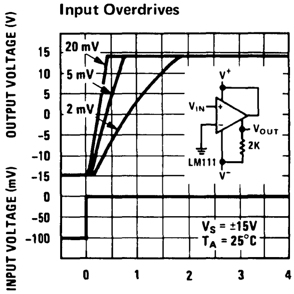
Response Time for Various Input Overdrives



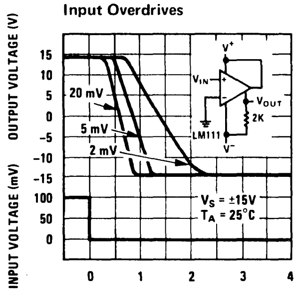
Output Saturation Voltage



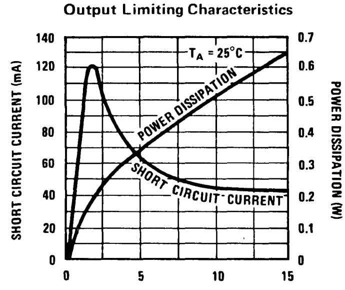
Response Time for Various Input Overdrives



Response Time for Various Input Overdrives

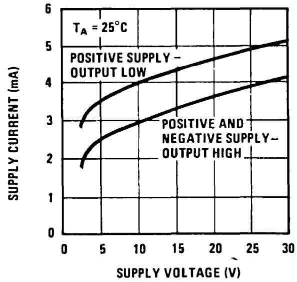


Output Limiting Characteristics

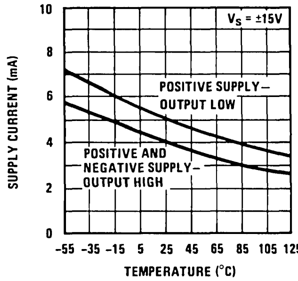


typical performance characteristics (con't)

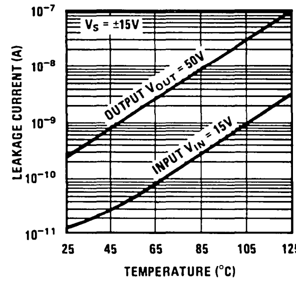
Supply Current



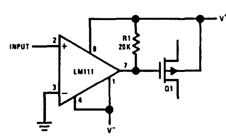
Supply Current



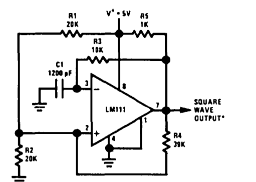
Leakage Currents



typical applications (con't)

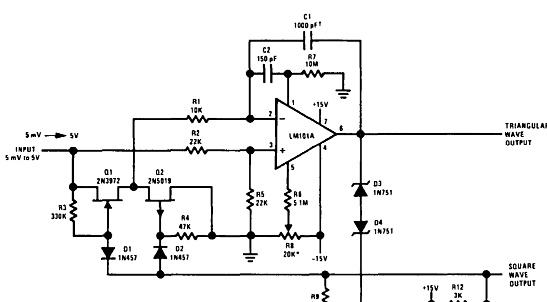


Zero Crossing Detector Driving MOS Switch



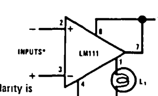
*TTL or DTL fanout of two.

100 kHz Free Running Multivibrator



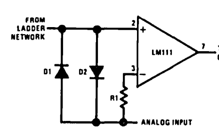
*Adjust for symmetrical square wave time when V_{IN} = 5 mV.
†Minimum capacitance 20 pF Maximum frequency 50 kHz

10 Hz to 10 kHz Voltage Controlled Oscillator

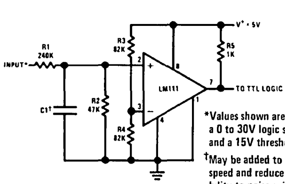


*Input polarity is reversed when using pin 1 as output.

Driving Ground-Referred Load

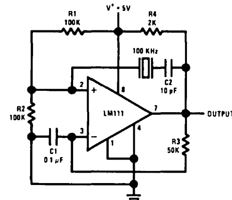


Using Clamp Diodes to Improve Response

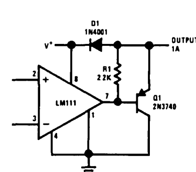


*Values shown are for a 0 to 30V logic swing and a 15V threshold.
†May be added to control speed and reduce susceptability to noise spikes.

TTL Interface with High Level Logic



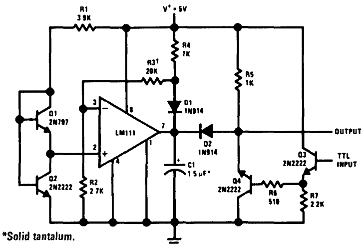
Crystal Oscillator



Comparator and Solenoid Driver

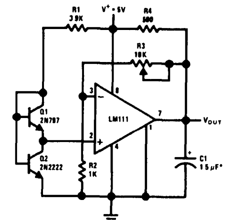
3

typical applications (con't)



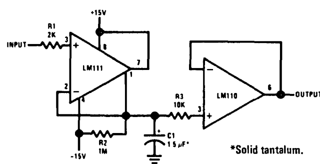
*Solid tantalum.
†Adjust to set clamp level.

Precision Squarer



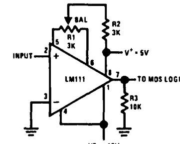
*Solid tantalum.

Low Voltage Adjustable Reference Supply

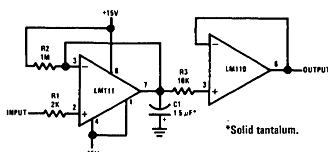


*Solid tantalum.

Positive Peak Detector

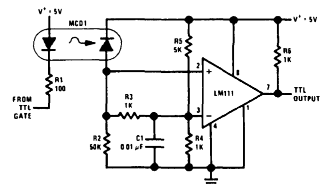


Zero Crossing Detector driving MOS logic

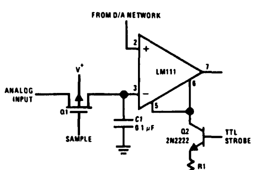


*Solid tantalum.

Negative Peak Dectector

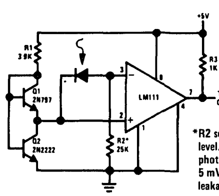


Digital Transmission Isolator



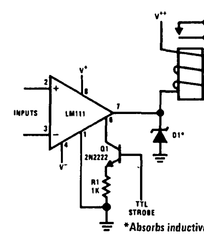
*Typical input current is 50 pA with inputs strobed off.

Strobing off Both Input* and Output Stages



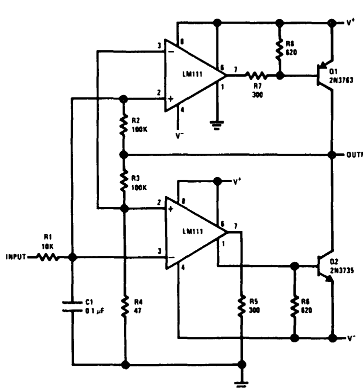
*R2 sets the comparison level. At comparison, the photodiode has less than 5 mV across it, decreasing leakage by an order of magnitude.

Precision Photodiode Comparator

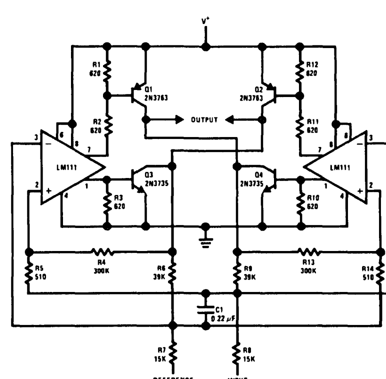


*Absorbs inductive kickback of relay and protects IC from severe voltage transients on V^{++} line.

Relay Driver with Strobe



Switching Power Amplifier



Switching Power Amplifier

Voltage Comparators/Buffers

LM311 voltage comparator

general description

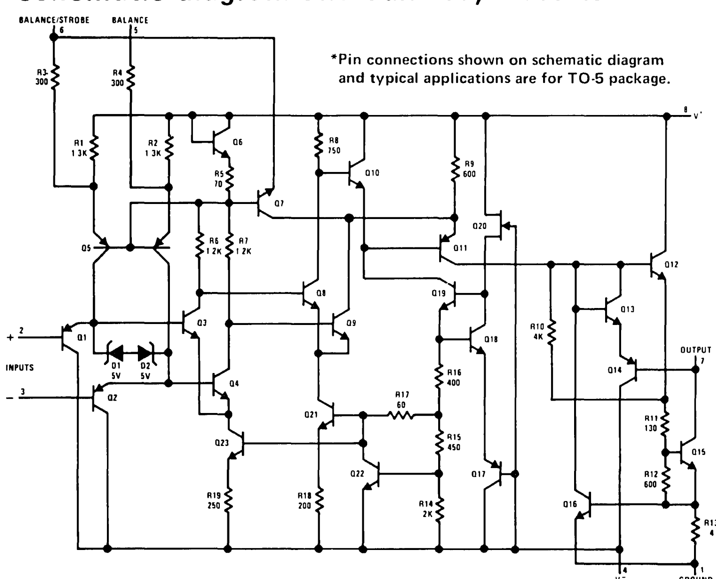
The LM311 is a voltage comparator that has input currents more than a hundred times lower than devices like the LM306 or LM710C. It is also designed to operate over a wider range of supply voltages: from standard ±15V op amp supplies down to the single 5V supply used for IC logic. Its output is compatible with RTL, DTL and TTL as well as MOS circuits. Further, it can drive lamps or relays, switching voltages up to 40V at currents as high as 50 mA.

features

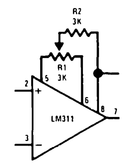
- Operates from single 5V supply
- Maximum input current: 250 nA
- Maximum offset current: 50 nA
- Differential input voltage range: ±30V
- Power consumption: 135 mW at ±15V

Both the input and the output of the LM311 can be isolated from system ground, and the output can drive loads referred to ground, the positive supply or the negative supply. Offset balancing and strobe capability are provided and outputs can be wire OR'ed. Although slower than the LM306 and LM710C (200 ns response time vs 40 ns) the device is also much less prone to spurious oscillations. The LM311 has the same pin configuration as the LM306 and LM710C.

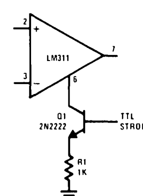
schematic diagram and auxiliary circuits



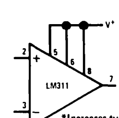
*Pin connections shown on schematic diagram and typical applications are for TO-5 package.



Offset Balancing



Strobing

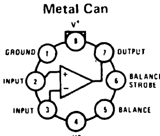


*Increases typical common mode slew from 7.0V/µs to 18V/µs.

Increasing Input Stage Current*

connection diagrams *

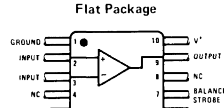
Metal Can



Note: Pin 4 connected to case.
TOP VIEW

Order Number LM311H
See Package 11

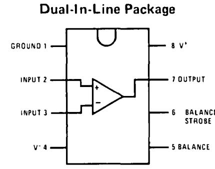
Flat Package



Note: Pin 5 connected to bottom of package.
TOP VIEW

Order Number LM311F
See Package 3

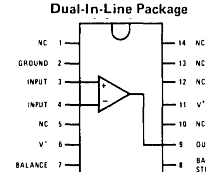
Dual-In-Line Package



TOP VIEW

Order Number LM311N
See Package 20

Dual-In-Line Package



Note: Pin 6 connected to bottom of package.
TOP VIEW

Order Number LM311D
See Package 1
Order Number LM311N-14
See Package 22

absolute maximum ratings

Total Supply Voltage (V_{84})	36V
Output to Negative Supply Voltage (V_{74})	40V
Ground to Negative Supply Voltage (V_{14})	30V
Differential Input Voltage	±30V
Input Voltage (Note 1)	±15V
Power Dissipation (Note 2)	500 mW
Output Short Circuit Duration	10 sec
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	–65°C to 150°C
Lead Temperature (soldering, 10 sec)	300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage (Note 4)	$T_A = 25°C$, $R_S \leq 50K$		2.0	7.5	mV
Input Offset Current (Note 4)	$T_A = 25°C$		6.0	50	nA
Input Bias Current	$T_A = 25°C$		100	250	nA
Voltage Gain	$T_A = 25°C$		200		V/mV
Response Time (Note 5)	$T_A = 25°C$		200		ns
Saturation Voltage	$V_{IN} \leq -10$ mV, $I_{OUT} = 50$ mA $T_A = 25°C$		0.75	1.5	V
Strobe On Current	$T_A = 25°C$		3.0		mA
Output Leakage Current	$V_{IN} \geq 10$ mV, $V_{OUT} = 35V$ $T_A = 25°C$		0.2	50	nA
Input Offset Voltage (Note 4)	$R_S \leq 50K$			10	mV
Input Offset Current (Note 4)				70	nA
Input Bias Current				300	nA
Input Voltage Range			±14		V
Saturation Voltage	$V^+ \geq 4.5V$, $V^- = 0$ $V_{IN} \leq -10$ mV, $I_{SINK} \leq 8$ mA		0.23	0.4	V
Positive Supply Current	$T_A = 25°C$		5.1	7.5	mA
Negative Supply Current	$T_A = 25°C$		4.1	5.0	mA

Note 1: This rating applies for ±15V supplies. The positive input voltage limit is 30V above the negative supply. The negative input voltage limit is equal to the negative supply voltage or 30V below the positive supply, whichever is less.

Note 2: The maximum junction temperature of the LM311 is 85°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

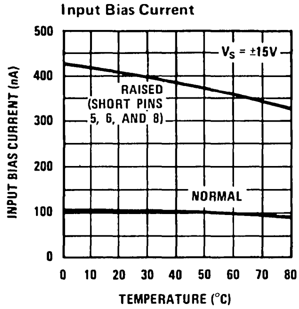
Note 3: These specifications apply for $V_S = \pm15V$ and $0°C < T_A < 70°C$, unless otherwise specified. The offset voltage, offset current and bias current specifications apply for any supply voltage from a single 5V supply up to ±15V supplies.

Note 4: The offset voltages and offset currents given are the maximum values required to drive the output within a volt of either supply with 1 mA load. Thus, these parameters define an error band and take into account the worst case effects of voltage gain and input impedance.

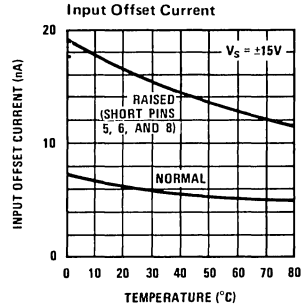
Note 5: The response time specified (see definitions) is for a 100 mV input step with 5 mV overdrive.

typical performance characteristics

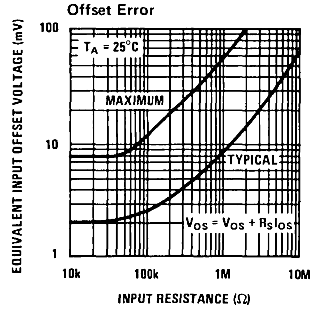
Input Bias Current



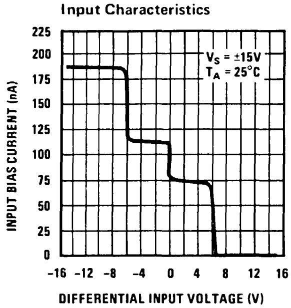
Input Offset Current



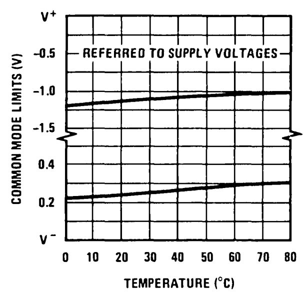
Offset Error



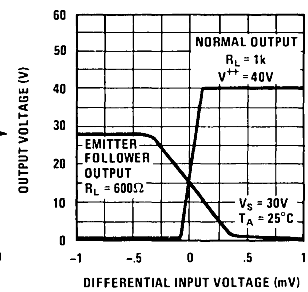
Input Characteristics



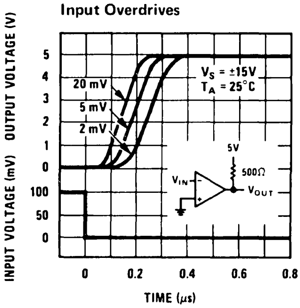
Common Mode Limits



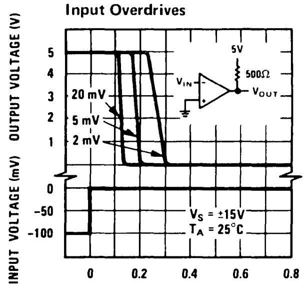
Transfer Function



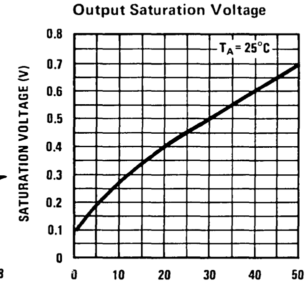
Response Time for Various Input Overdrives



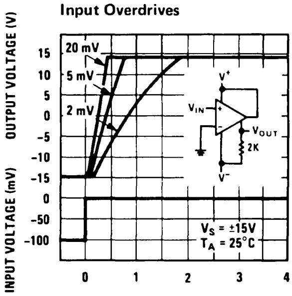
Response Time for Various Input Overdrives



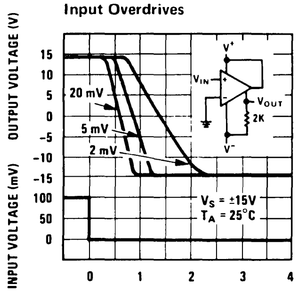
Output Saturation Voltage



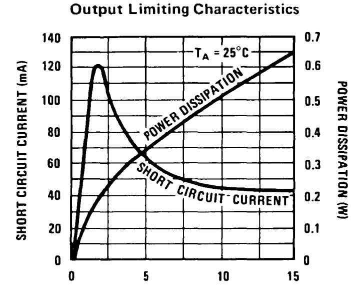
Response Time for Various Input Overdrives



Response Time for Various Input Overdrives

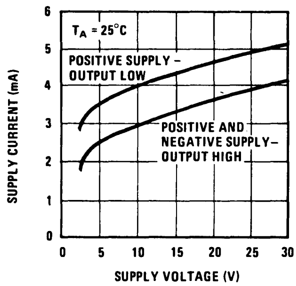


Output Limiting Characteristics

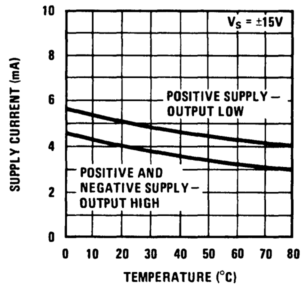


typical performance characteristics (con't)

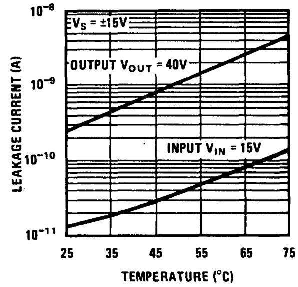
Supply Current



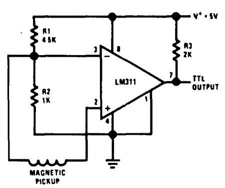
Supply Current



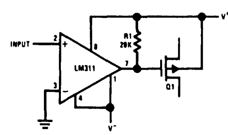
Leakage Currents



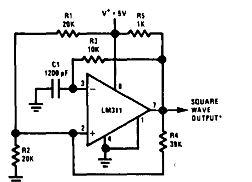
typical applications



Detector for Magnetic Transducer

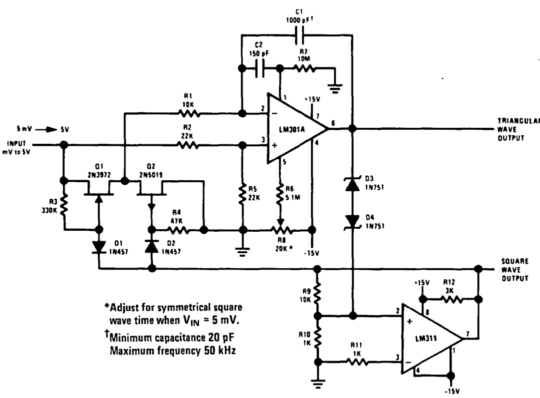


Zero Crossing Detector Driving MOS Switch



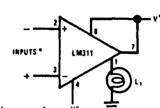
*TTL or DTL fanout of two.

100 kHz Free Running Multivibrator



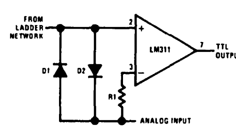
*Adjust for symmetrical square wave time when V_{IN} = 5 mV.
†Minimum capacitance 20 pF
Maximum frequency 50 kHz

10 Hz to 10 kHz Voltage Controlled Oscillator

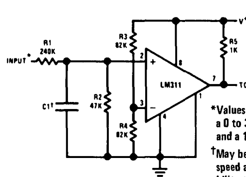


*Input polarity is reversed when using pin 1 as output.

Driving Ground-Referred Load

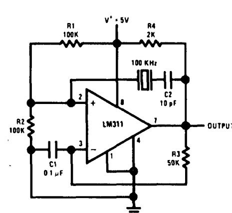


Using Clamp Diodes to Improve Response

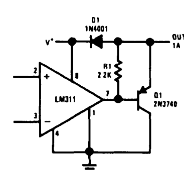


*Values shown are for a 0 to 30V logic swing and a 15V threshold.
†May be added to control speed and reduce suscepta-bility to noise spikes.

TTL Interface with High Level Logic

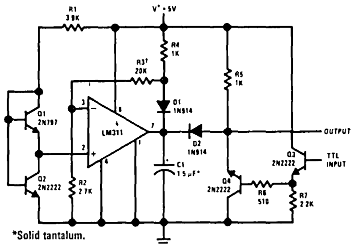


Crystal Oscillator



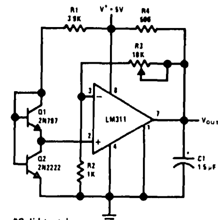
Comparator and Solenoid Driver

typical applications (con't)



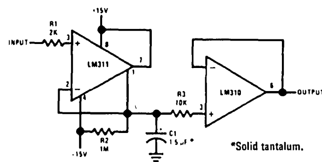
*Solid tantalum.
†Adjust to set clamp level.

Precision Squarer



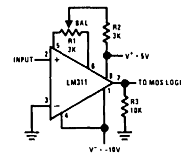
*Solid tantalum.

Low Voltage Adjustable Reference Supply

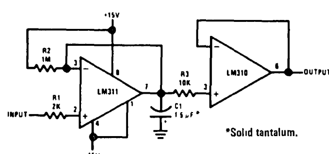


*Solid tantalum.

Positive Peak Detector

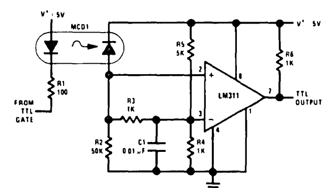


Zero Crossing Detector driving MOS logic

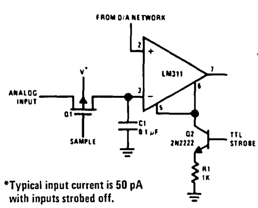


*Solid tantalum.

Negative Peak Dectector

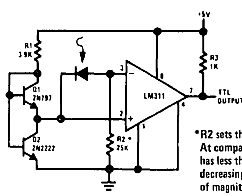


Digital Transmission Isolator



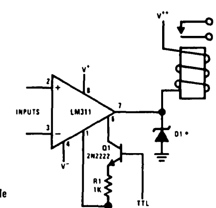
*Typical input current is 50 pA with inputs strobed off.

Strobing off Both Input* and Output Stages



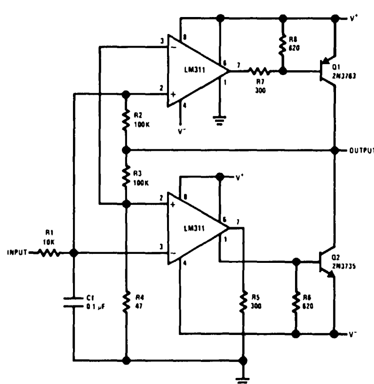
*R2 sets the comparison level. At comparison, the photodiode has less than 5 mV across it, decreasing leakages by an order of magnitude.

Precision Photodiode Comparator

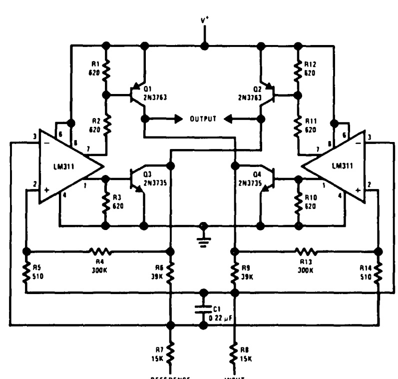


*Absorbs inductive kickback of relay and protects IC from severe voltage transients on V^{++} line.

Relay Driver with Strobe



Switching Power Amplifier



Switching Power Amplifier

3

Voltage Comparators/Buffers

LM119/LM219 high speed dual comparator general description

The LM119/LM219 are precision high speed dual comparators fabricated on a single monolithic chip. They are designed to operate over a wide range of supply voltages down to a single 5V logic supply and ground. Further, they have higher gain and lower input currents than devices like the LM710. The uncommitted collector of the output stage makes the LM119 compatible with RTL, DTL and TTL as well as capable of driving lamps and relays at currents up to 25 mA. Outstanding features include:

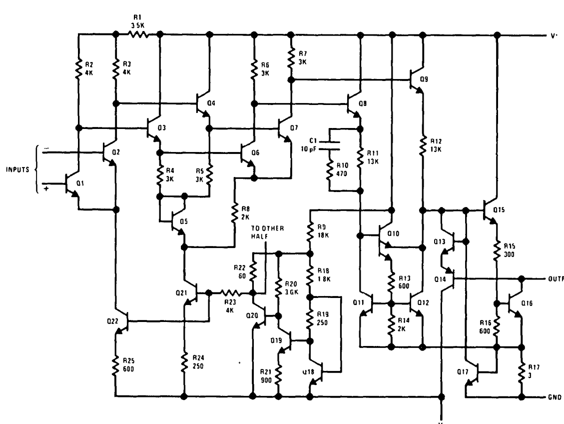
features

- Two independent comparators
- Operates from a single 5V supply
- Typically 80 ns response time at ±15V
- Minimum fan-out of 2 each side
- Maximum input current of 1 μA over temperature
- Inputs and outputs can be isolated from system ground
- High common mode slew rate

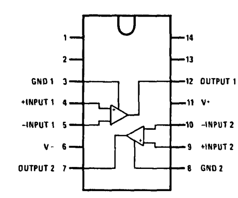
Although designed primarily for applications requiring operation from digital logic supplies, the LM119 is fully specified for power supplies up to ±15V. It features faster response than the LM111 at the expense of higher power dissipation. However, the high speed, wide operating voltage range and low package count make the LM119 much more versatile than older devices like the LM711.

The LM219 is identical to the LM119, except that its performance is specified over a −25°C to 85°C temperature range instead of −55°C to 125°C.

schematic and connection diagrams

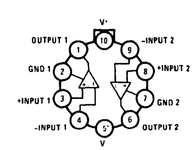


Dual-In-Line-Package



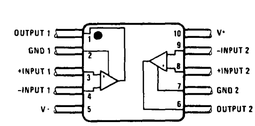
Order Number LM119D or LM219D
See Package 1

Metal Can Package



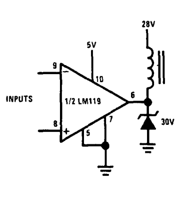
Order Number LM119H or LM219H
See Package 12

Flat Package

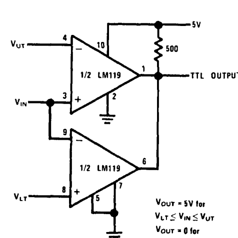


Order Number LM119F or LM219F
See Package 3

typical applications



Relay Driver



Window Detector

absolute maximum ratings

Total Supply Voltage	36V
Output to Negative Supply Voltage	36V
Ground to Negative Supply Voltage	25V
Ground to Positive Supply Voltage	18V
Differential Input Voltage	±5V
Input Voltage (Note 1)	±15V
Power Dissipation (Note 2)	500 mW
Output Short Circuit Duration	10 sec
Operating Temperature Range LM119	−55°C to 125°C
LM219	−25°C to 85°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage (Note 4)	$T_A = 25°C$, $R_S \le 5k$		0.7	4.0	mV
Input Offset Current (Note 4)	$T_A = 25°C$		30	75	nA
Input Bias Current	$T_A = 25°C$		150	500	nA
Voltage Gain	$T_A = 25°C$	10	40		V/mV
Response Time (Note 5)	$T_A = 25°C$ $V_S = \pm15V$		80		ns
Saturation Voltage	$V_{IN} \le -5$ mV, $I_{OUT} = 25$ mA $T_A = 25°C$		0.75	1.5	V
Output Leakage Current	$V_{IN} \ge 5$ mV, $V_{OUT} = 35V$ $T_A = 25°C$		0.2	2	μA
Input Offset Voltage (Note 4)	$R_S \le 5k$			7	mV
Input Offset Current (Note 4)				100	nA
Input Bias Current				1000	nA
Input Voltage Range	$V_S = \pm15V$		±13		V
	$V^+ = 5V$, $V^- = 0$	1		3	V
Saturation Voltage	$V^+ \ge 4.5V$, $V^- = 0$ $V_{IN} \le -6$ mV, $I_{SINK} \le 3.2$ mA $T_A \ge 0°C$		0.23	0.4	V
	$T_A \le 0°C$			0.6	V
Output Leakage Current	$V_{IN} \ge 5$ mV, $V_{OUT} = 35V$		1	10	μA
Differential Input Voltage				±5	V
Positive Supply Current	$T_A = 25°C$, $V^+ = 5V$, $V^- = 0$		4.3		mA
Positive Supply Current	$T_A = 25°C$ $V_S = \pm15V$		8	11.5	mA
Negative Supply Current	$T_A = 25°C$ $V_S = \pm15V$		3	4.5	mA

Note 1: For supply voltages less than ±15V the absolute maximum input voltage is equal to the supply voltage.

Note 2: The maximum junction temperature of the LM119 is 150°C, while that of the LM219 is 110°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W when mounted on a 1/16-inch-thick epoxy glass board with ten, 0.03-inch-wide, 2-ounce copper conductors. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

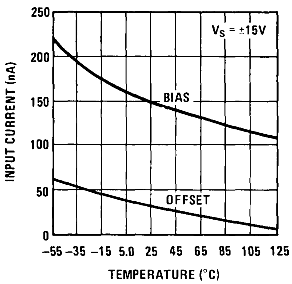
Note 3: These specifications apply for $V_S = \pm15V$ and $-55°C \le T_A \le 125°C$, unless otherwise stated. With the LM219, however, all temperature specifications are limited to $-25°C \le T_A \le 85°C$. The offset voltage, offset current and bias current specifications apply for any supply voltage from a single 5V supply up to ±15V supplies.

Note 4: The offset voltages and offset currents given are the maximum values required to drive the output within a volt of either supply with a 1 mA load. Thus, these parameters define an error band and take into account the worst case effects of voltage gain and input impedance.

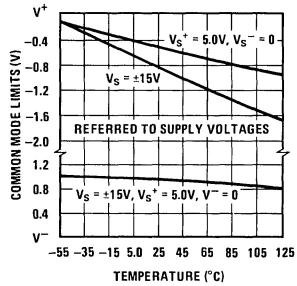
Note 5: The response time specified is for a 100 mV input step with 5 mV overdrive.

typical performance characteristics

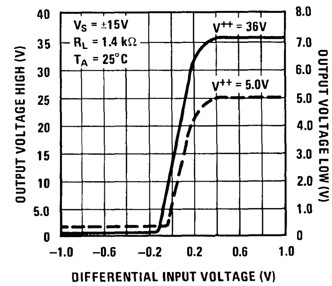
Input Currents



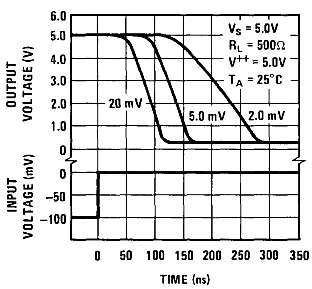
Common Mode Limits



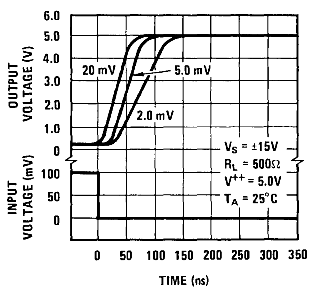
Transfer Function



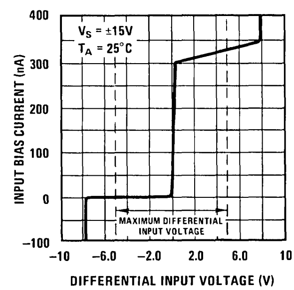
Response Time for Various Input Overdrives



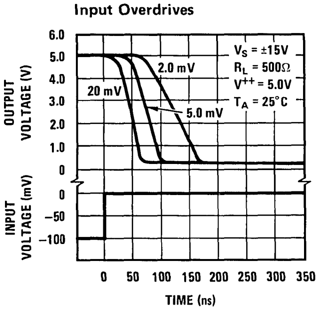
Response Time for Various Input Overdrives



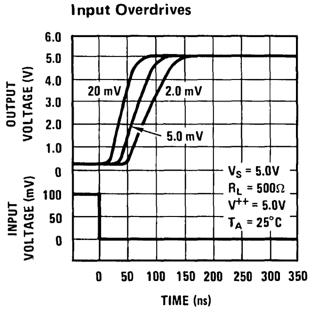
Input Characteristics



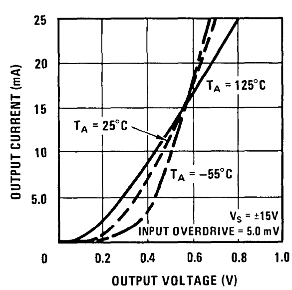
Response Time for Various Input Overdrives



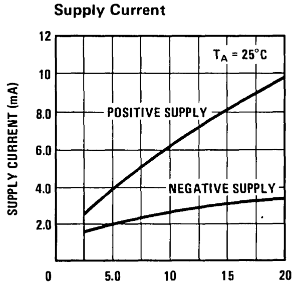
Response Time for Various Input Overdrives



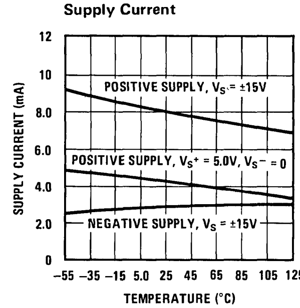
Output Saturation Voltage



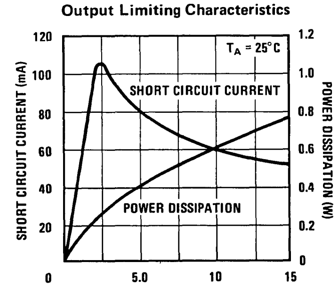
Supply Current



Supply Current



Output Limiting Characteristics



Voltage Comparators/Buffers

LM319 high speed dual comparator

general description

The LM319 is a precision high speed dual comparator fabricated on a single monolithic chip. It is designed to operate over a wide range of supply voltages down to a single 5V logic supply and ground. Further, it has higher gain and lower input currents than devices like the LM710. The uncommitted collector of the output stage makes the LM319 compatible with RTL, DTL and TTL as well as capable of driving lamps and relays at currents up to 25 mA.

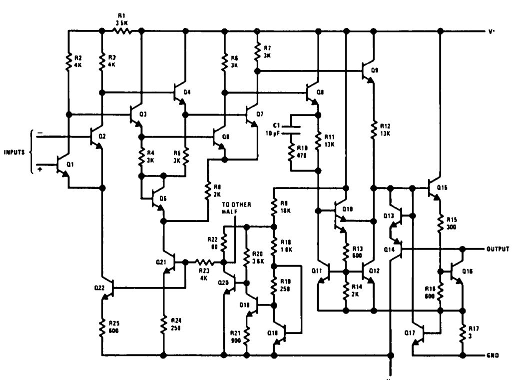
features

- Two independent comparators
- Operates from a single 5V supply
- Typically 80 ns response time at ±15V
- Minimum fan-out of 2 each side
- Maximum input current of 1 μA
- Inputs and outputs can be isolated from system ground
- High common mode slew rate

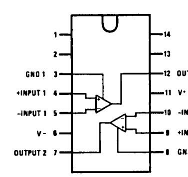
Although designed primarily for applications requiring operation from digital logic supplies, the LM319 is fully specified for power supplies up to ±15V. It features faster response than the LM111 at the expense of higher power dissipation. However, the high speed, wide operating voltage range and low package count make the LM319 much more versatile than older devices like the LM711.

The LM319 has its performance specified over a 0°C to 70°C temperature range.

schematic and connection diagrams



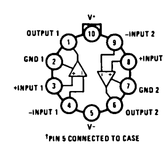
Dual In-Line-Package



Order Number LM319D
See Package 1

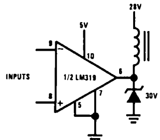
Order Number LM319N
See Package 22

Metal Can Package†

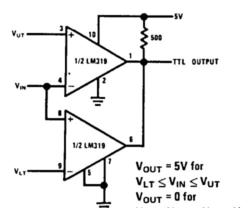


Order Number LM319H
See Package 12

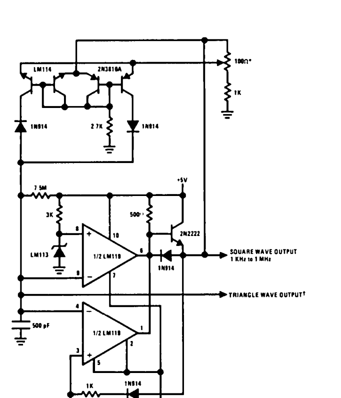
typical applications



Relay Driver



Window Detector



*Frequency adjust.
†Must be buffered for $R_L \le 10\ M\Omega$.

Wide Range Variable Oscillator

absolute maximum ratings

Total Supply Voltage	36V	Power Dissipation (Note 2)	500 mW
Output to Negative Supply Voltage	36V	Output Short Circuit Duration	10 sec
Ground to Negative Supply Voltage	25V	Operating Temperature Range LM319	0°C to 70°C
Ground to Positive Supply Voltage	18V	Storage Temperature Range	-65°C to 150°C
Differential Input Voltage	±5V	Lead Temperature (Soldering, 10 sec)	300°C
Input Voltage (Note 1)	±15V		

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage (Note 4)	$T_A = 25°C, R_S \leq 5k$		2.0	8.0	mV
Input Offset Current (Note 4)	$T_A = 25°C$		80	200	nA
Input Bias Current	$T_A = 25°C$		250	1000	nA
Voltage Gain	$T_A = 25°C$	8	40		V/mV
Response Time (Note 5)	$T_A = 25°C$ $V_S = \pm 15V$		80		ns
Saturation Voltage	$V_{IN} \leq -10$ mV, $I_{OUT} = 25$ mA $T_A = 25°C$		0.75	1.5	V
Output Leakage Current	$V_{IN} \geq 10$ mV, $V_{OUT} = 35V$ $T_A = 25°C$		0.2	10	μA
Input Offset Voltage (Note 4)	$R_S \leq 5k$			10	mV
Input Offset Current (Note 4)				300	nA
Input Bias Current				1200	nA
Input Voltage Range	$V_S = \pm 15V$		±13		V
	$V^+ = 5V, V^- = 0$	1		3	V
Saturation Voltage	$V^+ \geq 4.5V, V^- = 0$ $V_{IN} \leq -10$ mV, $I_{SINK} \leq 3.2$ mA		0.3	0.4	V
Differential Input Voltage				±5	V
Positive Supply Current	$T_A = 25°C, V^+ = 5V, V^- = 0$		4.3		mA
Positive Supply Current	$T_A = 25°C$ $V_S = \pm 15V$		8	12.5	mA
Negative Supply Current	$T_A = 25°C$ $V_S = \pm 15V$		3	5	mA

Note 1: For supply voltages less than ±15V the absolute maximum input voltage is equal to the supply voltage.

Note 2: The maximum junction temperature of the LM319 is 85°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient, or 45°C/W, junction to case. The thermal resistance of the dual-in-line package is 100°C/W, junction to ambient.

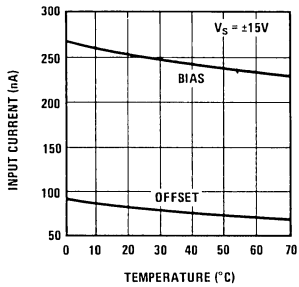
Note 3: These specifications apply for $V_S = \pm 15V$ and $0°C \leq T_A \leq 70°C$, unless otherwise stated. The offset voltage, offset current and bias current specifications apply for any supply voltage from a single 5V supply up to ±15V supplies.

Note 4: The offset voltages and offset currents given are the maximum values required to drive the output within a volt of either supply with a 1 mA load. Thus, these parameters define an error band and take into account the worst case effects of voltage gain and input impedance.

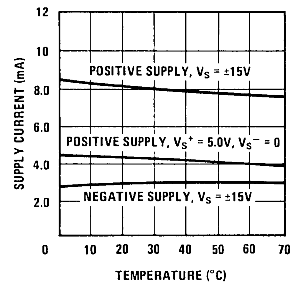
Note 5: The response time specified is for a 100 mV input step with 5 mV overdrive.

typical performance characteristics

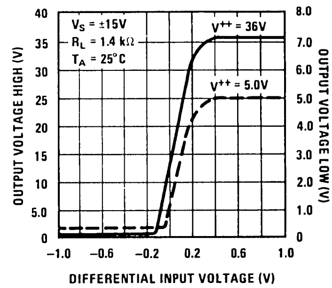
Input Currents



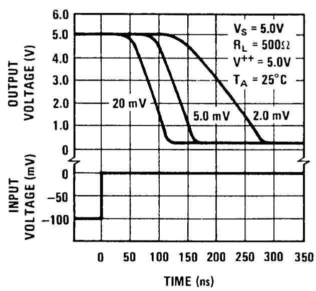
Supply Currents



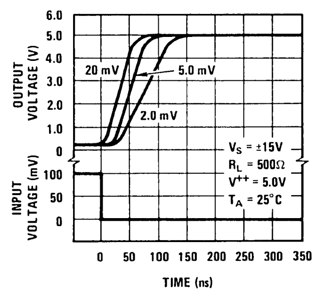
Transfer Function



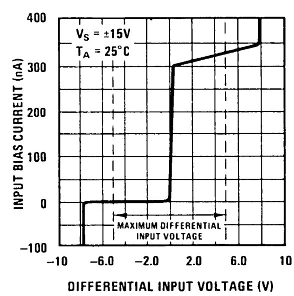
Response Time for Various Input Overdrives



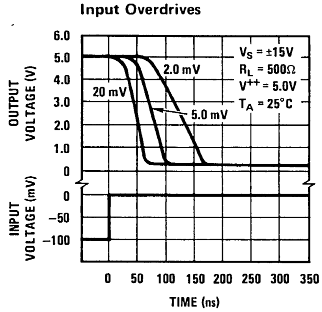
Response Time for Various Input Overdrives



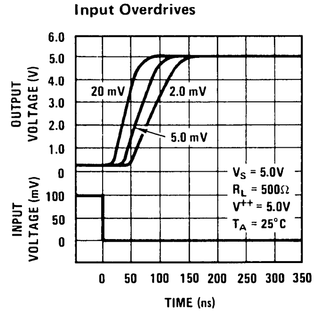
Input Characteristics



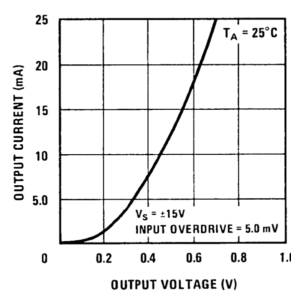
Response Time for Various Input Overdrives



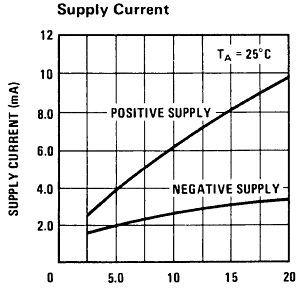
Response Time for Various Input Overdrives



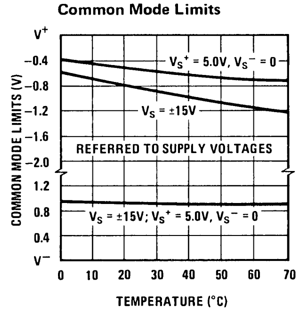
Output Saturation Voltage



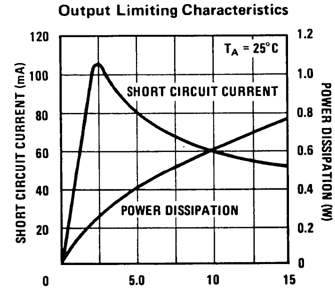
Supply Current



Common Mode Limits



Output Limiting Characteristics



Voltage Comparators/Buffers

LM139/LM239/LM339 quad comparator

general description

The LM139 series consists of four independent voltage comparators which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage. These comparators also have a unique characteristic in that the input common-mode voltage range includes ground, even though operated from a single power supply voltage.

Application areas include limit comparators, simple analog to digital converters; pulse, squarewave and time delay generators; wide range VCO; MOS clock timers; multivibrators and high voltage digital logic gates. The LM139 series was designed to directly interface with TTL and CMOS. When operated from both plus and minus power supplies, the LM339 will directly interface with MOS logic — where the low power drain of the LM339 is a distinct advantage over standard comparators.

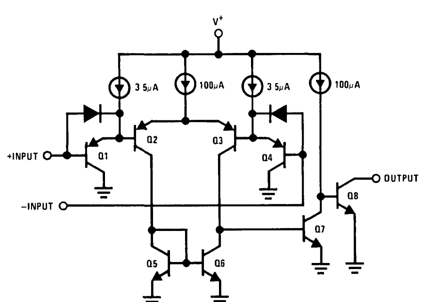
advantages

- Eliminates need for dual supplies
- Allows sensing near GND
- Compatible with all forms of logic
- Power drain suitable for battery operation

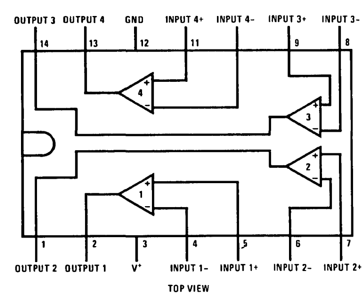
features

- Wide single supply
  Voltage range 2 V_{DC} to 36 V_{DC}
  or dual supplies ±1 V_{DC} to ±18 V_{DC}
- Very low supply current drain (0.8 mA) — independent of supply voltage (1 mW/comparator at +5 V_{DC})
- Low input biasing current 35 nA
- Low input offset current 3 nA
  and offset voltage 3 mV
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Low output saturation voltage 1 mV at 5μA
  70 mV at 1 mA
- Output voltage compatible with TTL (fanout of 2), DTL, ECL, MOS and CMOS logic systems

schematic and connection diagrams

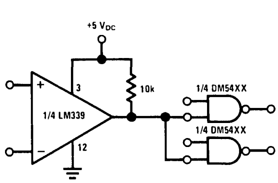


Dual-In-Line and Flat Package

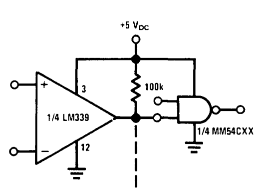


Order Number	Order Number	Order Number
LM139F	LM139D, LM239D, or LM339D	LM339N
See Package 4	See Package 1	See Package 22

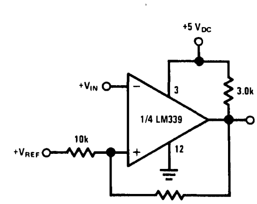
typical applications



Driving TTL



Driving CMOS



Comparator with Hysteresis

absolute maximum ratings

Supply Voltage, V^+	$36\ V_{DC}$ or $\pm 18\ V_{DC}$
Differential Input Voltage	$36\ V_{DC}$
Input Voltage	$-0.3\ V_{DC}$ to $+36\ V_{DC}$
Power Dissipation (Note 1)	
Molded DIP (LM339N)	570 mW
Cavity DIP (LM139D, LM239D & LM339D)	900 mW
Flat Pack (LM139F)	800 mW
Output Short-Circuit to GND (Note 2)	Continuous
Input Current ($V_{IN} < -0.3\ V_{DC}$)(Note 3)	50 mA
Operating Temperature Range	
LM339	0°C to +70°C
LM239	−25°C to +85°C
LM139	−55°C to +125°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics ($V^+ = +5.0\ V_{DC}$, see Note 4)

PARAMETER	CONDITIONS	LM139			LM239, LM339			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = +25°C$ (Note 9)		±2	±5.0		±2	±5.0	mV_{DC}
Input Bias Current (Note 5)	$I_{IN(+)}$ or $I_{IN(-)}$ With Output in Linear Range, $T_A = +25°C$		25	100		25	250	nA_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $T_A = +25°C$		±3	±25		±5	±50	nA_{DC}
Input Common-Mode Voltage Range (Note 6)	$T_A = +25°C$	0		$V^+ - 1.5$	0		$V^+ - 1.5$	V_{DC}
Supply Current	$R_L = \infty$ On All Comparators $T_A = +25°C$		0.8	2.0		0.8	2.0	mA_{DC}
Voltage Gain	$R_L \geq 15\ k\Omega$, $T_A = +25°C$		200			200		V/mV
Large Signal Response Time	V_{IN} = TTL Logic Swing, $V_{REF} = +1.4\ V_{DC}$, $V_{RL} = 5.0\ V_{DC}$ and $R_L = 5.1\ k\Omega$		300			300		ns
Response Time (Note 7)	$V_{RL} = 5.0\ V_{DC}$ and $R_L = 5.1\ k\Omega$, $T_A = +25°C$		1.3			1.3		μs
Output Sink Current	$V_{IN(-)} \geq +1.0\ V_{DC}$, $V_{IN(+)} = 0$ and $V_O \leq +1.5\ V_{DC}$, $T_A = +25°C$	6	16		6	16		mA_{DC}
Saturation Voltage	$V_{IN(-)} \geq +1.0\ V_{DC}$, $V_{IN(+)} = 0$ and $I_{SINK} \leq 4.0\ mA$, $T_A = +25°C$		250	500		250	500	mV_{DC}
Output Leakage Current	$V_{IN(+)} \geq +1.0\ V_{DC}$, $V_{IN(-)} = 0$ and $V_{OUT} = 5.0\ V_{DC}$, $T_A = +25°C$		0.1			0.1		nA_{DC}
Input Offset Voltage	(Note 9)			9.0			9.0	mV_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$			±100			±150	nA_{DC}
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$ With Output in Linear Range			300			400	nA_{DC}
Input Common-Mode Voltage Range		0		$V^+ - 2.0$	0		$V^+ - 2.0$	V_{DC}
Saturation Voltage	$V_{IN(-)} \geq +1.0\ V_{DC}$, $V_{IN(+)} = 0$ and $I_{SINK} \leq 4.0\ mA$			700			700	mV_{DC}
Output Leakage Current	$V_{IN(+)} \geq +1.0\ V_{DC}$, $V_{IN(-)} = 0$ and $V_{OUT} = 30\ V_{DC}$			1.0			1.0	μA_{DC}
Differential Input Voltage (Note 8)	Keep All V_{IN}'s $\geq 0\ V_{DC}$ (or V^-, if used)			36			36	V_{DC}

Note 1: For operating at high temperatures, the LM339 must be derated based on +125°C maximum junction temperature and a thermal resistance of +175°C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM239 and LM139 must be derated based on a +150°C maximum junction temperature. The low bias dissipation and the ON-OFF characteristic of the outputs keeps the chip dissipation very small ($P_d \leq 100$ mW), provided the output transistors are allowed to saturate.

Note 2: Short circuits from the output to V^+ can cause excessive heating and eventual destruction. The maximum output current is approximately 20 mA independent of the magnitude of V^+.

Note 3: This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the comparators to go to the V^+ voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than $-0.3\ V_{DC}$.

Note 4: These specifications apply for $V^+ = +5.0\ V_{DC}$ and $-55°C \leq T_A \leq +125°C$, unless otherwise stated. With the LM239, all temperature specifications are limited to $-25°C \leq T_A \leq +85°C$ and the LM339 temperature specifications are limited to $0°C \leq T_A \leq +70°C$.

Note 5: The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the reference or input lines.

Note 6: The input common-mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3V. The upper end of the common-mode voltage range is $V^+ - 1.5V$, but either or both inputs can go to $+30\ V_{DC}$ without damage.

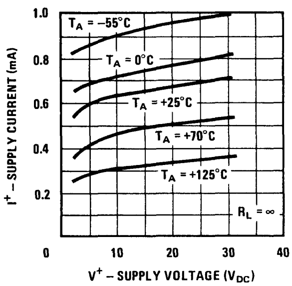
Note 7: The response time specified is for a 100 mV input step with 5.0 mV overdrive. For larger overdrive signals 300 ns can be obtained, see typical performance characteristics section.

Note 8: The positive excursions of the input can exceed the power supply voltage level, and if the other input voltage remains within the common-mode voltage range, the comparator will provide a proper output state. The low input voltage state must not be less than $-0.3\ V_{DC}$ (or $0.3\ V_{DC}$ below the magnitude of the negative power supply voltage, if used).

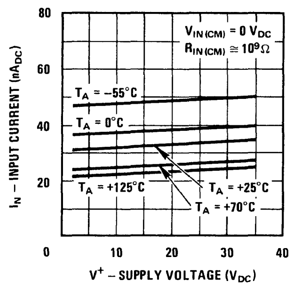
Note 9: At output switch point, $V_O \cong 1.4\ V_{DC}$, $R_S = 0\Omega$ with V^+ from $5\ V_{DC}$ to $30\ V_{DC}$; and over the full input common mode range ($0\ V_{DC}$ to $V^+ \pm 1.5\ V_{DC}$).

typical performance characteristics

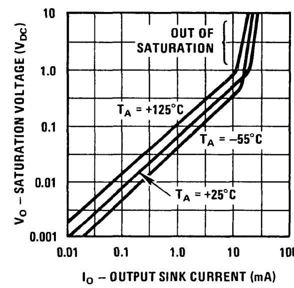
Supply Current



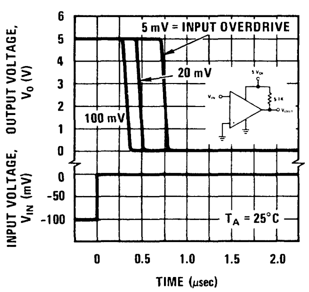
Input Current



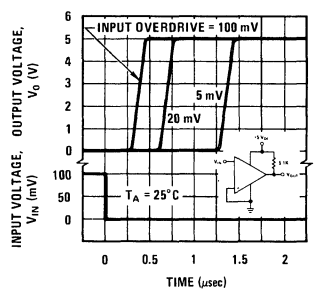
Output Saturation Voltage



Response Time for Various Input Overdrives — Negative Transition



Response Time for Various Input Overdrives — Positive Transition



application hints

The LM139 is a high gain, wide bandwidth device; which, like most comparators, can easily oscillate if the output lead is inadvertently allowed to capacitively couple to the inputs via stray capacitance. This shows up only during the output voltage transition intervals as the comparator changes states. Power supply bypassing is not required to solve this problem. Standard PC board layout is helpful as it reduces stray input-output coupling. Reducing the input resistors to <10 kΩ reduces the feedback signal levels and finally, adding even a small amount (1 to 10 mV) of positive feedback (hysteresis) causes such a rapid transition that oscillations due to stray feedback are not possible. Simply socketing the I/C and attaching resistors to the pins will cause input-output oscillations during the small transition intervals unless hysteresis is used. If the input signal is a pulse waveform, with relatively fast rise and fall times, hysteresis is not required.

All pins of any unused comparators should be grounded.

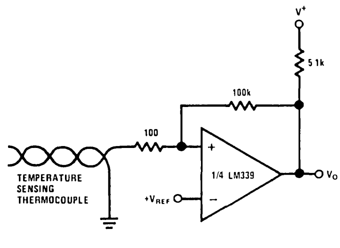
The bias network of the LM139 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from $2V_{DC}$ to $30\ V_{DC}$.

It is usually unnecessary to use a bypass capacitor across the power supply line.

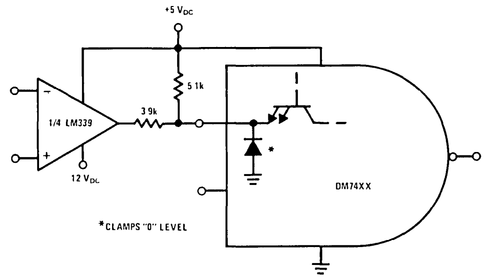
The differential input voltage may be larger than V^+ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than $-0.3\ V_{DC}$ (at 25°C). An input clamp diode and input resistor can be used as shown in the applications section.

The output of the LM139 is the uncommitted collector of a grounded-emitter NPN output transistor. Many collectors can be tied together to provide an output OR'ing function. An output "pull-up" resistor can be connected to any available power supply voltage within the permitted supply voltage range and there is no restriction on this voltage due to the magnitude of the voltage which is applied to the V^+ terminal of the LM139 package. The output can also be used as a simple SPST switch to ground (when a "pull-up" resistor is not used). The amount of current which the output device can sink is limited by the drive available (which is independent of V^+) and the β of this device. When the maximum current limit is reached (approximately 16 mA), the output transistor will come out of saturation and the output voltage will rise very rapidly. The output saturation voltage is limited by the approximately 60Ω r_{sat} of the output transistor. The low offset voltage of the output transistor (1 mV) allows the output to clamp essentially to ground level for small load currents.

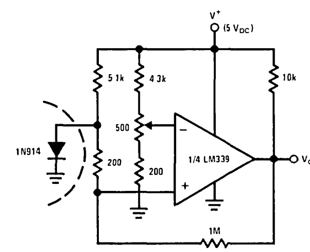
typical applications (con't)



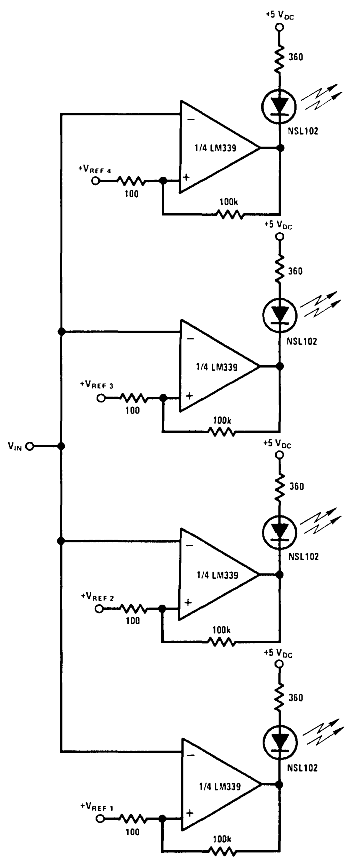
Ground Referenced Thermocouple in Single Supply System



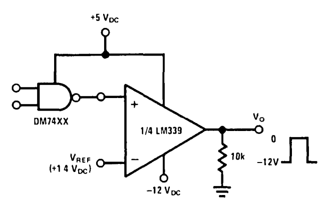
MOS to TTL Logic Translator



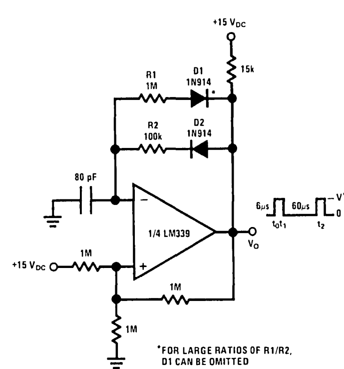
Remote Temperature Sensing



Visible Voltage Indicator

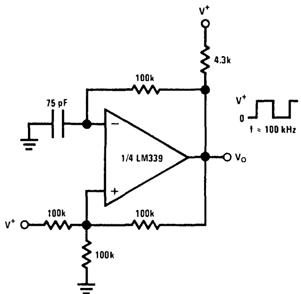


TTL to MOS Logic Converter

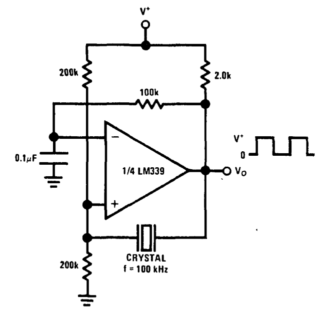


Pulse Generator

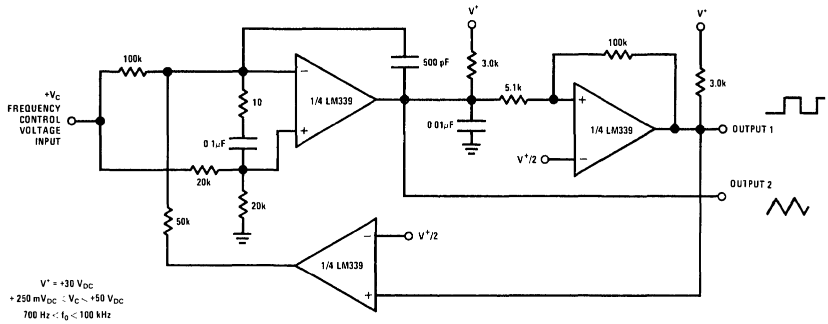
typical applications (con't)



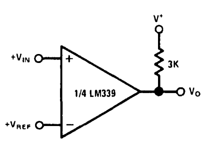
Squarewave Oscillator



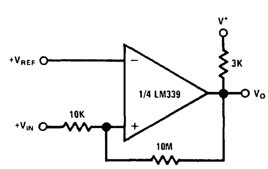
Crystal Controlled Oscillator



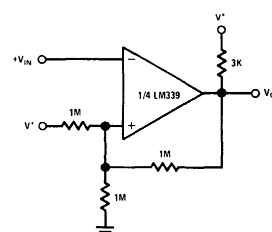
Two-Decade High-Frequency VCO



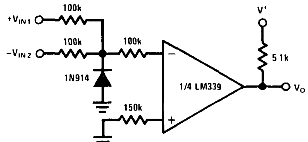
Basic Comparator



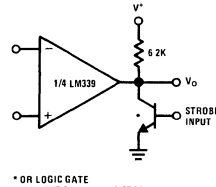
Non-Inverting Comparator with Hysteresis



Inverting Comparator with Hysteresis



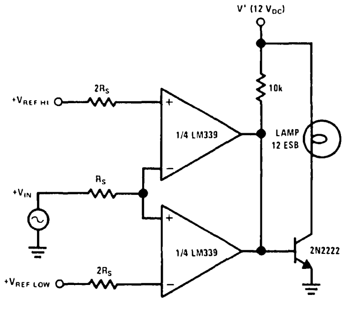
Comparing Input Voltages
of Opposite Polarity



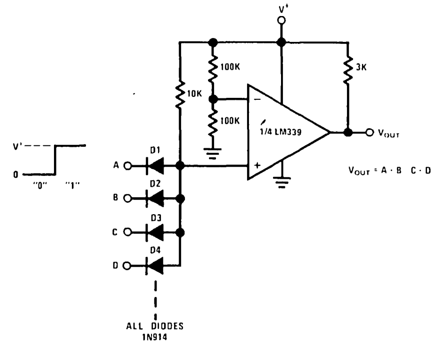
* OR LOGIC GATE
WITHOUT PULL-UP RESISTOR

Output Strobing

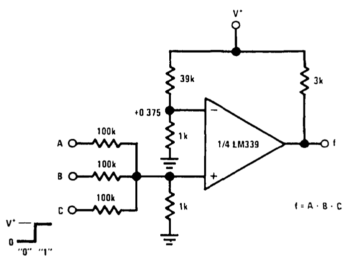
typical applications (con't) ($V^+ = 15\ V_{DC}$)



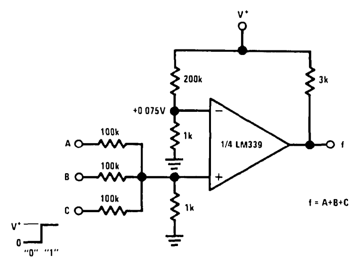
Limit Comparator



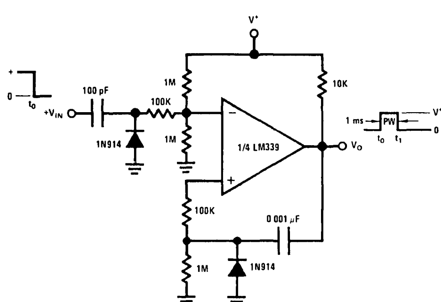
Large Fan-in AND Gate



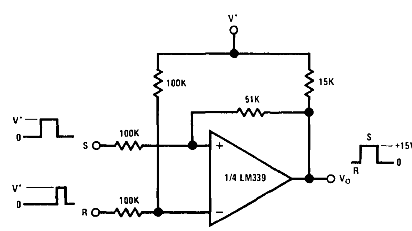
AND Gate



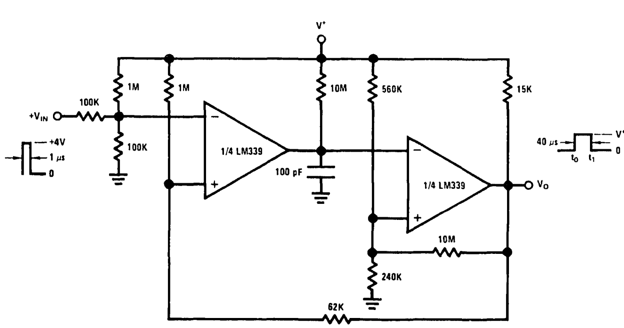
OR Gate



One-Shot Multivibrator



Bi-Stable Multivibrator



One-Shot Multivibrator with Input Lock Out

3

Voltage Comparators/Buffers

LM139A/LM239A/LM339A low offset voltage quad comparator

general description

The LM139A series consists of four independent precision voltage comparators with an offset voltage specification of 2.0 mV max. for all four comparators which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage. These comparators also have a unique characteristic in that the input common-mode voltage range includes ground, even though operated from a single power supply voltage.

Application areas include limit comparators, simple analog to digital converters; pulse, squarewave and time delay generators; wide range VCO; MOS clock timers; multivibrators and high voltage digital logic gates. The LM139A series was designed to directly interface with TTL and CMOS. When operated from both plus and minus power supplies, the LM339A will directly interface with MOS logic—where the low power drain of the LM339A is a distinct advantage over standard comparators.

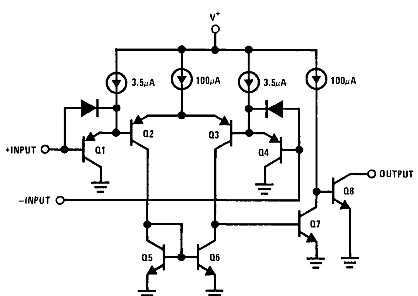
advantages

- High precision comparators
- Reduced V_{OS} drift over temperature
- Eliminates need for dual supplies
- Allows sensing near GND
- Compatible with all forms of logic
- Power drain suitable for battery operation

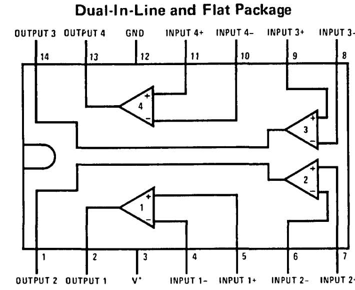
features

- Wide single supply
  Voltage range 2.0 V_{DC} to 36 V_{DC}
  or dual supplies ±1.0 V_{DC} to ±18 V_{DC}
- Very low supply current drain (0.8 mA)—independent of supply voltage (1.0 mW/comparator at +5.0 V_{DC})
- Low input biasing current 35 nA
- Low input offset current 3.0 nA
  and maximum offset voltage 2.0 mV
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Low output 1.0 mV at 5.0μA
  saturation voltage 70 mV at 1.0 mA
- Output voltage compatible with TTL, DTL, ECL, MOS and CMOS logic systems

schematic and connection diagrams



Dual-In-Line and Flat Package

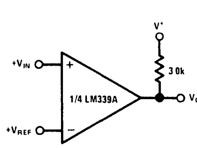


Order Number LM139AF
See Package 4

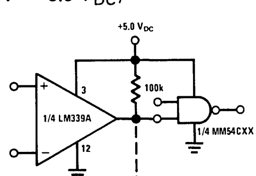
Order Number LM139AD, LM239AD or LM339AD
See Package 1

Order Number LM339AN
See Package 22

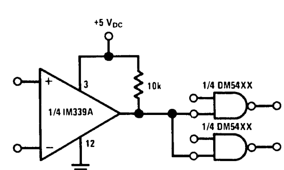
typical applications ($V^+ = 5.0\ V_{DC}$)



Basic Comparator



Driving CMOS



Driving TTL

absolute maximum ratings

Supply Voltage, V^+ — 36 V_{DC} or ±18 V_{DC}
Differential Input Voltage — 36 V_{DC}
Input Voltage — −0.3 V_{DC} to +36 V_{DC}
Power Dissipation (Note 1)
  Molded DIP (LM339AN) — 570 mW
  Cavity DIP (LM139AD, LM239AD, and LM339AD) — 900 mW
  Flat Pack (LM139AF) — 800 mW
Output Short-Circuit to GND (Note 2) — Continuous
Input Current (V_{IN} < −0.3 V_{DC}) (Note 3) — 50 mA
Operating Temperature Range
  LM339A — 0°C to +70°C
  LM239A — −25°C to +85°C
  LM139A — −55°C to +125°C
Storage Temperature Range — −65°C to +150°C
Lead Temperature (Soldering, 10 seconds) — 300°C

electrical characteristics (V^+ = +5.0 V_{DC}, see Note 4)

PARAMETER	CONDITIONS	LM139A MIN	LM139A TYP	LM139A MAX	LM239A, LM339A MIN	LM239A, LM339A TYP	LM239A, LM339A MAX	UNITS
Input Offset Voltage	T_A = +25°C (Note 9)		±1.0	±2.0		±1.0	±2.0	mV_{DC}
Input Bias Current (Note 5)	$I_{IN(+)}$ or $I_{IN(-)}$ with Output in Linear Range, T_A = +25°C		25	100		25	250	nA_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, T_A = +25°C		±3.0	±25		±5.0	±50	nA_{DC}
Input Common-Mode Voltage Range (Note 6)	T_A = +25°C	0		V^+−1.5	0		V^+−1.5	V_{DC}
Supply Current	R_L = ∞ on all Comparators T_A = +25°C		0.8	2.0		0.8	2.0	mA_{DC}
Voltage Gain	$R_L \geq$ 15 kΩ, T_A = +25°C, V^+ = 15 V_{DC} (To Support Large V_O Swing)	50	200		50	200		V/mV
Large Signal Response Time	V_{IN} = TTL Logic Swing, V_{REF} = +1.4 V_{DC}, V_{RL} = 5.0 V_{DC}, R_L = 5.1 kΩ and T_A = +25°C		300			300		ns
Response Time (Note 7)	V_{RL} = 5.0 V_{DC} and R_L = 5.1 kΩ, T_A = +25°C		1.3			1.3		μs
Output Sink Current	$V_{IN(-)} \geq$ +1.0 V_{DC}, $V_{IN(+)}$ = 0, and $V_O \leq$ +1.5 V_{DC}, T_A = +25°C	6.0	16		6.0	16		mA_{DC}
Saturation Voltage	$V_{IN(-)} \geq$ +1.0 V_{DC}, $V_{IN(+)}$ = 0, and $I_{SINK} \leq$ 4.0 mA, T_A = +25°C		250	500		250	500	mV_{DC}
Output Leakage Current	$V_{IN(+)} \geq$ +1.0 V_{DC}, $V_{IN(-)}$ = 0 and V_O = 5.0 V_{DC}, T_A = +25°C		0.1			0.1		nA_{DC}
Input Offset Voltage	(Note 9)			4.0			4.0	mV_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$			±100			±150	nA_{DC}
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$ with Output in Linear Range			300			400	nA_{DC}
Input Common-Mode Voltage Range		0		V^+−2.0	0		V^+−2.0	V_{DC}
Saturation Voltage	$V_{IN(-)} \geq$ +1.0 V_{DC}, $V_{IN(+)}$ = 0 and $I_{SINK} \leq$ 4.0 mA			700			700	mV_{DC}
Output Leakage Current	$V_{IN(+)} \geq$ +1.0 V_{DC}, $V_{IN(-)}$ = 0 and V_O = 30 V_{DC}			1.0			1.0	μA_{DC}
Differential Input Voltage (Note 8)	Keep all V_{IN}'s $\geq$ 0 V_{DC} (or V^-, if used)			V^+			V^+	V_{DC}

Note 1: For operating at high temperatures, the LM339A must be derated based on a +125°C maximum junction temperature and a thermal resistance of +175°C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM239A and LM139A must be derated based on a +150°C maximum junction temperature. The low bias dissipation and the ON-OFF characteristic of the outputs keeps the chip dissipation very small (Pd ≤ 100 mW), provided the output transistors are allowed to saturate.

Note 2: Short circuits from the output to V^+ can cause excessive heating and eventual destruction. The maximum output current is approximately 20 mA independent of the magnitude of V^+.

Note 3: This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the comparators to go to the V^+ voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than −0.3 V_{DC}.

Note 4: These specifications apply for V^+ = +5.0 V_{DC} and −55°C ≤ T_A ≤ +125°C, unless otherwise stated. With the LM239A all temperature specifications are limited to −25°C ≤ T_A ≤ +85°C and the LM339A temperature specifications are limited to 0°C ≤ T_A ≤ +70°C.

Note 5: The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the reference or input lines.

Note 6: The input common-mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3V. The upper end of the common-mode voltage range is V^+ −1.5V, but either or both inputs can go to +30 V_{DC} without damage.

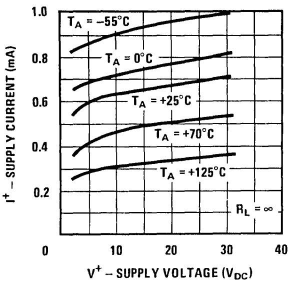
Note 7: The response time specified is for a 100 mV input step with 5.0 mV overdrive. For larger overdrive signals 300 ns can be obtained, see typical performance characteristics section.

Note 8: If the voltage applied to any input exceeds V^+, all four comparator outputs will go to the high voltage level. The low input voltage state must not be less than −0.3 V_{DC} (or 0.3 V_{DC} below the magnitude of the negative power supply, if used).

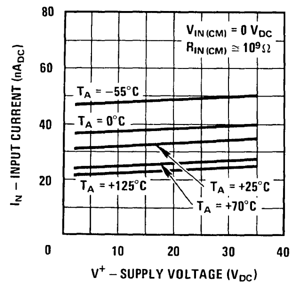
Note 9: At output switch point, $V_O \cong$ 1.4 V_{DC}, R_S = 0Ω with V^+ from 5.0 V_{DC} to 30 V_{DC}; and over the full input common mode range (0 V_{DC} to V^+ −1.5 V_{DC}).

typical performance characteristics

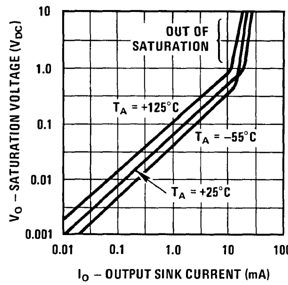
Supply Current



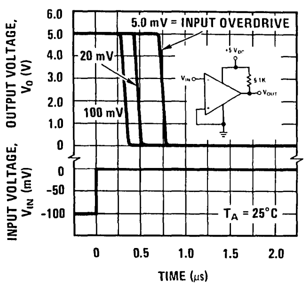
Input Current



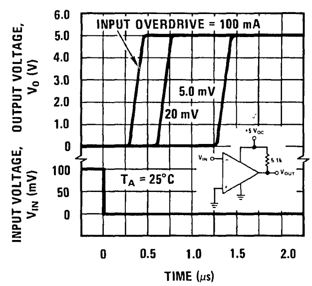
Output Saturation Voltage



Response Time for Various Input Overdrives – Negative Transition



Response Time for Various Input Overdrives – Positive Transition



application hints

The LM139A is a high gain, wide bandwidth device; which, like most comparators, can easily oscillate if the output lead is inadvertently allowed to capacitively couple to the inputs via stray capacitance. This shows up only during the output voltage transition intervals as the comparator changes states. Power supply bypassing is not required to solve this problem. Standard PC board layout is helpful as it reduces stray input-output coupling. Reducing the input resistors to < 10 kΩ reduces the feedback signal levels and finally, adding even a small amount (1.0 to 10 mV) of positive feedback (hysteresis) causes such a rapid transition that oscillations due to stray feedback are not possible. Simply socketing the IC and attaching resistors to the pins will cause input-output oscillations during the small transition intervals unless hysteresis is used. If the input signal is a pulse waveform, with relatively fast rise and fall times, hysteresis is not required.

All pins of any unused comparators should be grounded.

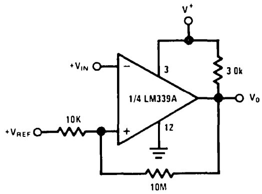
The bias network of the LM139A establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from 2.0 V_{DC} to 30 V_{DC}.

It is usually unnecessary to use a bypass capacitor across the power supply line.

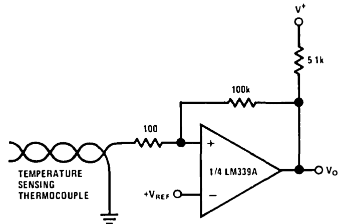
The differential input voltage may be larger than V^+ without damaging the device (see Note 8). Protection should be provided to prevent the input voltages from going negative more than −0.3 V_{DC} (at 25°C). An input clamp diode can be used as shown in the applications section.

The output of the LM139A is the uncommitted collector of a grounded-emitter NPN output transistor. Many collectors can be tied together to provide an output OR'ing function. An output pull-up resistor can be connected to any available power supply voltage within the permitted supply voltage range and there is no restriction on this voltage due to the magnitude of the voltage which is applied to the V^+ terminal of the LM139A package. The output can also be used as a simple SPST switch to ground (when a pull-up resistor is not used). The amount of current which the output device can sink is limited by the drive available (which is independent of V^+) and the β of this device. When the maximum current limit is reached (approximately 16 mA), the output transistor will come out of saturation and the output voltage will rise very rapidly. The output saturation voltage is limited by the approximately 60Ω r_{sat} of the output transistor. The low offset voltage of the output transistor (1.0 mV) allows the output to clamp essentially to ground level for small load currents.

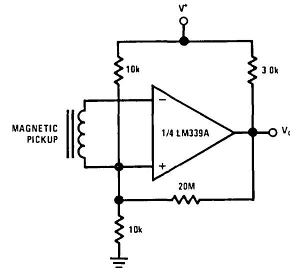
typical applications (con't) ($V^+ = 5.0\ V_{DC}$)



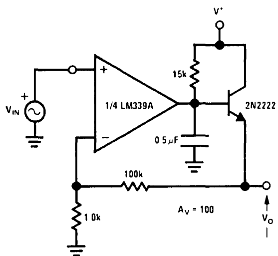
Comparator with Hysteresis



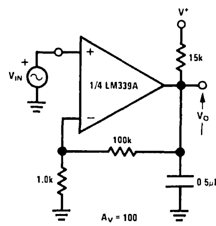
Ground Referenced Thermocouple in Single Supply System



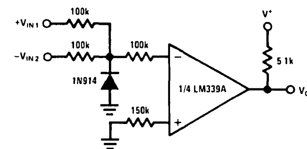
Transducer Amplifier



Low Frequency Op Amp (V_O = 0V for V_{IN} = 0V)



Low Frequency Op Amp



Comparing Input Voltages of Opposite Polarity

3

Voltage Comparators/Buffers

LM160/LM260/LM360 high speed differential comparator

general description

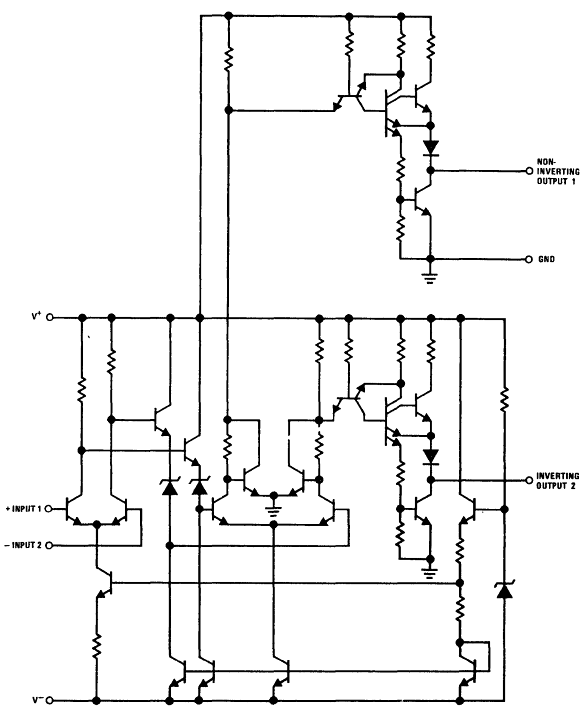
The LM160/LM260/LM360 is a very high speed differential input, complementary TTL output voltage comparator with improved characteristics over the μA760/μA760C, for which it is a pin-for-pin replacement. The device has been optimized for greater speed, input impedance and fan-out, and lower input offset voltage. Typically delay varies only 3 ns for overdrive variations of 5 mV to 500 mV.

Complementary outputs having minimum skew are provided. Applications involve high speed analog to digital convertors and zero-crossing detectors in disc file systems.

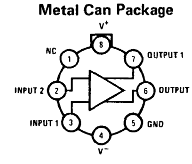
features

- Guaranteed high speed 20 ns max
- Tight delay matching on both outputs
- Complementary TTL outputs
- High input impedance
- Low speed variation with overdrive variation
- Fan-out of 4
- Low input offset voltage
- Series 74 TTL compatible

schematic and connection diagrams

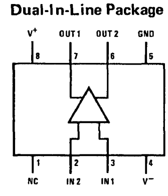


Metal Can Package



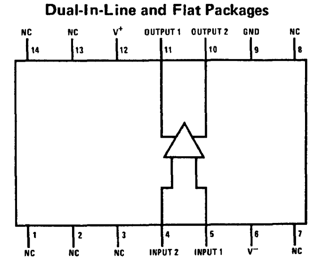
Order Number LM160H, LM260H or LM360H
See Package 11

Dual-In-Line Package



Order Number LM360N-8
See Package 20

Dual-In-Line and Flat Packages



Order Number LM160D, LM260D or LM360D
See Package 1

Order Number LM360N-14
See Package 22

Order Number LM160F
See Package 4

absolute maximum ratings

Positive Supply Voltage	+8V	Operating Temperature Range	
Negative Supply Voltage	−8V	LM160	−55°C to +125°C
Peak Output Current	20 mA	LM260	−25°C to +85°C
Differential Input Voltage	±5V	LM360	0°C to +70°C
Input Voltage	$V^+ \geq V_{IN} \geq V^-$	Storage Temperature Range	−65°C to +150°C
		Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics ($T_{MIN} \leq T_A \leq T_{MAX}$)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Conditions					
Supply Voltage V_{CC}^+		4.5	5	6.5	V
Supply Voltage V_{CC}^-		−4.5	−5	−6.5	V
Input Offset Voltage	$R_S \leq 200\Omega$		2	5	mV
Input Offset Current			.5	3	μA
Input Bias Current			5	20	μA
Output Resistance (Either Output)	$V_{OUT} = V_{OH}$		100		Ω
Response Time	T_A = 25°C, V_S = ±5V (Note 1)		13	25	ns
	T_A = 25°C, V_S = ±5V (Note 2)		12	20	ns
	T_A = 25°C, V_S = ±5V (Note 3)		14		ns
Response Time Difference Between Outputs					
(t_{pd} of $+V_{IN1}$) − (t_{pd} of $-V_{IN2}$)	T_A = 25°C, (Note 1)		2		ns
(t_{pd} of $+V_{IN2}$) − (t_{pd} of $-V_{IN1}$)	T_A = 25°C, (Note 1)		2		ns
(t_{pd} of $+V_{IN1}$) − (t_{pd} of $+V_{IN2}$)	T_A = 25°C, (Note 1)		2		ns
(t_{pd} of $-V_{IN1}$) − (t_{pd} of $-V_{IN2}$)	T_A = 25°C, (Note 1)		2		ns
Input Resistance	f = 1 MHz		17		kΩ
Input Capacitance	f = 1 MHz		3		pF
Average Temperature Coefficient of Input Offset Voltage	$R_S = 50\Omega$		8		μV/°C
Average Temperature Coefficient of Input Offset Current			7		nA/°C
Common Mode Input Voltage Range	V_S = ±6.5V	±4	±4.5		V
Differential Input Voltage Range		±5			V
Output High Voltage (Either Output)	I_{OUT} = −320μA, V_S = ±4.5V	2.4	3		V
Output Low Voltage (Either Output)	I_{SINK} = 6.4 mA		.25	.4	V
Positive Supply Current	V_S = ±6.5V		18	32	mA
Negative Supply Current	V_S = ±6.5V		−9	−16	mA

Note 1: Response time measured from the 50% point of a 30 mVp-p 10 MHz sinusoidal input to the 50% point of the output.
Note 2: Response time measured from the 50% point of a 2 Vp-p 10 MHz sinusoidal input to the 50% point of the output.
Note 3: Response time measured from the start of a 100 mV input step with 5 mV overdrive to the time when the output crosses the logic threshold.

Voltage Comparators/Buffers

LM161/LM261/LM361 high speed differential comparators

general description

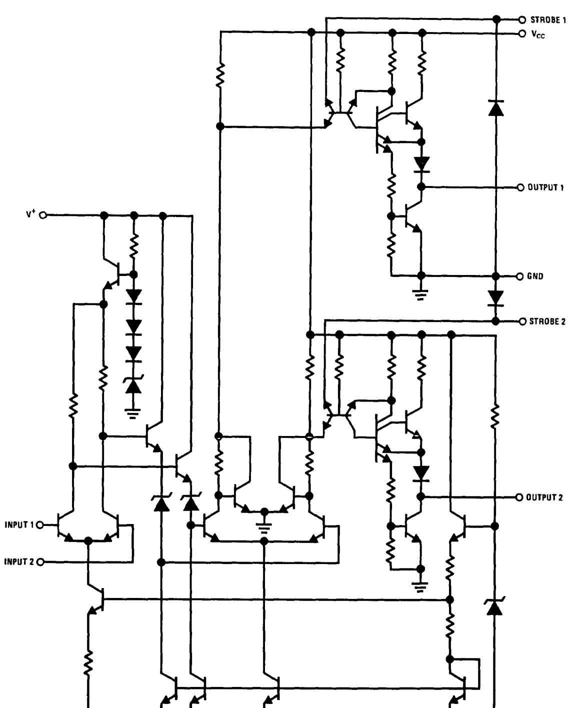
The LM161/LM261/LM361 is a very high speed differential input, complementary TTL output voltage comparator with improved characteristics over the SE529/NE529 for which it is a pin-for-pin replacement. The device has been optimized for greater speed performance and lower input offset voltage. Typically delay varies only 3 ns for over-drive variations of 5 mV to 500 mV. It may be operated from op amp supplies (±15V).

Complementary outputs having minimum skew are provided. Applications involve high speed analog to digital convertors and zero-crossing detectors in disc file systems.

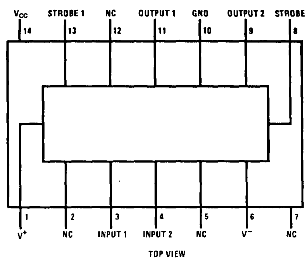
features

- Independent strobes
- Guaranteed high speed 20 ns max
- Tight delay matching on both outputs
- Complementary TTL outputs
- Operates from op amp supplies ±15V
- Low speed variation with overdrive variation
- Low input offset voltage
- Versatile supply voltage range

schematic and connection diagrams

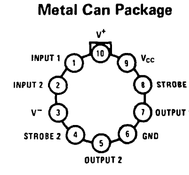


Dual-In-Line and Flat Package



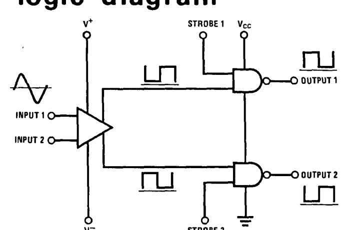
Order Number LM361N
See Package 22
Order Number LM161D, LM261D
or LM361D
See Package 1
Order Number LM161F
See Package 4

Metal Can Package



Order Number LM161H, LM261H
or LM361H
See Package 12

logic diagram



absolute maximum ratings

Positive Supply Voltage, V^+	+16V
Negative Supply Voltage, V^-	−16V
Gate Supply Voltage, V_{CC}	+7V
Output Voltage	+7V
Differential Input Voltage	±5V
Input Common Mode Voltage	±6V
Power Dissipation	600 mW
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	
LM161	−55°C to +125°C
LM261	−25°C to +85°C
LM361	0°C to +70°C
Lead Temperature (Soldering, 10 sec)	300°C

operating conditions

	MIN	TYP	MAX
Supply Voltage V^+			
LM161/LM261	5V		15V
LM361	5V		15V
Supply Voltage V^-			
LM161/LM261	−6V		−15V
LM361	−6V		−15V
Supply Voltage V_{CC}			
LM161/LM261	4.5V	5V	5.5V
LM361	4.75V	5V	5.25V

electrical characteristics ($V^+ = +10V$, $V_{CC} = +5V$, $V^- = -10V$, $T_{MIN} \le T_A \le T_{MAX}$, unless noted)

PARAMETER	CONDITIONS	LIMITS LM161/LM261 MIN	LM161/LM261 TYP	LM161/LM261 MAX	LM361 MIN	LM361 TYP	LM361 MAX	UNITS
Input Offset Voltage			1	3		1	5	mV
Input Bias Current	$T_A = 25°C$		5			10		μA
				20			30	μA
Input Offset Current	$T_A = 25°C$		2			2		μA
				3			5	μA
Voltage Gain	$T_A = 25°C$		3			3		V/mV
Input Resistance	$T_A = 25°C$, f = 1 kHz		20			20		kΩ
Logical "1" Output Voltage	$V_{CC} = 4.75V$, $I_{SOURCE} = -.5$ mA	2 4	3.3		2.4	3.3		V
Logical "0" Output Voltage	$V_{CC} = 4.75V$, $I_{SINK} = 6.4$ mA			.4			.4	V
Strobe Input "1" Current	$V_{CC} = 5.25V$, $V_{STROBE} = 2.4V$			200			200	μA
Strobe Input "0" Current	$V_{CC} = 5.25V$, $V_{STROBE} = .4V$			−1.6			−1.6	mA
Strobe Input "0" Voltage	$V_{CC} = 4.75V$			.8			.8	V
Strobe Input "1" Voltage	$V_{CC} = 4.75V$	2			2			V
Output Short Circuit Current	$V_{CC} = 5.25V$, $V_{OUT} = 0V$	−18		−55	−18		−55	mA
Supply Current I^+	$V^+ = 10V$, $V^- = -10V$, $V_{CC} = 5.25V$, $-55°C \le T_A \le 125°C$			4.5				mA
Supply Current I^+	$V^+ = 10V$, $V^- = -10V$, $V_{CC} = 5.25V$, $0°C \le T_A \le 70°C$						5	mA
Supply Current I^-	$V^+ = 10V$, $V^- = -10V$, $V_{CC} = 5.25V$, $-55°C \le T_A \le 125°C$			10				mA
Supply Current I^-	$V^+ = 10V$, $V^- = -10V$, $V_{CC} = 5.25V$, $0°C \le T_A \le 70°C$						10	mA
Supply Current I_{CC}	$V^+ = 10V$, $V^- = -10V$, $V_{CC} = 5.25V$, $-55°C \le T_A \le 125°C$			18				mA
Supply Current I_{CC}	$V^+ = 10V$, $V^- = -10V$, $V_{CC} = 5.25V$, $0°C \le T_A \le 70°C$						20	mA
TRANSIENT RESPONSE	$V_{IN} = 50$ mV Overdrive							
Propagation Delay Time ($t_{pd(0)}$)	$T_A = 25°C$		14	20		14	20	ns
Propagation Delay Time ($t_{pd(1)}$)	$T_A = 25°C$		14	20		14	20	ns
Delay Between Output A and B	$T_A = 25°C$		2	5		2	5	ns
Strobe Delay Time ($t_{pd(0)}$)	$T_A = 25°C$		8			8		ns
Strobe Delay Time ($t_{pd(1)}$)	$T_A = 25°C$		8			8		ns

Voltage Comparators/Buffers

LM710 voltage comparator

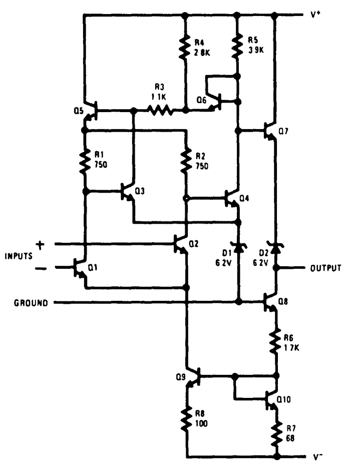
general description

The LM710 is a high-speed voltage comparator intended for use as an accurate, low-level digital level sensor or as a replacement for operational amplifiers in comparator applications where speed is of prime importance. The circuit has a differential input and a single-ended output, with saturated output levels compatible with practically all types of integrated logic.

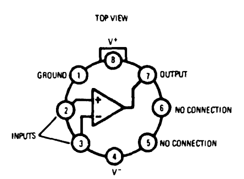
The device is built on a single silicon chip which insures low offset and thermal drift. The use of a minimum number of stages along with minority-carrier lifetime control (gold doping) makes the circuit much faster than operational amplifiers in saturating comparator applications. In fact, the low stray and wiring capacitances that can be realized with monolithic construction make the device difficult to duplicate with discrete components operating at equivalent power levels.

The LM710 is useful as a pulse height discriminator, a voltage comparator in high-speed A/D converters or a go, no-go detector in automatic test equipment. It also has applications in digital systems as an adjustable-threshold line receiver or an interface between logic types. In addition, the low cost of the unit suggests it for applications replacing relatively simple discrete component circuitry.

schematic* and connection diagrams



Metal Can

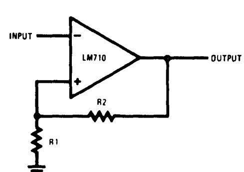


Note: Pin 4 connected to case.

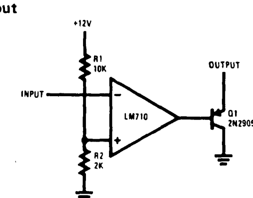
Order Number LM710H
See Package 11

typical applications*

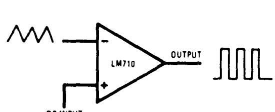
Schmidt Trigger



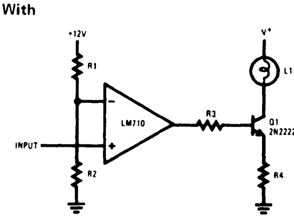
Line Receiver With Increased Output Sink Current



Pulse Width Modulator



Level Detector With Lamp Driver



*Pin connections shown are for metal can.

absolute maximum ratings

Positive Supply Voltage	14.0V
Negative Supply Voltage	-7.0V
Peak Output Current	10 mA
Differential Input Voltage	±5.0V
Input Voltage	±7.0V
Power Dissipation	
TO-99 (Note 1)	300 mW
Flat Package (Note 2)	200 mW
Operating Temperature Range	-55°C to +125°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 60 sec)	300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	T_A = 25°C, $R_S \le 200\Omega$ V_{CM} = 0V		0.6	2.0	mV
Input Offset Current	T_A = 25°C, V_{OUT} = 1.4V		0.75	3.0	μA
Input Bias Current	T_A = 25°C		13	20	μA
Voltage Gain	T_A = 25°C	1250	1700		
Output Resistance	T_A = 25°C		200		Ω
Output Sink Current	T_A = 25°C, $V_{IN} \le -5$ mV V_{OUT} = 0	2.0	2.5		mA
Response Time (Note 4)	T_A = 25°C		40		ns
Input Offset Voltage	$R_S \le 200\Omega$, V_{CM} = 0V			3.0	mV
Average Temperature Coefficient of Input Offset Voltage	$-55°C \le T_A \le 125°C$ $R_S \le 50\Omega$		3.0	10	μV/°C
Input Offset Current	T_A = 125°C T_A = -55°C		0.25 1.8	3.0 7.0	μA μA
Average Temperature Coefficient of Input Offset Current	$25°C \le T_A \le 125°C$ $-55°C \le T_A \le 25°C$		5.0 15	25 75	nA/°C nA/°C
Input Bias Current	T_A = -55°C		27	45	μA
Input Voltage Range	V^- = -7.0V	±5.0			V
Common Mode Rejection Ratio	$R_S \le 200\Omega$	80	100		dB
Differential Input Voltage Range		±5.0V			V
Voltage Gain		1000			
Positive Output Level	$V_{IN} \ge 5$ mV, $0 \le I_{OUT} \le -5$ mA	2.5	3.2	4.0	V
Negative Output Level	$V_{IN} \le -5$ mV	-1.0	-0.5	0	V
Output Sink Current	T_A = 125°C, $V_{IN} \le -5$ mV V_{OUT} = 0V	0.5	1.7		mA
	T_A = -55°C, $V_{IN} \le -5$ mV V_{OUT} = 0	1.0	2.3		mA
Positive Supply Current	$V_{IN} \le -5$ mV		5.2	9.0	mA
Negative Supply Current			4.6	7.0	mA
Power Consumption	$V_{IN} \le -5$ mV I_{OUT} = 0 mA		90	150	mW

Note 1: Rating applies for case temperatures to +125°C; derate linearly at 5.6 mW/°C for ambient temperatures above +105°C.

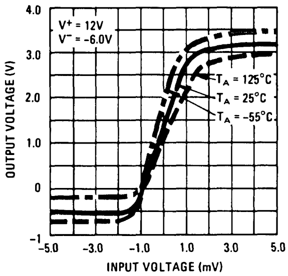
Note 2: Derate linearly at 4.4 mW/°C for ambient temperatures above +100°C.

Note 3: These specifications apply for V^+ = 12.0V, V^- = -6.0V, $-55°C \le T_A \le +125°C$ unless otherwise specified. The input offset voltage and input offset current (see definitions) are specified for a logic threshold voltage of 1.8V at -55°C, 1.4V at +25°C, and 1.0V at +125°C.

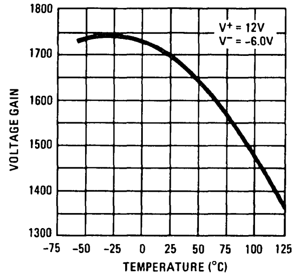
Note 4: The response time specified (see definitions) is for a 100 mV input step with 5 mV overdrive.

typical performance characteristics

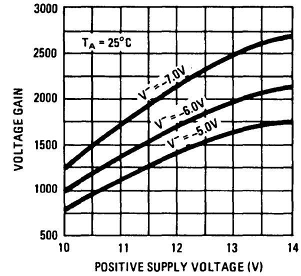
Transfer Function



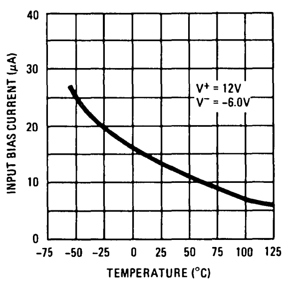
Voltage Gain



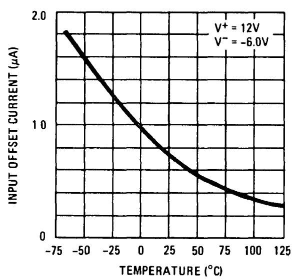
Voltage Gain



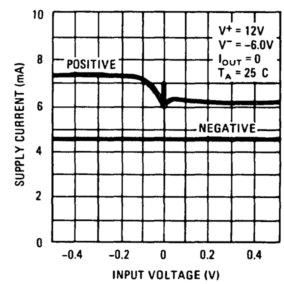
Input Bias Current



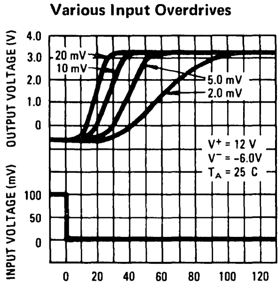
Input Offset Current



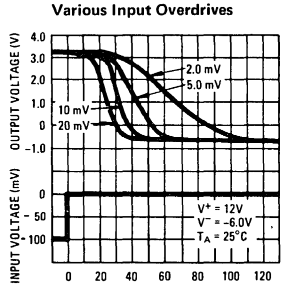
Supply Current



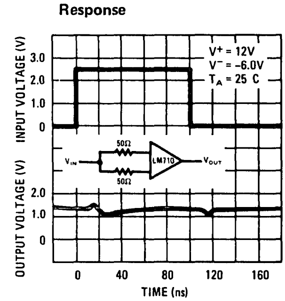
Response Time For Various Input Overdrives



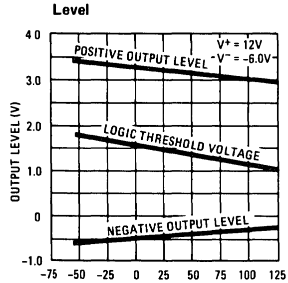
Response Time For Various Input Overdrives



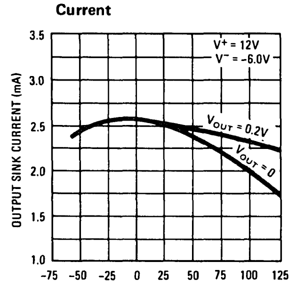
Common Mode Pulse Response



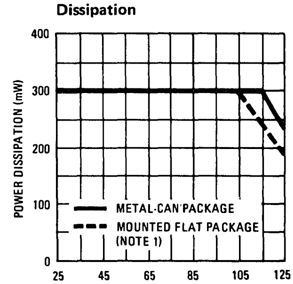
Output Voltage Level



Output Sink Current



Maximum Power Dissipation



Voltage Comparators/Buffers

LM710C voltage comparator

general description

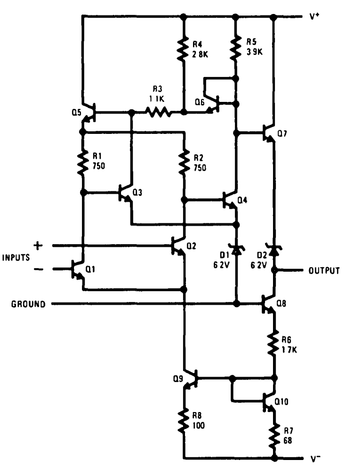
The LM710C is a high-speed voltage comparator intended for use as an accurate, low-level digital level sensor or as a replacement for operational amplifiers in comparator applications where speed is of prime importance. The circuit has a differential input and a single-ended output, with saturated output levels compatible with practically all types of integrated logic.

The device is built on a single silicon chip which insures low offset and thermal drift. The use of a minimum number of stages along with minority-carrier lifetime control (gold doping) makes the circuit much faster than operational amplifiers in saturating comparator applications. In fact, the low stray and wiring capacitances that can be realized with monolithic construction make the device difficult to duplicate with discrete components operating at equivalent power levels.

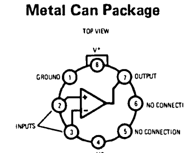
The LM710C is useful as a pulse height discriminator, a voltage comparator in high-speed A/D converters or a go, no-go detector in automatic test equipment. It also has applications in digital systems as an adjustable-threshold line receiver or an interface between logic types. In addition, the low cost of the unit suggests it for applications replacing relatively simple discrete component circuitry.

The LM710C is the commercial/industrial version of the LM710A. It is identical to the LM710A except that operation is specified over a 0°C to 70°C temperature range.

schematic* and connection diagrams



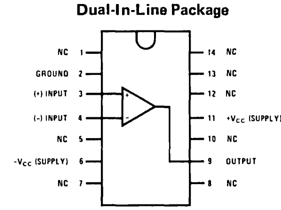
Metal Can Package



Note: Pin 4 connected to case.

Order Number LM710CH
See Package 11

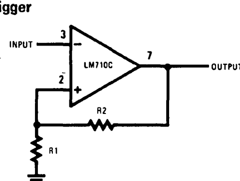
Dual-In-Line Package



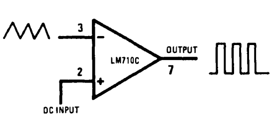
Order Number LM710CN
See Package 22

typical applications*

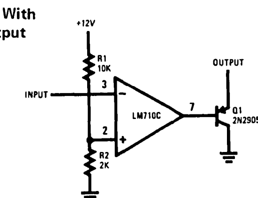
Schmidt Trigger



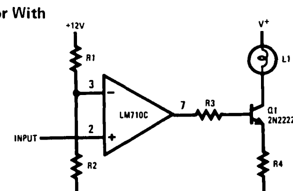
Pulse Width Modulator



Line Receiver With Increased Output Sink Current



Level Detector With Lamp Driver



*Pin connections shown are for metal can.

3

absolute maximum ratings

Positive Supply Voltage	14.0V
Negative Supply Voltage	−7.0V
Peak Output Current	10 mA
Differential Input Voltage	±5.0V
Input Voltage	±7.0V
Power Dissipation (Note 1)	
TO-99	300 mW
Flat Package	200 mW
Output Short Circuit Duration	10 sec
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNITS
Input Offset Voltage	T_A = 25°C, R_S<200Ω V_{CM} = 0V		1.6	5.0	mV
Input Offset Current	T_A = 25°C, V_{OUT} = 1.4V		1.8	5.0	μA
Input Bias Current	T_A = 25°C		16	25	μA
Voltage Gain	T_A = 25°C	1000	1500		
Output Resistance	T_A = 25°C		200		Ω
Output Sink Current	T_A = 25°C, $\Delta V_{IN} \geq$ 10 mV V_{OUT} = 0	1.6	2.5		mA
Response Time (Note 3)	T_A = 25°C		40		ns
Input Offset Voltage	$R_S \leq$200Ω, V_{CM} = 0V			6.5	mV
Average Temperature Coefficient of Input Offset Voltage	0°C≤T_A≤70°C $R_S \leq$50Ω		5.0	20	μV/°C
Input Offset Current				7.5	μA
Average Temperature Coefficient of Input Offset Current	25°C≤T_A≤70°C 0°C≤T_A≤25°C		15 24	50 100	nA/°C nA/°C
Input Bias Current	T_A = 0°C		25	40	μA
Input Voltage Range	V^- = −7.0V	±5.0			V
Common Mode Rejection Ratio	$R_S \leq$ 200Ω	70	98		dB
Differential Input Voltage Range		±5.0			V
Voltage Gain		800			
Positive Output Level	$V_{IN} \geq$10 mV 0 ≤ I_{OUT} ≤ −5 mA	2.5	3.2	4.0	V
Negative Output Level	$V_{IN} \leq$ −10 mV	-1.0	-0.5	0	V
Output Sink Current	$V_{IN} \leq$ −10 mV, V_{OUT} = 0V	0.5			mA
Positive Supply Current	$V_{IN} \leq$ −10 mV		5.2	9.0	mA
Negative Supply Current			4.6	7.0	mA
Power Consumption				150	mW

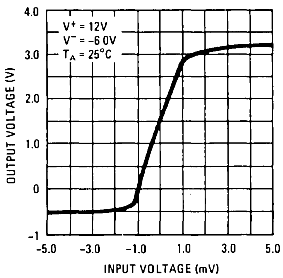
Note 1: Ratings apply for ambient temperatures to 70°C.

Note 2: These specifications apply for V^+ = 12.0V, V^- = 6.0V, 0°C ≤ T_A ≤ 70°C unless otherwise specified. The input offset voltage and input offset current (see definitions) are specified for a logic threshold voltage of 1.5V at 0°C, 1.4V at 25°C and 1.2V at 70°C.

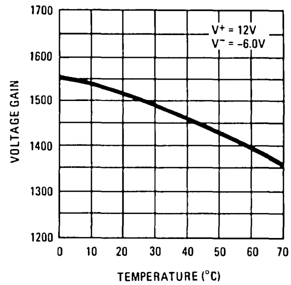
Note 3: The response time specified (see definitions) is for a 100 mV input step with 5 mV overdrive.

typical performance characteristics

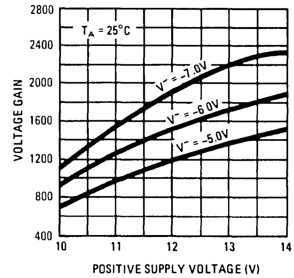
Transfer Function



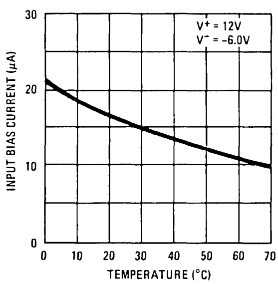
Voltage Gain



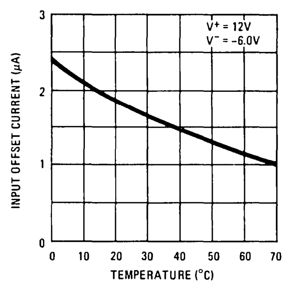
Voltage Gain



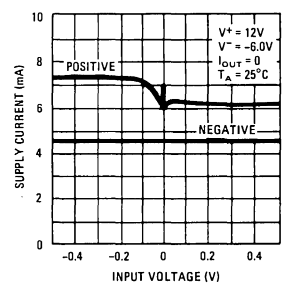
Input Bias Current



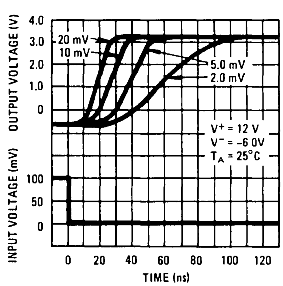
Input Offset Current



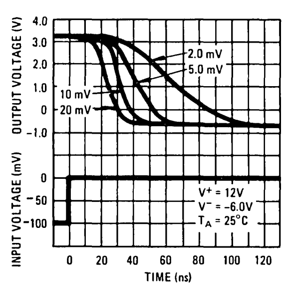
Supply Current



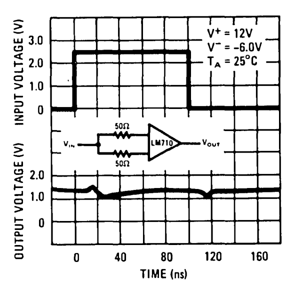
Response Time For Various Input Overdrives



Response Time For Various Input Overdrives



Common Mode Pulse Response



3

Voltage Comparators/Buffers

LM711 dual comparator

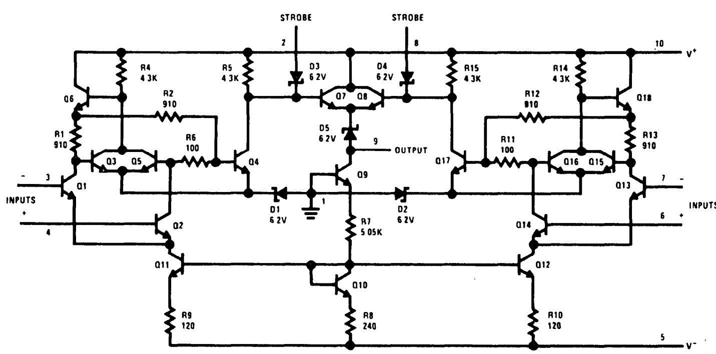
general description

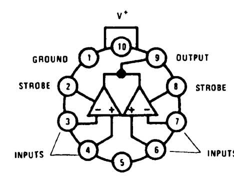
The LM711 contains two voltage comparators with separate differential inputs, a common output and provision for strobing each side independently. Similar to the LM710, the device features low offset and thermal drift, a large input voltage range, low power consumption, fast recovery from large overloads and compatibility with most integrated logic circuits.

With the addition of an external resistor network, the LM711 can be used as a sense amplifier for core memories. The input thresholding, combined with the high gain of the comparator, eliminates many of the inaccuracies encountered with conventional sense amplifier designs. Further, it has the speed and accuracy needed for reliably detecting the outputs of cores as small as 20 mils.

The LM711 is also useful in other applications where a dual comparator with OR'ed outputs is required, such as a double-ended limit detector. By using common circuitry for both halves, the device can provide high speed with lower power dissipation than two single comparators. The LM711 is available in either an 10-lead low profile TO-5 header or a 1/4" by 1/4" metal flat package.

schematic** and connection diagrams



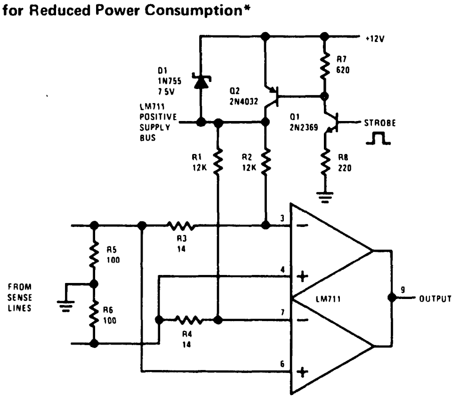


Note: Pin 5 connected to case.

Order Number LM711H
See Package 14

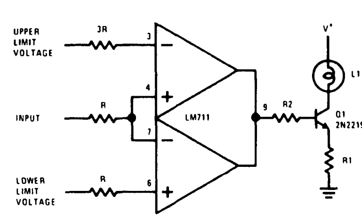
typical applications**

Sense Amplifier With Supply Strobing for Reduced Power Consumption*



*Standby dissipation is about 40 mW.

Double-Ended Limit Detector With Lamp Driver



**Pin connections shown are for metal can.

absolute maximum ratings

Positive Supply Voltage	+14.0V
Negative Supply Voltage	−7.0V
Peak Output Current	25 mA
Differential Input Voltage	±5.0V
Input Voltage	±7.0V
Strobe Voltage	0 to +6.0V
Internal Power Dissipation (Note 1)	300 mW
Operating Temperature Range	-55°C to 125°C
Storage Temperature Range	-65°C to 150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (These specifications apply for $T_A = 25°C$, $V^+ = 12V$, $V^- = -6V$)

PARAMETER	CONDITIONS (Note 2)	MIN.	TYP.	MAX.	UNIT
Input Offset Voltage	$R_S \leq 200\Omega$, $V_{CM} = 0$		1.0	3.5	mV
	$R_S \leq 200\Omega$, $-5V \leq V_{CM} \leq +5V$		1.0	5.0	mV
Input Offset Current			0.5	10.0	μA
Input Bias Current			25	75	μA
Voltage Gain		750	1500		
Response Time (Note 3)			40		ns
Strobe Release Time			12		ns
Input Voltage Range	$V^- = -7.0V$	±5.0			V
Differential Input Voltage Range		±5.0			V
Output Resistance			200		Ω
Positive Output Level	$V_{IN} \geq 10$ mV		4.5	5.0	V
Loaded Positive Output Level	$V_{IN} \geq 10$ mV, $I_{OUT} = -5$ mA	2.5	3.5		V
Negative Output Level	$V_{IN} \leq -10$ mV	−1.0		0	V
Strobed Output Level	$V_{STROBE} \leq 0.3V$	−1.0		0	V
Output Sink Current	$V_{IN} \leq -10$ mV, $V_{OUT} \geq 0$	0.5	0.8		mA
Strobe Current	$V_{STROBE} = 100$ mV		1.2	2.5	mA
Positive Supply Current	$V_{IN} \leq -10$ mV		8.6		mA
Negative Supply Current			3.9		mA
Power Consumption			130	200	mW
The following specifications apply for $-55°C \leq T_A \leq 125°C$:					
Input Offset Voltage	$R_S \leq 200\Omega$, $V_{CM} = 0$			4.5	mV
	$R_S \leq 200\Omega$			6.0	mV
Input Offset Current				20	μA
Input Bias Current				150	μA
Average Temperature Coefficient of Input Offset Voltage			5.0		μV/°C
Voltage Gain		500			

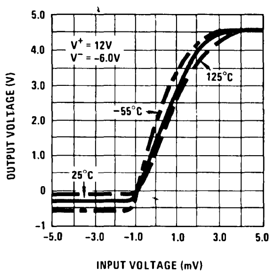
Note 1: Rating applies for case temperatures to +125°C; derate linearly at 5.6 mW/°C for ambient temperatures above 105°C.

Note 2: The input offset voltage and input offset current (see definitions) are specified for a logic threshold voltage of 1.8V at −55°C, 1.4V at +25°C, and 1.0V at +125°C.

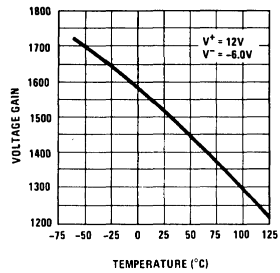
Note 3: The response time specified is for a 100 mV input step with 5 mV overdrive (see definitions).

typical performance characteristics

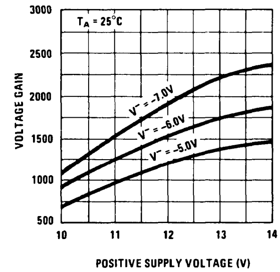
Transfer Function



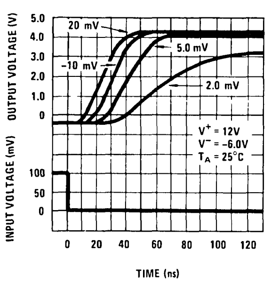
Voltage Gain



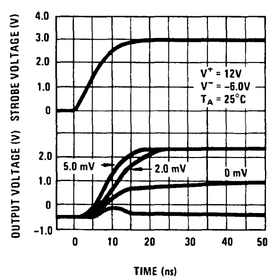
Voltage Gain



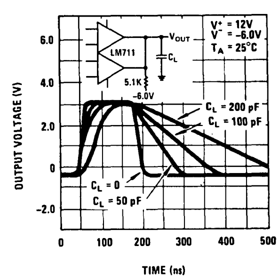
Response Time for Various Input Overdrives



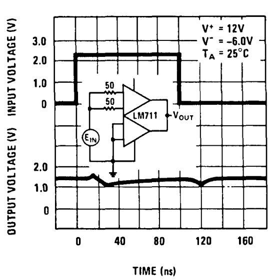
Strobe Release Time for Various Input Overdrives



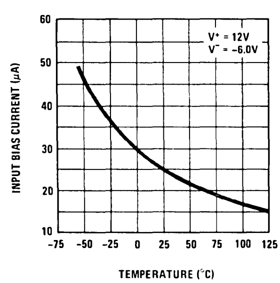
Output Pulse Stretching With Capacitive Loading



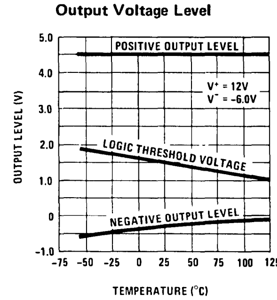
Common Mode Pulse Response



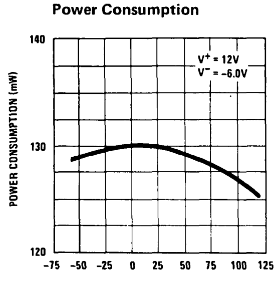
Input Bias Current



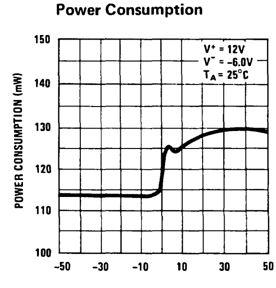
Output Voltage Level



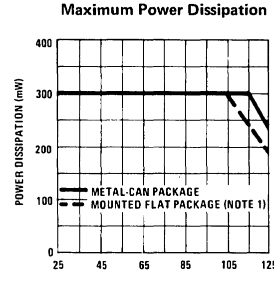
Power Consumption



Power Consumption



Maximum Power Dissipation



Voltage Comparators/Buffers

LM711C dual comparator

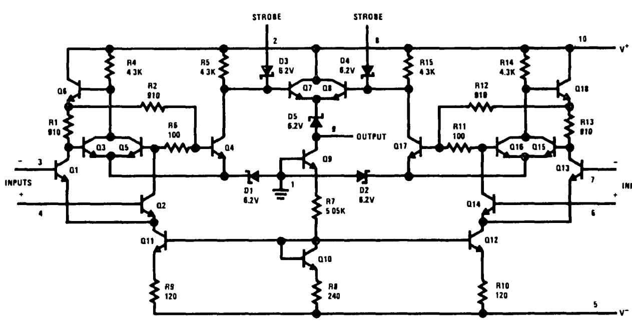
general description

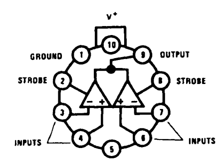
The LM711C contains two voltage comparators with separate differential inputs, a common output and provision for strobing each side independently. Similar to the LM710C, the device features low offset and thermal drift, a large input voltage range, low power consumption, fast recovery from large overloads and compatibility with most integrated logic circuits.

With the addition of an external resistor network, the LM711C can be used as a sense amplifier for core memories. The input thresholding, combined with the high gain of the comparator, eliminates many of the inaccuracies encountered with conventional sense amplifier designs. Further, it has the speed and accuracy needed for reliably detecting the outputs of cores as small as 20 mils.

The LM711C is also useful in other applications where a dual comparator with OR'ed outputs is required, such as a double-ended limit detector. By using common circuitry for both halves, the device can provide high speed with lower power dissipation than two single comparators. The LM711C is the commercial/industrial version of the LM711. It is identical to the LM711, except that operation is specified over a 0°C to 70°C temperature range.

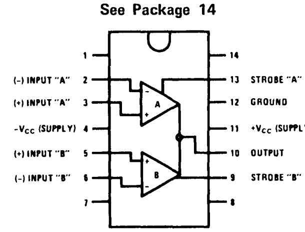
schematic** and connection diagrams





Note: Pin 5 connected to case.

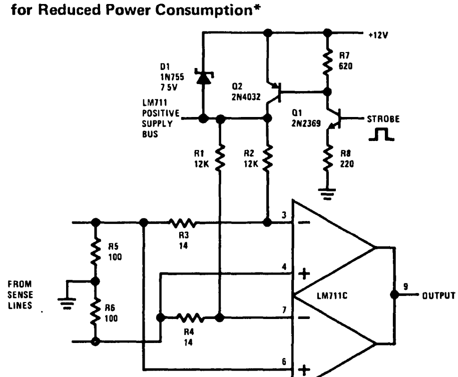
Order Number LM711CH
See Package 14



Order Number LM711CN
See Package 22

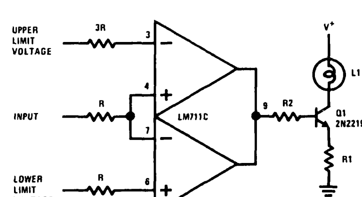
typical applications**

Sense Amplifier With Supply Strobing for Reduced Power Consumption*



*Standby dissipation is about 40 mW.

Double-Ended Limit Detector With Lamp Driver



**Pin connections shown are for metal can.

3

absolute maximum ratings

Positive Supply Voltage	+14.0V
Negative Supply Voltage	-7.0V
Peak Output Current	25 mA
Differential Input Voltage	±5.0V
Input Voltage	±7.0V
Strobe Voltage	0 to +6.0V
Internal Power Dissipation (Note 1)	300 mW
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	-65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics

(The following specfications apply for $T_A = 25°C$, $V^+ = 12.0V$, $V^- = -6.0V$ unless otherwise specified)

PARAMETER	CONDITIONS (Note 2)	MIN.	TYP.	MAX.	UNIT
Input Offset Voltage	$R_S \leq 200\Omega$, $V_{CM} = 0$		1.0	5.0	mV
	$R_S \leq 200\Omega$, $-5V \leq V_{CM} \leq +5V$		1.0	7.5	mV
Input Offset Current			0.5	15	μA
Input Bias Current			25	100	μA
Voltage Gain		700	1500		
Response Time (Note 3)			40		ns
Strobe Release Time			12		ns
Input Voltage Range	$V^- = -7.0V$	±5.0			V
Differential Input Voltage Range		±5.0			V
Output Resistance			200		Ω
Positive Output Level	$V_{IN} \geq 10$ mV		4.5	5.0	V
Loaded Positive Output Level	$V_{IN} \geq 10$ mV, $I_{OUT} = -5$ mA	2.5	3.5		V
Negative Output Level	$V_{IN} \leq -10$ mV	-1.0	-0.5	0	V
Strobed Output Level	$V_{STROBE} \leq 0.3V$	-1.0		0	V
Output Sink Current	$V_{IN} \leq -10$ mV, $V_{OUT} \geq 0$	0.5	0.8		mA
Strobe Current	$V_{STROBE} = 100$ mV		1.2	2.5	mA
Positive Supply Current	$V_{IN} \leq -10$ mV		8.6		mA
Negative Supply Current			3.9		mA
Power Consumption			130	230	mW
The following specifications apply for $0°C \leq T_A \leq +70°C$:					
Input Offset Voltage	$R_S \leq 200\Omega$, $V_{CM} = 0$			6.0	mV
	$R_S \leq 200\Omega$, $-5V \leq V_{CM} \leq +5V$			10	mV
Input Offset Current				25	μA
Input Bias Current				150	μA
Average Temperature Coefficient of Input Offset Voltage			5.0		μV/°C
Voltage Gain		500			

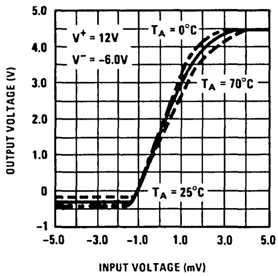
Note 1: Ratings apply for ambient temperatures to 70°C.

Note 2: The input offset voltage and input offset current (see definitions) are specified for a logic threshold voltage of 1.5V at 0°C, 1.4V at 25°C, and 1.2V at +70°C.

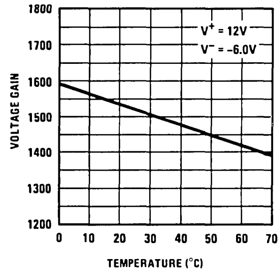
Note 3: The response time specified (see definitions) is for a 100 mV input step with 5 mV overdrive.

typical performance characteristics

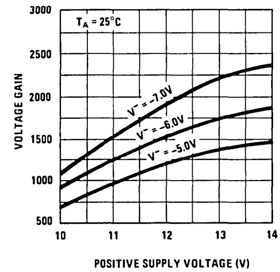
Transfer Function



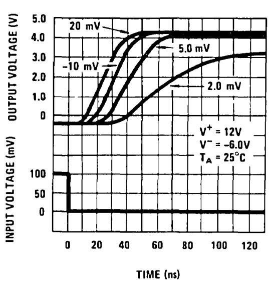
Voltage Gain



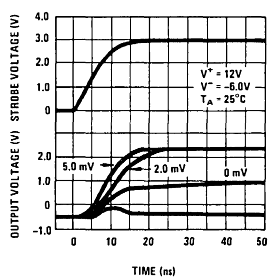
Voltage Gain



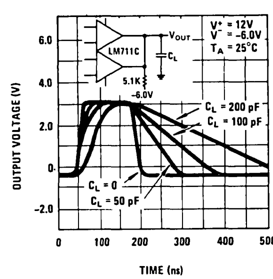
Response Time for Various Input Overdrives



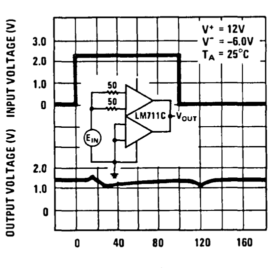
Strobe Release Time for Various Input Overdrives



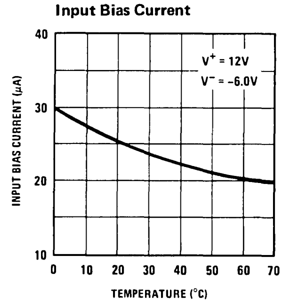
Output Pulse Stretching With Capacitive Loading



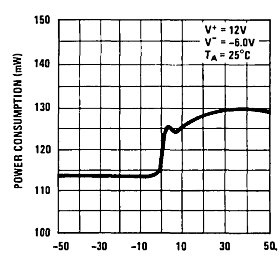
Common Mode Pulse Response



Input Bias Current



Power Consumption



Voltage Comparators/Buffers

LM1514/LM1414 dual differential voltage comparator

general description

The LM1514/LM1414 is a dual differential voltage comparator intended for applications requiring high accuracy and fast response times. The device is constructed on a single monolithic silicon chip.

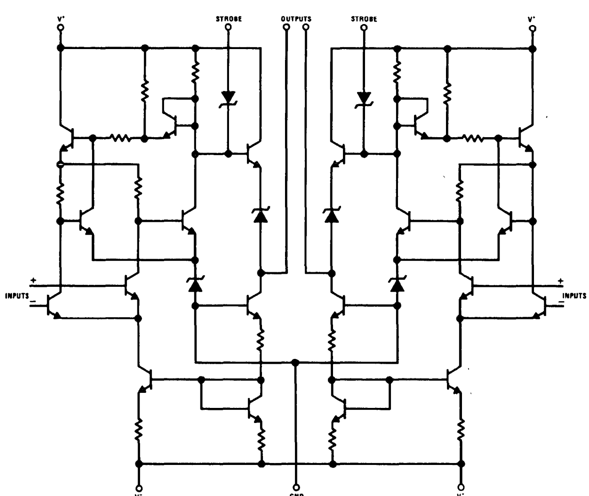
The LM1514/LM1414 is useful as a variable threshold Schmitt trigger, a pulse height discriminator, a voltage comparator in high-speed A-D converters, a memory sense amplifier or a high noise immunity line receiver. The output of the comparator is compatible with all integrated logic forms. The LM1514/LM1414 meet or exceed the specifications for the MC1514/MC1414 and are pin-for-pin replacements. The LM1514 is available in the ceramic dual-in-line package. The LM1414 is available in either the ceramic or molded dual-in-line package.

The LM1514 is specified for operation over the −55°C to +125°C military temperature range. The LM1414 is specified for operation over the 0°C to +70°C temperature range.

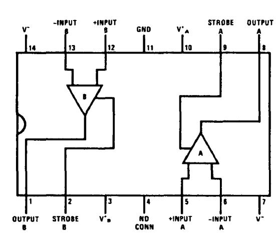
features

- Two totally separate comparators per package
- Independent strobe capability
- High speed 30 ns typ
- Low input offset voltage and current
- High output sink current over temperature
- Output compatible with TTL/DTL logic
- Molded or ceramic dual-in-line package

schematic and connection diagram



Dual-In-Line Package



Order Number LM1414J or LM1514J
See Package 16
Order Number LM1414N
See Package 22

absolute maximum ratings (Note 1)

Positive Supply Voltage		+14.0V
Negative Supply Voltage		−7.0V
Peak Output Current		10 mA
Differential Input Voltage		±5.0V
Input Voltage		±7.0V
Power Dissipation (Note 2)		600 mW
Operating Temperature Range	LM1514	−55°C to +125°C
	LM1414	0°C to +70°C
Storage Temperature Range		−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)		300°C

electrical characteristics for T_A = 25°C, V^+ = +12V, V^- = −6V, unless otherwise specified

PARAMETER	CONDITIONS	LM1514			LM1414			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$R_S \le 200\Omega$, V_{CM} = 0V, V_{OUT} = 1.4V		0.6	2.0		1.0	5.0	mV
Input Offset Current	V_{CM} = 0V, V_{OUT} = 1.4V		0.8	3.0		1.2	5.0	μA
Input Bias Current				20			25	μA
Voltage Gain		1250			1000			
Output Resistance			200			200		Ω
Differential Input Voltage Range		±5.0			±5.0			V
Input Voltage Range	V^- = −7.0V	±5.0			±5.0			V
Common Mode Rejection Ratio	$R_S \le 200\Omega$, V^- = −7.0V	80	100		70	100		dB
Positive Output Voltage	$V_{IN} \ge 7.0$ mV, $0 \le I_{OUT} \le -5.0$ mA	2.5	3.2	4.0	2.5	3.2	4.0	V
Negative Output Voltage	$V_{IN} \le -7.0$ mV	−1.0	−0.5	0	−1.0	−0.5	0	V
Strobed Output Voltage	$V_{STROBE} \le 0.3$V	−1.0	−0.5	0	−1.0	−0.5	0	V
Strobe "0" Current	V_{STROBE} = 100 mV		−1.2	−2.5		−1.2	−2.5	mA
Positive Supply Current	$V_{IN} \le -7$ mV			18			18	mA
Negative Supply Current	$V_{IN} \le -7$ mV			−14			−14	mA
Power Consumption			180	300		180	300	mW
Response Time	(Note 3)		30			30		ns
LM1514/LM1414: The following apply for $T_L \le T_A \le T_H$ (Note 4) unless otherwise specified								
Input Offset Voltage	$R_S \le 200\Omega$, V_{OUT} = 1.8V for $T_A = T_L$			3.0			6.5	mV
	V_{CM} = 0V, V_{OUT} = 1.0V for $T_A = T_H$			3.0			6.5	mV
Input Bias Current				45			40	μA
Temperature Coefficient of Input Offset Voltage			3.0			5.0		μV/°C
Input Offset Current	V_{CM} = 0V, V_{OUT} = 1.8V, $T_A = T_L$			7.0			7.5	μA
	V_{CM} = 0V, V_{OUT} = 1.0V, $T_A = T_H$			3.0			7.5	μA
Voltage Gain		1000			800			
Output Sink Current	$V_{IN} \le -9.0$ mV, $V_{OUT} \ge 0$V	2.8	4.0		1.6	2.5		mA

Note 1: Voltage values are with respect to network ground terminal. Positive current is defined as current into the referenced pin.

Note 2: LM1514 ceramic package: The maximum junction temperature is +150°C, for operating at elevated temperatures, devices must be derated linearly at 12.5 mW/°C. LM1414 ceramic package: The maximum junction temperature is +95°C for operating at elevated temperatures, devices must be derated linearly at 12.5 mW/°C. LM1414 molded package: The maximum junction temperature is +115°C, for operating at elevated temperatures, devices must be derated linearly at 6.7 mW/°C.

Note 3: The response time specified (see definitions) for a 100 mV input step with 5 mV overdrive.

Note 4: For LM1514, T_L = −55°C, T_H = +125°C. For LM1414, T_L = 0°C, T_H = +70°C.

Voltage Comparators/Buffers

LM2901 quad comparator

general description

The LM2901 consists of four independent voltage comparators which were designed specifically for automotive and industrial control systems. They operate from a single power supply over a wide range of voltages and the low power supply current drain is independent of the magnitude of the power supply voltage. These comparators also have a unique characteristic in that the input common-mode voltage range includes ground, even though operated from a single power supply voltage.

Application areas include limit comparators, simple analog to digital converters; pulse, squarewave and time delays generators; wide range VCO; MOS clock timers; multivibrators and high voltage digital logic gates. The LM2901 was designed to directly interface with CMOS—where the low power drain of the LM2901 is a large advantage over standard comparator products.

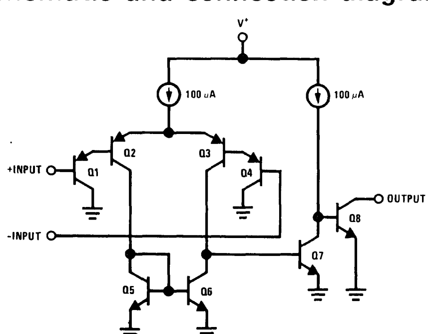
advantages

- Eliminates need for dual supplies
- Allows sensing near GND
- Compatible with all forms of logic
- Power drain suitable for battery operation

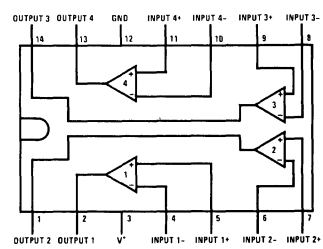
features

- Wide single supply voltage range — $2\ V_{DC}$ to $36\ V_{DC}$
- Very low supply current drain (0.8 mA) — independent of supply voltage (1 mW/comparator at $+5\ V_{DC}$)
- Low input biasing current — 35 nA
- Low input offset current — 3 nA; and offset voltage — 3 mV
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Low output saturation voltage — 1 mV at 5µA; 70 mV at 1 mA
- Output voltage compatible with CMOS logic systems

schematic and connection diagrams

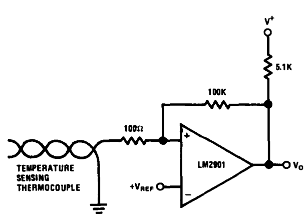


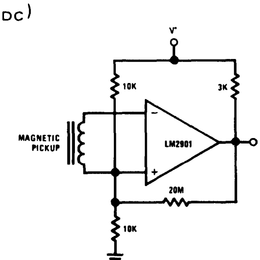
Dual-In-Line Package

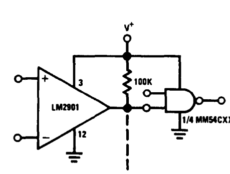


Order Number LM2901N
See Package 22

typical applications $(V^{+} = 5\ V_{DC})$







absolute maximum ratings

Supply Voltage, V^+	36 V_{DC}
Differential Input Voltage	36 V_{DC}
Input Voltage	−0.3 V_{DC} to +36 V_{DC}
Power Dissipation (Note 1)	570 mW
Output Short-Circuit to GND (Note 2)	Continuous
Operating Temperature Range	−40°C to +85°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 60 sec)	300°C

electrical characteristics (V^+ = +5 V_{DC} and T_A = 25°C unless otherwise noted)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	At Output Switch Point, $V_0 \cong 1.4\ V_{DC}$; $V_{REF} = +1.4\ V_{DC}$ and $R_S = 0\Omega$		2	7	mV_{DC}
Input Bias Current (Note 3)	$I_{IN(+)}$ or $I_{IN(-)}$ With Output in Linear Range		25	250	nA_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$		±5	±50	mA_{DC}
Input Common-Mode Voltage Range (Note 4)		0		V^+ −1.5	V_{DC}
Supply Current	$R_L = \infty$ On All Comparators		0.8	2	mA_{DC}
Voltage Gain	$R_L = 15\ k\Omega$		200		V/mV
Response Time (Note 5)	$V_{RL} = 5.0\ V_{DC}$ and $R_L = 5.1\ k\Omega$		1.3		µs
Output Sink Current	$V_{IN(-)} = +1\ V_{DC}$, $V_{IN(+)} = 0$ and $V_0 \leq +1.5\ V_{DC}$	6	16		mA_{DC}
Saturation Voltage	$V_{IN(-)} = +1\ V_{DC}$, $V_{IN(+)} = 0$ and $I_{SINK} = 3$ mA		200	400	mV_{DC}
Output Leakage Current	$V_{IN(+)} = +1\ V_{DC}$, $V_{IN(-)} = 0$ and $V_{OUT} = 5\ V_{DC}$		0.1		nA_{DC}

Note 1: For operating at high temperatures, the LM2901 must be derated based on a +125°C maximum junction temperature and a thermal resistance of 175°C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient. The low bias dissipation and the ON-OFF characteristic of the outputs keeps the chip dissipation very small ($P_d \leq 100$ mW), provided the output transistors are allowed to saturate.

Note 2: Short circuits from the output to V^+ can cause excessive heating and eventual destruction. The maximum output current is approximately 20 mA independent of the magnitude of V^+.

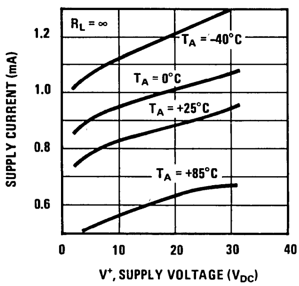
Note 3: The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the reference or input lines.

Note 4: The input common-mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3V. The upper end of the common-mode voltage range is $V^+ - 1.5V$, but either or both inputs can go to +30 V_{DC} without damage.

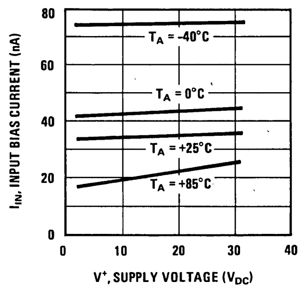
Note 5: The response time specified is for a 100 mV input step with 5 mV overdrive. For larger overdrive signals 300 ns can be obtained, see typical performance characteristics section.

typical performance characteristics

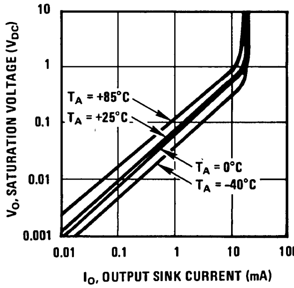
Supply Current



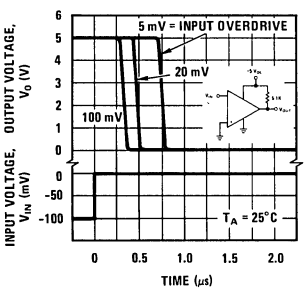
Input Current



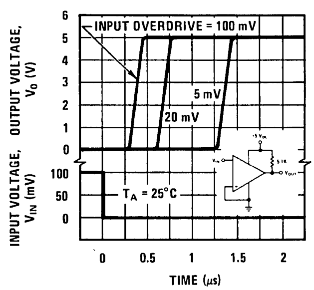
Output Saturation Voltage



Response Time for Various Input Overdrives — Negative Transition



Response Time for Various Input Overdrives — Positive Transition



application hints

The LM2901 is a high gain, wide bandwidth device; which, like most comparators, can easily oscillate if the output lead is inadvertently allowed to capacitively couple to the inputs via stray capacitance. This shows up only during the output voltage transition intervals as the comparator changes states. Power supply bypassing is not required to solve this problem. Standard PC board layout is helpful as it reduces stray input-output coupling. Reducing the input resistors to <10 kΩ reduces the feedback signal levels and finally, adding even a small amount (1 to 10 mV) of positive feedback (hysteresis) causes such a rapid transition that oscillations due to stray feedback are not possible. Simply socketing the IC and attaching resistors to the pins will cause input-output oscillations during the small transition intervals unless hysteresis is used. If the input signal is a pulse waveform, with relatively fast rise and fall times, hysteresis is not required.

All pins of any unused comparators should be grounded.

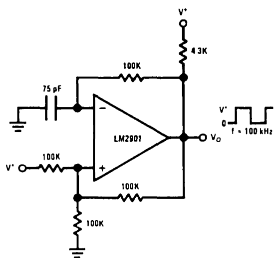
The bias network of the LM2901 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from $2V_{DC}$ to $30\ V_{DC}$.

It is usually unnecessary to use a bypass capacitor across the power supply line.

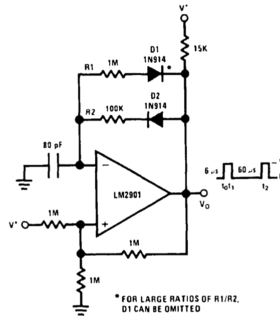
The differential input voltage may be larger than V^+ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than $-0.3\ V_{DC}$ (at 25°C). An input clamp diode can be used as shown in the applications section.

The output of the LM2901 is the uncommitted collector of a grounded-emitter NPN output transistor. Many collectors can be tied together to provide an output OR'ing function. An output pull-up resistor can be connected to any available power supply voltage within the permitted supply voltage range and there is no restriction on this voltage due to the magnitude of the voltage which is applied to the V^+ terminal of the LM2901 package. The output can also be used as a simple SPST switch to ground (when a pull-up resistor is not used). The amount of current which the output device can sink is limited by the drive available (which is independent of V^+) and the β of this device. When the maximum current limit is reached (approximately 16 mA), the output transistor will come out of saturation and the output voltage will rise very rapidly. The output saturation voltage is limited by the approximately 60Ω r_{sat} of the output transistor. The low offset voltage of the output transistor (1 mV) allows the output to clamp essentially to ground level for small load currents.

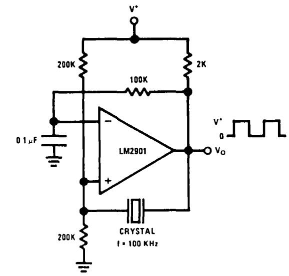
typical applications (con't) ($V^+ = 15\ V_{DC}$)



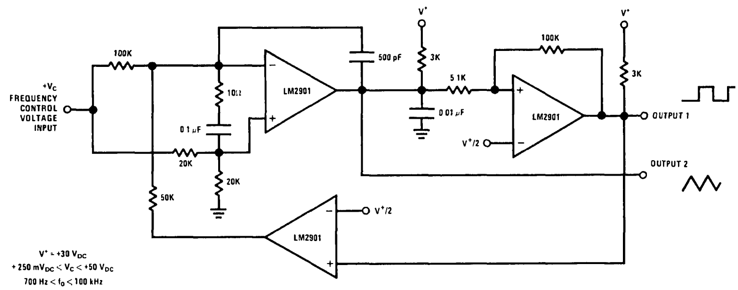
Squarewave Oscillator



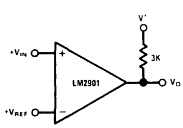
Pulse Generator



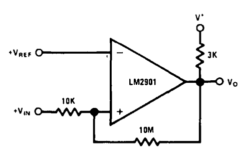
Crystal Controlled Oscillator



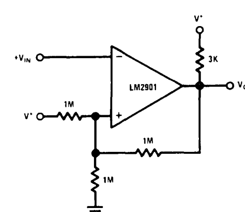
Two-Decade High-Frequency VCO



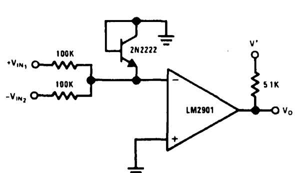
Basic Comparator



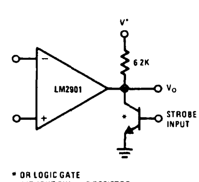
Non-Inverting Comparator with Hysteresis



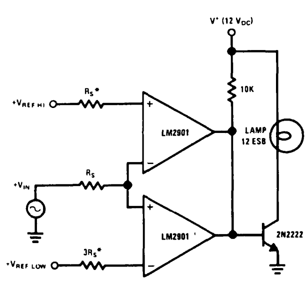
Inverting Comparator with Hysteresis



Comparing Input Voltages of Opposite Polarity



Output Strobing

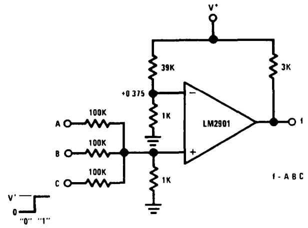


* Input bias current flow through R_S (of V_{IN} source) can cause comparator voltage errors (for $(3\ I_{IN})(R_S)$ V_{REF}). This can be reduced by adding R_S and $3R_S$ as shown.

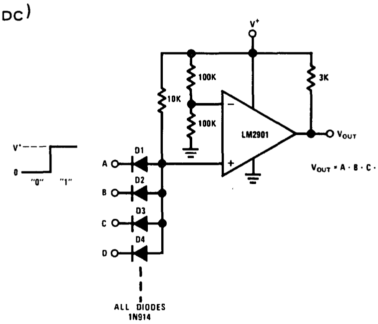
Limit Comparator

3

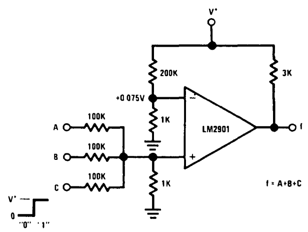
typical applications (con't) ($V^+ = 15\ V_{DC}$)



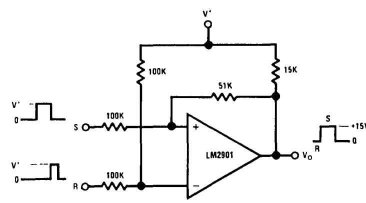
AND Gate



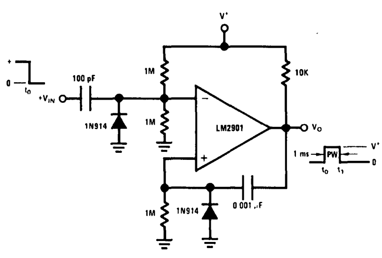
Large Fan-in AND Gate



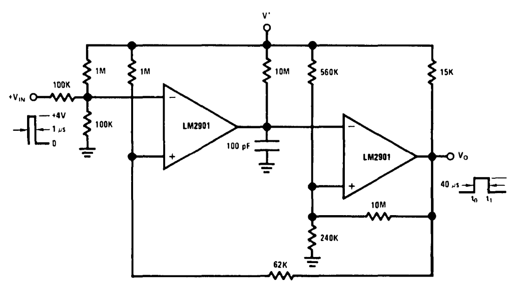
OR Gate



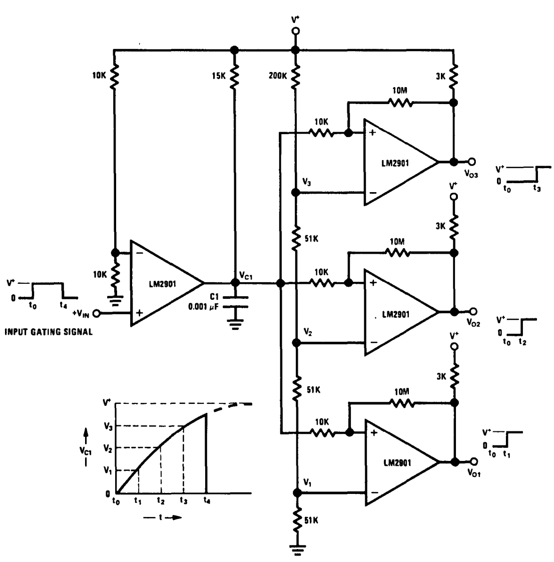
Bi-Stable Multivibrator



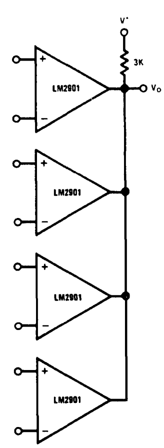
One-Shot Multivibrator



One-Shot Multivibrator with Input Lock Out

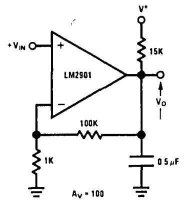


Time Delay Generator

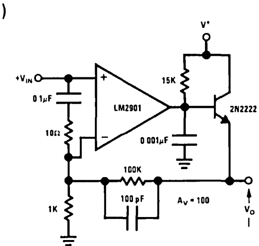


ORing the Outputs

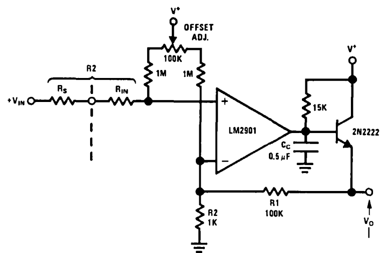
typical applications (con't) ($V^+ = 15\ V_{DC}$)



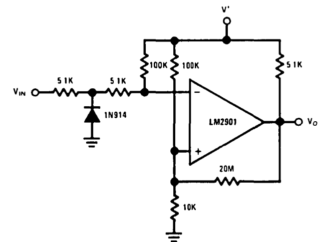
Low Frequency Op Amp



Improved Op Amp

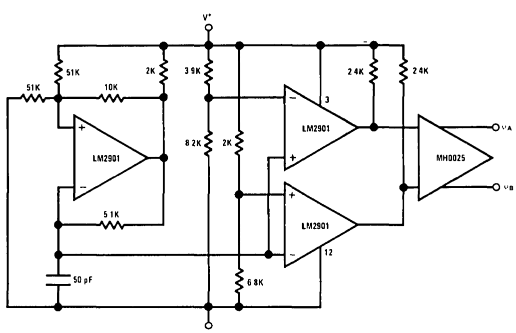


Low Frequency Op Amp with Offset Adjust

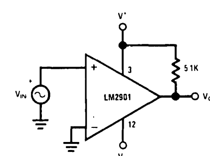


Zero Crossing Detector (Single Power Supply)

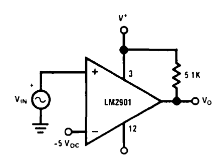
split-supply applications ($V^+ = +15\ V_{DC}$ & $V^- = -15\ V_{DC}$)



MOS Clock Driver



Zero Crossing Detector



Comparator With a Negative Reference

Voltage Comparators/Buffers

LM3302 quad comparator

general description

The LM3302 consists of four independent voltage comparators which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage. These comparators also have a unique characteristic in that the input common-mode voltage range includes ground, even though operated from a single power supply voltage.

Application areas include limit comparators, simple analog to digital converters; pulse, squarewave and time delay generators; wide range VCO; MOS clock timers; multivibrators and high voltage digital logic gates. The LM3302 was designed to directly interface with TTL and CMOS. When operated from both plus and minus power supplies, the LM3302 will directly interface with MOS logic—where the low power drain of the LM3302 is a distinct advantage over standard comparators.

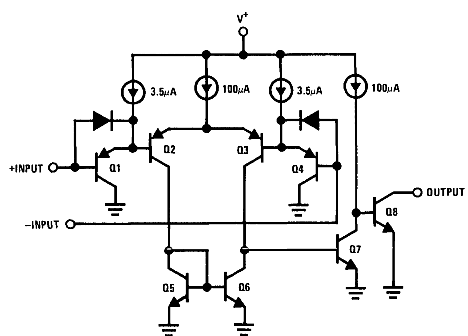
advantages

- Eliminates need for dual supplies
- Allows sensing near GND
- Compatible with all forms of logic
- Power drain suitable for battery operation

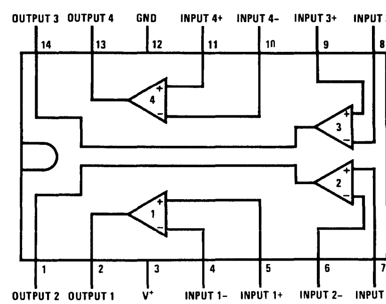
features

- Wide single supply
  - Voltage range: $2\ V_{DC}$ to $28\ V_{DC}$
  - or dual supplies: $\pm 1\ V_{DC}$ to $\pm 14\ V_{DC}$
- Very low supply current drain (0.8 mA) — independent of supply voltage (1 mW/comparator at $+5\ V_{DC}$)
- Low input biasing current: 35 nA
- Low input offset current: 3 nA
  - and offset voltage: 3 mV
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Low output saturation voltage: 1 mV at 5μA; 70 mV at 1 mA
- Output voltage compatible with TTL (fanout of 2), DTL, ECL, MOS and CMOS logic systems

schematic and connection diagrams



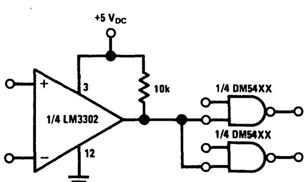
Dual-In-Line Package



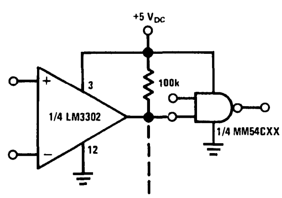
TOP VIEW

Order Number LM3302N
See Package 22

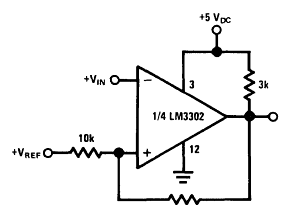
typical applications



Driving TTL



Driving CMOS



Comparator with Hysteresis

absolute maximum ratings

Supply Voltage, V^+	28 V_{DC} or ±14 V_{DC}
Differential Input Voltage	28 V_{DC}
Input Voltage	−0.3 V_{DC} to +28 V_{DC}
Power Dissipation (Note 1)	570 mW
Output Short-Circuit to GND (Note 2)	Continuous
Input Current ($V_{IN} < -0.3\ V_{DC}$) (Note 3)	50 mA
Operating Temperature Range	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics ($V^+ = +5.0\ V_{DC}$) (Note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	At Output Switch Point, $V_O \cong 1.4\ V_{DC}$, $V_{REF} = +1.4\ V_{DC}$, $R_S = 0\Omega$, $T_A = +25°C$		±3	±20	mV_{DC}
Input Bias Current (Note 5)	$I_{IN(+)}$ or $I_{IN(-)}$ With Output in Linear Range, $T_A = +25°C$		25	500	nA_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $T_A = +25°C$		±3	±100	nA_{DC}
Input Common-Mode Voltage Range (Note 6)	$T_A = +25°C$	0		$V^+ - 1.5$	V_{DC}
Supply Current	$R_L = \infty$ On All Comparators, $T_A = +25°C$		0.8	2	mA_{DC}
Voltage Gain	$R_L \geq 15\ k\Omega$, $T_A = +25°C$	2	30		V/mV
Large Signal Response Time	V_{IN} = TTL Logic Swing, $V_{REF} = +1.4\ V_{DC}$, $V_{RL} = 5.0\ V_{DC}$, $R_L = 5.1\ k\Omega$		300		ns
Response Time (Note 7)	$V_{RL} = 5.0\ V_{DC}$, $R_L = 5.1\ k\Omega$, $T_A = +25°C$		1.3		µs
Output Sink Current	$V_{IN(-)} \geq +1.0\ V_{DC}$, $V_{IN(+)} = 0$, $V_O \leq +1.5\ V_{DC}$, $T_A = +25°C$	2	16		mA_{DC}
Saturation Voltage	$V_{IN(-)} \geq +1.0\ V_{DC}$, $V_{IN(+)} = 0$, $I_{SINK} \leq 4.0$ mA, $T_A = +25°C$		250	500	mV_{DC}
Output Leakage Current	$V_{IN(+)} \geq +1.0\ V_{DC}$, $V_{IN(-)} = 0$, $V_{OUT} = 5.0\ V_{DC}$, $T_A = +25°C$		0.1		nA_{DC}
Input Offset Voltage	At Output Switch Point, $V_O \cong 1.4\ V_{DC}$, $V_{REF} = +1.4\ V_{DC}$, $R_S = 0\Omega$			40	mV_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$			±100	nA_{DC}
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$ With Output in Linear Range			1000	nA_{DC}
Input Common-Mode Voltage Range		0		$V^+ - 2.0$	V_{DC}
Saturation Voltage	$V_{IN(-)} \geq +1.0\ V_{DC}$, $V_{IN(+)} = 0$, $I_{SINK} \leq 4.0$ mA			700	mV_{DC}
Output Leakage Current	$V_{IN(+)} \geq +1.0\ V_{DC}$, $V_{IN(-)} = 0$, $V_{OUT} = 28\ V_{DC}$			1	μA_{DC}
Differential Input Voltage (Note 8)	Keep All V_{IN}'s $\geq 0\ V_{DC}$ (or V^-, if used)			V_{CC}	V_{DC}

Note 1: For operating at high temperatures, the LM3302 must be derated based on +125°C maximum junction temperature and a thermal resistance of 175°C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient.

Note 2: Short circuits from the output to V^+ can cause excessive heating and eventual destruction. The maximum output current is approximately 20 mA independent of the magnitude of V^+.

Note 3: This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the comparators to go to the V^+ voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than −0.3 V_{DC}.

Note 4: These specifications apply for $V^+ = +5.0\ V_{DC}$ and $-40°C \leq T_A \leq +85°C$.

Note 5: The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the reference or input lines.

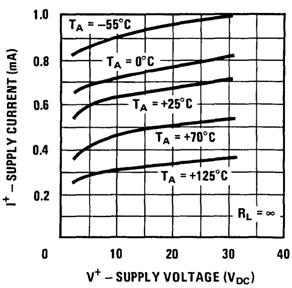
Note 6: The input common-mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3V. The upper end of the common-mode voltage range is $V^+ - 1.5V$, but either or both inputs can go to +30 V_{DC} without damage.

Note 7: The response time specified is for a 100 mV input step with 5.0 mV overdrive. For larger overdrive signals 300 ns can be obtained, see typical performance characteristics section.

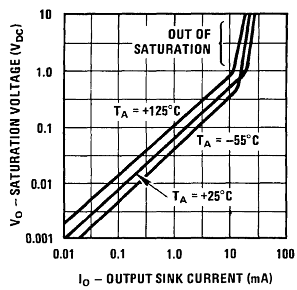
Note 8: The positive excursions of the inputs can exceed the power supply voltage level and if the other input voltage remains within the common-mode voltage range, the comparator will provide a proper output state. The low input voltage state must not be less than −0.3 V_{DC} (or 0.3 V_{DC} below the magnitude of the negative power supply voltage, if used).

typical performance characteristics

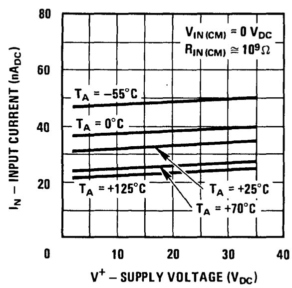
Supply Current



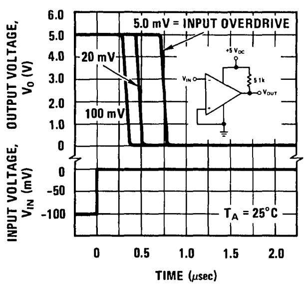
Input Current



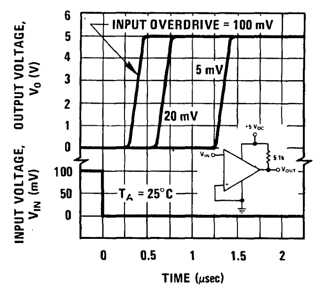
Output Saturation Voltage



Response Time for Various Input Overdrives — Negative Transition



Response Time for Various Input Overdrives — Positive Transition



application hints

The LM3302 is a high gain, wide bandwidth device; which, like most comparators, can easily oscillate if the output lead is inadvertently allowed to capacitively couple to the inputs via stray capacitance. This shows up only during the output voltage transition intervals as the comparator changes states. Power supply bypassing is not required to solve this problem. Standard PC board layout is helpful as it reduces stray input-output coupling. Reducing the input resistors to < 10 kΩ reduces the feedback signal levels and finally, adding even a small amount (1 to 10 mV) of positive feedback (hysteresis) causes such a rapid transition that oscillations due to stray feedback are not possible. Simply socketing the I/C and attaching resistors to the pins will cause input-output oscillations during the small transition intervals unless hysteresis is used. If the input signal is a pulse waveform, with relatively fast rise and fall times, hysteresis is not required.

All pins of any unused comparators should be grounded.

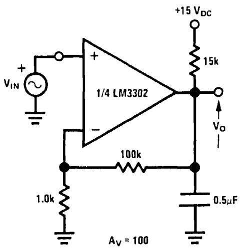
The bias network of the LM3302 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from 2 V_{DC} to 28 V_{DC}.

It is usually unnecessary to use a bypass capacitor across the power supply line.

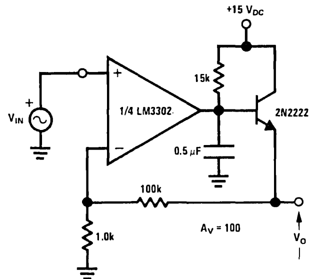
The differential input voltage may be larger than V^+ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than –0.3 V_{DC} (at 25°C). An input clamp diode and input resistor can be used as shown in the applications section.

The output of the LM3302 is the uncommitted collector of a grounded-emitter NPN output transistor. Many collectors can be tied together to provide an output OR'ing function. An output "pull-up" resistor can be connected to any available power supply voltage within the permitted supply voltage range and there is no restriction on this voltage due to the magnitude of the voltage which is applied to the V^+ terminal of the LM3302 package. The output can also be used as a simple SPST switch to ground (when a "pull-up" resistor is not used). The amount of current which the output device can sink is limited by the drive available (which is independent of V^+) and the β of this device. When the maximum current limit is reached (approximately 16 mA), the output transistor will come out of saturation and the output voltage will rise very rapidly. The output saturation voltage is limited by the approximately 60Ω r_{sat} of the output transistor. The low offset voltage of the output transistor (1 mV) allows the output to clamp essentially to ground level for small load currents.

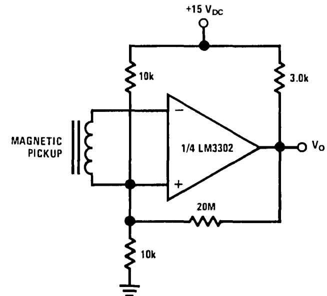
typical applications (con't)



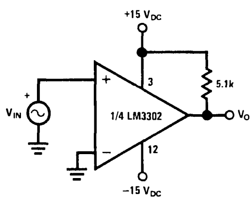
Low Frequency Op Amp



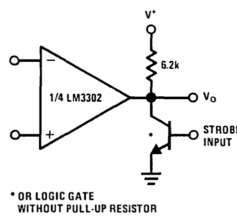
Low Frequency Op Amp
(V_O = 0V for V_{IN} = 0V)



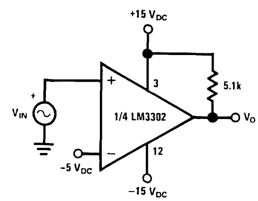
Transducer Amplifier



Zero Crossing Detector



Output Strobing



Comparator with a Negative Reference

Functional Blocks

LM122/LM222/LM322 precision timer

general description

The LM122 is a precision timer that offers great versatility with high accuracy. It operates off unregulated supplies from 4.5V to 40V while maintaining constant timing periods from microseconds to hours. Internal logic and regulator circuits complement the basic timing function enabling the LM122 to operate in many different applications with a minimum of external components.

The output of the timer is a floating transistor with built in current limiting. It can drive either ground referred or supply referred loads up to 40V and 50 mA. The floating nature of this output makes it ideal for interfacing, lamp or relay driving, and signal conditioning where an open collector or emitter is required. A "logic reverse" circuit can be programmed by the user to make the output transistor either "on" or "off" during the timing period.

The trigger input to the LM122 has a threshold of 1.6V independent of supply voltage, but it is fully protected against inputs as high as ±40V – even when using a 5V supply. The circuitry reacts only to the rising edge of the trigger signal, and is immune to any trigger voltage during the timing periods.

An internal 3.15V regulator is included in the timer to reject supply voltage changes and to provide the user with a convenient reference for applications other than a basic timer. External loads up to 5 mA can be driven by the regulator. An internal 2V divider between the reference and ground sets the timing period to 1 RC. The timing period can be voltage controlled by driving this divider with an external source through the V_{ADJ} pin. Timing ratios of 50:1 can be easily achieved.

The comparator used in the LM122 utilizes high gain PNP input transistors to achieve 300 pA typical input bias current over a common mode range of 0V to 3V. A boost terminal allows the user to increase comparator operating current for timing periods less than 1 ms. This lets the timer operate over a 3μs to multi-hour timing range with excellent repeatability.

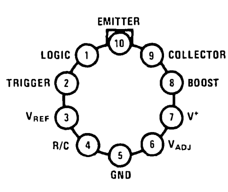
The LM122 operates over a temperature range of −55°C to +125°C. An electrically identical LM222 is specified from −25°C to +85°C. The timer is available in TO-5, flat package, and dual-in-line packages.

features

- Immune to changes in trigger voltage during timing interval
- Timing periods from microseconds to hours
- Internal logic reversal
- Immune to power supply ripple or noise during the timing interval
- Operates from 4.5V to 40V supplies
- Input protected to ±40V
- Floating transistor output with internal current limiting
- Internal regulated reference
- Timing period can be voltage controlled
- TTL compatible input and output

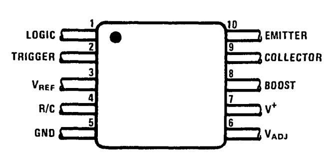
connection diagrams

Metal Can Package



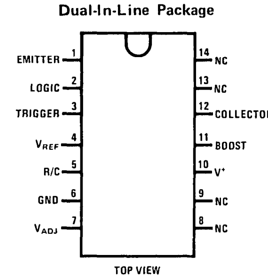
Order Number LM122H, LM22H or LM322H
See Package 14

Flat Package



Order Number LM122F
See Package 3

Dual-In-Line Package



Order Number LM322N
See Package 22

absolute maximum ratings

Power Dissipation	500 mW
V^+ Voltage	40V
Collector Output Voltage	40V
V_{REF} Current	5 mA
Trigger Voltage	±40V
V_{ADJ} Voltage (Forced)	5V
Logic Reverse Voltage	5.5V
Output Short Circuit Duration (Note 1)	
Lead Temperature (Soldering, 10 sec)	300°C

LM122/LM222 electrical characteristics (Note 2)

PARAMETERS	CONDITIONS	MIN	TYP	MAX	UNITS
Timing Ratio (Note 3)	$T_A = 25°C$, $4.5V \leq V^+ \leq 40V$	.626	.632	.638	
	Boost Tied to V^+	.620	.632	.644	
Comparator Input Current	$T_A = 25°C$, $4.5V \leq V^+ \leq 40V$		.3	1	nA
	Boost Tied to V^+		30	100	nA
Trigger Voltage	$T_A = 25°C$, $4.5V \leq V^+ \leq 40V$	1.2	1.6	2	V
Trigger Current	$T_A = 25°C$, $V_{TRIG} = 2V$		25		μA
Supply Current	$T_A = 25°C$, $4.5V \leq V^+ \leq 40V$		2.5	4	mA
Timing Ratio	$4.5V \leq V^+ \leq 40V$	.620		.644	
	Boost Tied to V^+	.620		.644	
Comparator Input Current (Note 4)	$4.5V \leq V^+ \leq 40V$	−5		5	nA
	Boost Tied to V^+			100	nA
Trigger Voltage	$4.5V \leq V^+ \leq 40V$	.8		2.5	V
Trigger Current	$V_{TRIG} = 2.5V$			200	μA
Output Leakage Current	$V_{CE} = 40V$			1	μA
Capacitor Saturation Voltage	$R_t \geq 1\ M\Omega$		2.5		mV
	$R_t = 10\ k\Omega$		25		mV
Reset Resistance			150		Ω
Reference Voltage	$T_A = 25°C$	3	3.15	3.3	V
Reference Regulation	$0 \leq I_{OUT} \leq 3\ mA$		20	50	mV
	$4.5V \leq V^+ \leq 40V$		6	25	mV
Collector Saturation Voltage	$I_L = 8\ mA$		.25	.4	V
	$I_L = 50\ mA$		.7	1.4	V
Emitter Saturation Voltage	$I_L = 3\ mA$, $T_A = 25°C$		1.8	2.2	V
	$I_L = 50\ mA$, $T_A = 25°C$		2.1	3	V
Average Temperature Coefficient of Timing Ratio			.003		%/°C
Minimum Trigger Width	$V_{TRIG} = 3.0V$		.25		μs

Note 1: Continuous output shorts are not allowed. Short circuit duration at ambient temperatures of 40°C may be calculated from $t = 120/V_{CE}$ seconds, where V_{CE} is the collector to emitter voltage across the output transistor during the short.

Note 2: Specifications include the temperature range, $-55°C \leq T_A \leq +125°C$ for the LM122 and $-25°C \leq T_A \leq +85°C$ for the LM222.

Note 3: Output pulse width can be calculated from the following equation: $t = (R_t)(C_t)[1 - 2(0.632 - r) - V_C/V_{REF}]$ where r is timing ratio and V_C is capacitor saturation voltage. This reduces to $t = (R_t)(C_t)$ for all but the most critical applications.

Note 4: Sign reversal may occur at high temperatures (> 100°C) where comparator input current is predominately leakage. See typical curves.

absolute maximum ratings

Power Dissipation	500 mW
V^+ Voltage	40V
Collector Output Voltage	40V
V_{REF} Current	5 mA
Trigger Voltage	±40V
V_{ADJ} Voltage (Forced)	5V
Logic Reverse Voltage	5.5V
Output Short Circuit Duration (Note 1)	
Lead Temperature (Soldering, 10 sec)	300°C

LM322
electrical characteristics (Note 2)

PARAMETERS	CONDITIONS	MIN	TYP	MAX	UNITS
Timing Ratio (Note 3)	T_A = 25°C, 4.5V ≤ V^+ ≤ 40V	.620	.632	.644	
	Boost Tied to V^+	.620	.632	.644	
Comparator Input Current	T_A = 25°C, 4.5V ≤ V^+ ≤ 40V		.3	1	nA
	Boost Tied to V^+		30	100	nA
Trigger Voltage	T_A = 25°C, 4.5V ≤ V^+ ≤ 40V	1.2	1.6	2	V
Trigger Current	T_A = 25°C, V_{TRIG} = 2V		25		μA
Supply Current	T_A = 25°C, 4.5V ≤ V^+ ≤ 40V		2.5	4.5	mA
Timing Ratio	4.5V ≤ V^+ ≤ 40V	.610		.654	
	Boost Tied to V^+	.610		.654	
Comparator Input Current (Note 4)	4.5V ≤ V^+ ≤ 40V	−2		2	nA
	Boost Tied to V^+			150	nA
Trigger Voltage	4.5V ≤ V^+ ≤ 40V	.8		2.5	V
Trigger Current	V_{TRIG} = 2.5V			200	μA
Output Leakage Current	V_{CE} = 40V			5	μA
Capacitor Saturation Voltage	R_t ≥ 1 MΩ		2.5		mV
	R_t = 10 kΩ		25		mV
Reset Resistance			150		Ω
Reference Voltage	T_A = 25°C	3	3.15	3.3	V
Reference Regulation	0 ≤ I_{OUT} ≤ 3 mA		20	50	mV
	4.5V ≤ V^+ ≤ 40V		6	25	mV
Collector Saturation Voltage	I_L = 8 mA		.25	.4	V
	I_L = 50 mA		.7	1.4	V
Emitter Saturation Voltage	I_L = 3 mA, T_A = 25°C		1.8	2.2	V
	I_L = 50 mA, T_A = 25°C		2.1	3	V
Average Temperature Coefficient of Timing Ratio			.003		%/°C
Minimum Trigger Width	V_{TRIG} = 3.0V		.25		μs

Note 1: Continuous output shorts are not allowed. Short circuit duration at ambient temperatures of 40°C may be calculated from $t = 120/V_{CE}$ seconds, where V_{CE} is the collector to emitter voltage across the output transistor during the short.

Note 2: Specifications include the temperature range 0°C to +70°C for the LM322 unless otherwise noted.

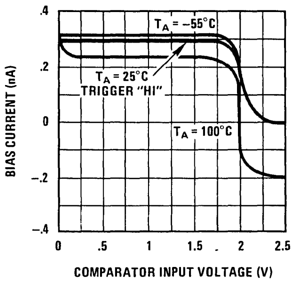
Note 3: Output pulse width can be calculated from the following equation: $t = (R_t)(C_t)[1 - 2(0.632 - r) - V_C/V_{REF}]$ where r is timing ratio and V_C is capacitor saturation voltage. This reduces to $t = (R_t)(C_t)$ for all but the most critical applications.

Note 4: Sign reversal may occur at high temperatures (> 70°C) where comparator input current is predominately leakage. See typical curves.

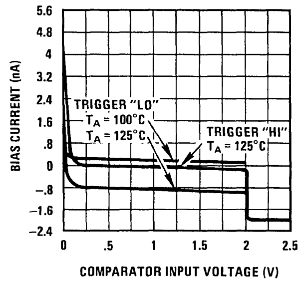
4

typical performance characteristics

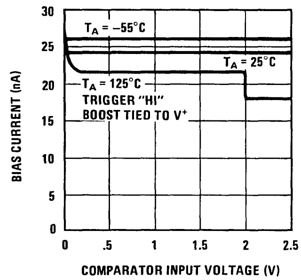
Comparator Bias Current



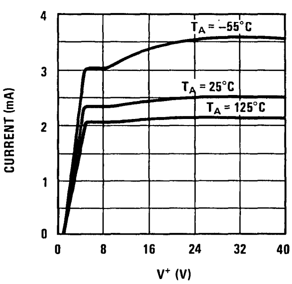
Comparator Bias Current



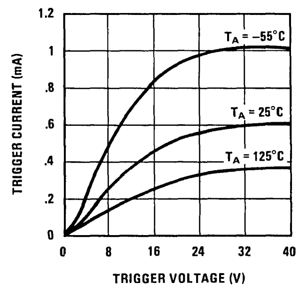
Comparator Bias Current



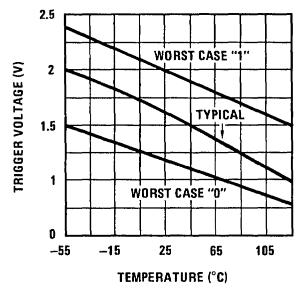
Supply Current



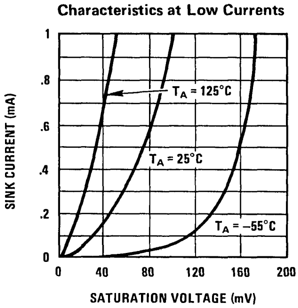
Trigger Input Characteristics



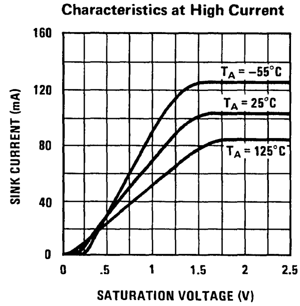
Trigger Threshold



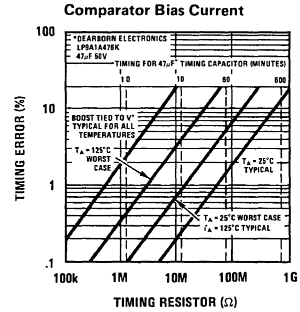
Output Transistor Saturation Characteristics at Low Currents



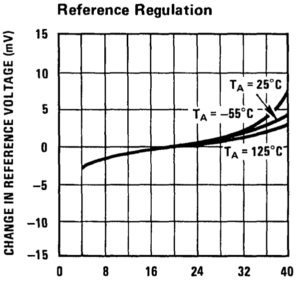
Collector Output Saturation Characteristics at High Current



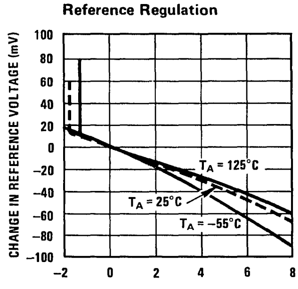
Timing Error Due to Comparator Bias Current



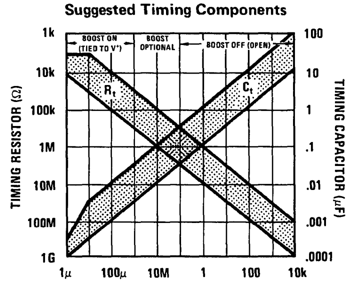
Reference Regulation



Reference Regulation

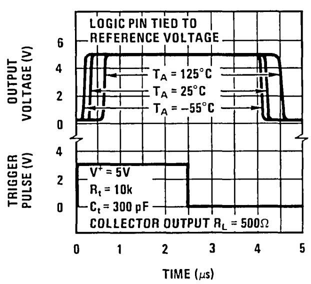


Suggested Timing Components

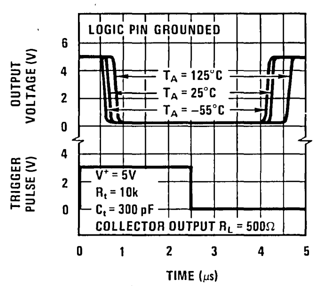


typical performance characteristics (con't)

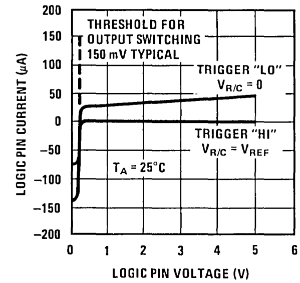
Short Output Pulse



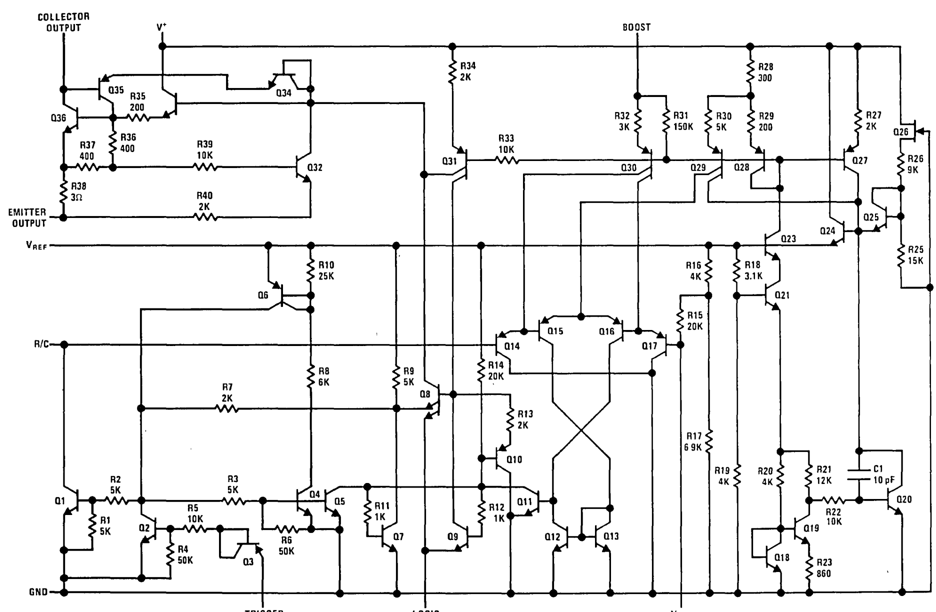
Short Output Pulse



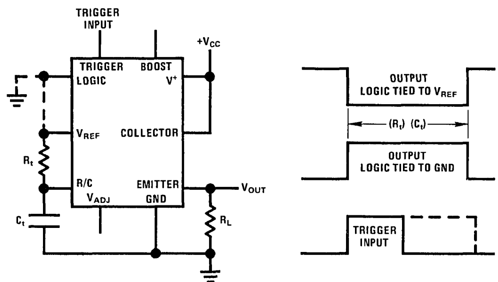
Logic Pin Characteristics



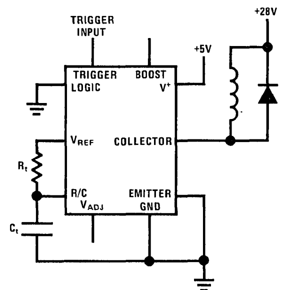
schematic diagram



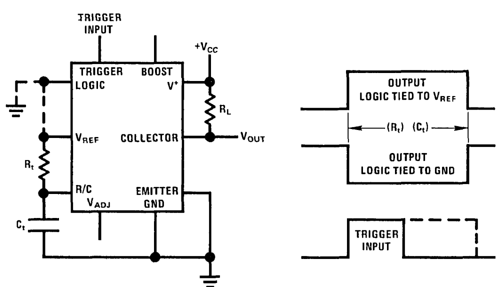
typical applications



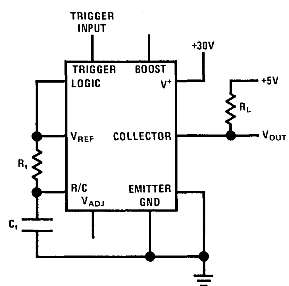
Basic Timer-Emitter Output and Timing Chart



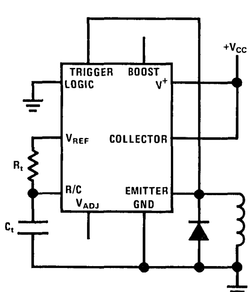
5V Logic Supply Driving 28V Relay



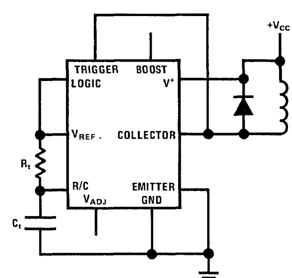
Basic Timer-Collector Output and Timing Chart



30V Supply Interfacing to 5V Logic

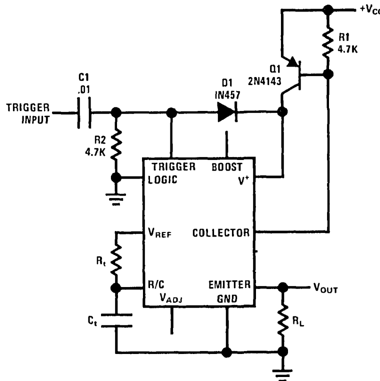


Time Out On Power Up
Relay Energized Until R_t C_t Seconds After V_{CC} is Applied

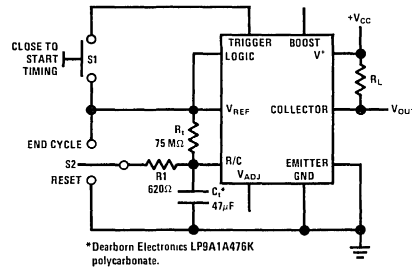


Time Out On Power Up
Relay Energized R_t C_t Seconds After V_{CC} is Applied

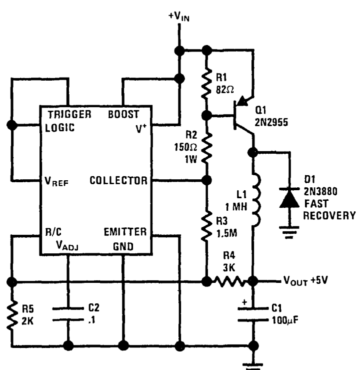
typical applications (con't)



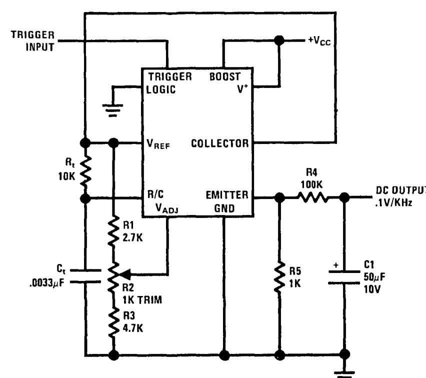
Zero Power Dissipation Between Timing Intervals



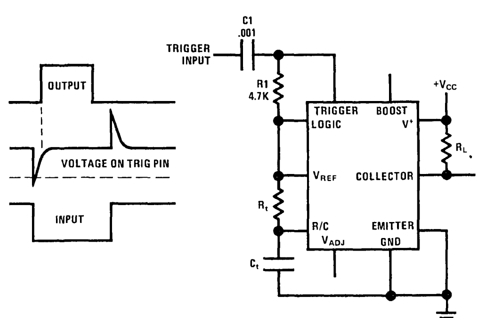
One Hour Timer with Reset & Manual Cycle End



5V Switching Regulator with 1 Amp
Output and 5.5V Minimum Input

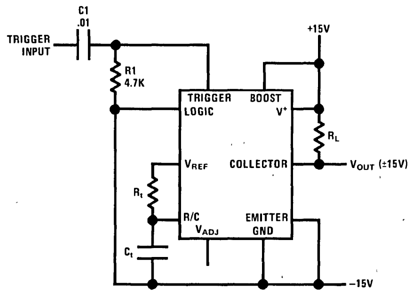


Frequency to Voltage Converter (Tachometer)
Output Independent of Supply Voltage



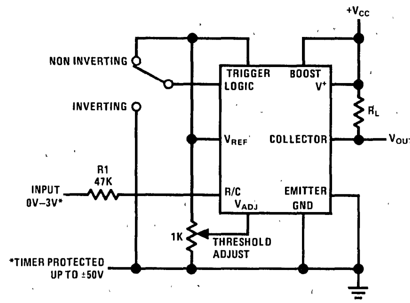
Timer Triggered by Negative Edge of Input Pulse

typical applications (con't)

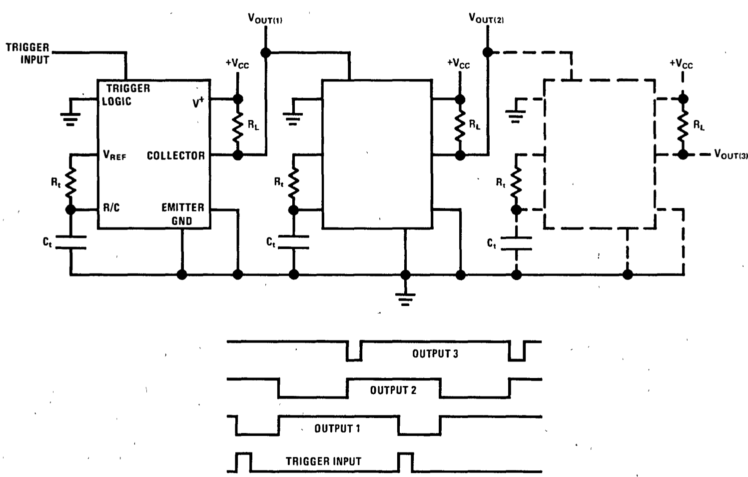


*Emitter terminal or emitter load must be tied to "GND" pin of timer.

Operating off ±15V Supplies*



Comparator with 0V to 3V Threshold



Chain of Timers and Timing Chart

Functional Blocks

LM555/LM555C timer

general description

The LM555 is a highly stable device for generating accurate time delays or oscillation. Additional terminals are provided for triggering or resetting if desired. In the time delay mode of operation, the time is precisely controlled by one external resistor and capacitor. For astable operation as an oscillator, the free running frequency and duty cycle are accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200 mA or drive TTL circuits.

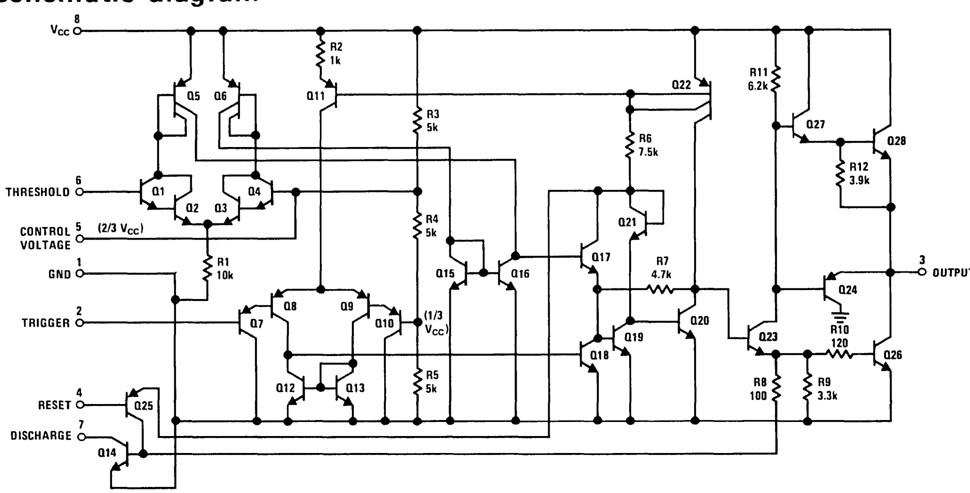
features

- Direct replacement for SE555/NE555
- Timing from microseconds through hours
- Operates in both astable and monostable modes
- Adjustable duty cycle
- Output can source or sink 200 mA
- Output and supply TTL compatible
- Temperature stability better than 0.005% per °C
- Normally on and normally off output

applications

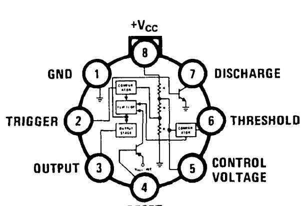
- Precision timing
- Pulse generation
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Linear ramp generator

schematic diagram



connection diagrams

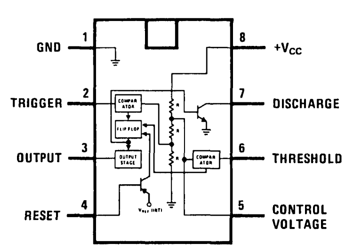
Metal Can Package



TOP VIEW

Order Number LM555H or LM555CH
See Package 11

Dual-In-Line Package



TOP VIEW

Order Number LM555CN
See Package 20

absolute maximum ratings

Supply Voltage	+18V
Power Dissipation (Note 1)	600 mW
Operating Temperature Ranges	
LM555C	0°C to +70°C
LM555	−55°C to +125°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (T_A = 25°C, V_{CC} = +5V to +15V, unless otherwise specified)

PARAMETER	CONDITIONS	LIMITS LM555 MIN	LM555 TYP	LM555 MAX	LM555C MIN	LM555C TYP	LM555C MAX	UNITS
Supply Voltage		4.5		18	4.5		16	V
Supply Current	V_{CC} = 5V, R_L = ∞		3	5		3	6	mA
	V_{CC} = 15V, R_L = ∞ (Low State) (Note 2)		10	12		10	15	mA
Timing Error, Monostable								
Initial Accuracy			0.5	2		1		%
Drift with Temperature	R_A, R_B = 1k to 100 k, C = 0.1µF, (Note 3)		30			50		ppm/°C
Accuracy over Temperature			1.5	3.0		1.5		%
Drift with Supply			0.05	0.2		0.1		%/V
Timing Error, Astable								
Initial Accuracy			1.5			2.25		%
Drift with Temperature			90			150		ppm/°C
Accuracy over Temperature			2.5			3.0		%
Drift with Supply			0.15			0.30		%/V
Threshold Voltage			0.667			0.667		x V_{CC}
Trigger Voltage	V_{CC} = 15V	4.8	5	5.2		5		V
	V_{CC} = 5V	1.45	1.67	1.9		1.67		V
Trigger Current			0.5			0.5		µA
Reset Voltage		0.4	0.5	1	0.4	0.5	1	V
Reset Current			0.1			0.1		mA
Threshold Current	(Note 4)		0.1	0.25		0.1	0.25	µA
Control Voltage Level	V_{CC} = 15V	9.6	10	10.4	9	10	11	V
	V_{CC} = 5V	2.9	3.33	3.8	2.6	3.33	4	V
Pin 7 Leakage Output High			1	100		1	100	nA
Pin 7 Sat (Note 5)								
Output Low	V_{CC} = 15V, I_7 = 15 mA		150			180		mV
Output Low	V_{CC} = 4.5V, I_7 = 4.5 mA		70			80		mV
Output Voltage Drop (Low)	V_{CC} = 15V							
	I_{SINK} = 10 mA		0.1	0.15		0.1	0.25	V
	I_{SINK} = 50 mA		0.4	0.5		0.4	0.75	V
	I_{SINK} = 100 mA		2	2.2		2	2.5	V
	I_{SINK} = 200 mA		2.5			2.5		V
	V_{CC} = 5V							
	I_{SINK} = 8 mA		0.1	0.25				V
	I_{SINK} = 5 mA					0.25	0.35	V
Output Voltage Drop (High)	I_{SOURCE} = 200 mA, V_{CC} = 15V		12.5			12.5		V
	I_{SOURCE} = 100 mA, V_{CC} = 15V	13	13.3		12.75	13.3		V
	V_{CC} = 5V	3	3.3		2.75	3.3		V
Rise Time of Output			100			100		ns
Fall Time of Output			100			100		ns

Note 1: For operating at elevated temperatures the device must be derated based on a +150°C maximum junction temperature and a thermal resistance of +45°C/W junction to case for TO-5 and +150°C/W junction to ambient for both packages.

Note 2: Supply current when output high typically 1 mA less at V_{CC} = 5V.

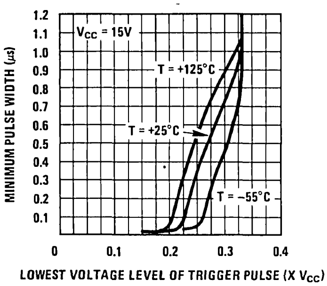
Note 3: Tested at V_{CC} = 5V and V_{CC} = 15V.

Note 4: This will determine the maximum value of $R_A + R_B$ for 15V operation. The maximum total ($R_A + R_B$) is 20 MΩ.

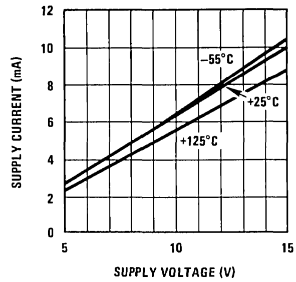
Note 5: No protection against excessive pin 7 current is necessary providing the package dissipation rating will not be exceeded.

typical performance characteristics

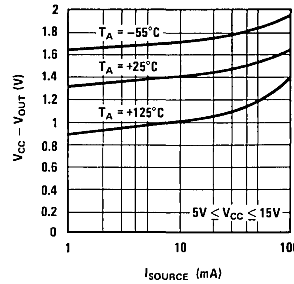
Minimum Pulse Width Required for Triggering



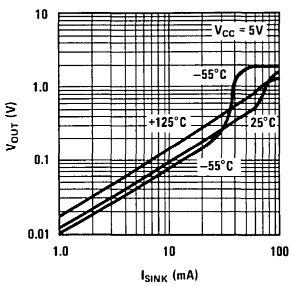
Supply Current vs Supply Voltage



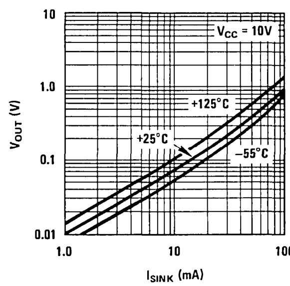
High Output Voltage vs Output Source Current



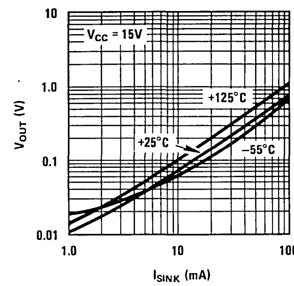
Low Output Voltage vs Output Sink Current



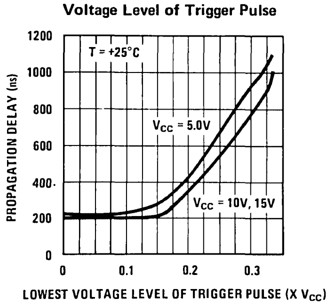
Low Output Voltage vs Output Sink Current



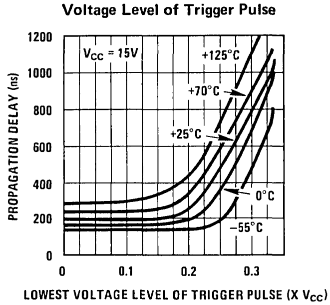
Low Output Voltage vs Output Sink Current



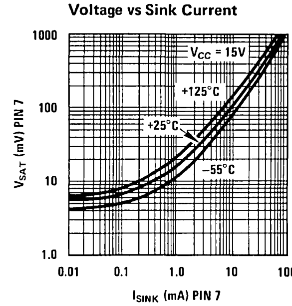
Output Propagation Delay vs Voltage Level of Trigger Pulse



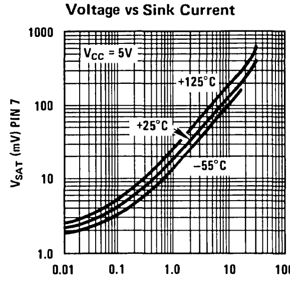
Output Propagation Delay vs Voltage Level of Trigger Pulse



Discharge Transistor (Pin 7) Voltage vs Sink Current



Discharge Transistor (Pin 7) Voltage vs Sink Current



applications information

MONOSTABLE OPERATION

In this mode of operation, the timer functions as a one-shot (*Figure 1*). The external capacitor is initially held discharged by a transistor inside the timer. Upon application of a negative trigger pulse of less than 1/3 V_{CC} to pin 2, the flip-flop is set which both releases the short circuit across the capacitor and drives the output high.

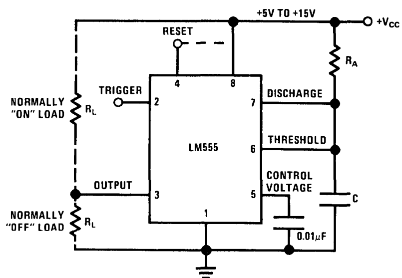
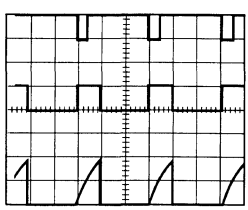


FIGURE 1. Monostable

The voltage across the capacitor then increases exponentially for a period of $t = 1.1\ R_A C$, at the end of which time the voltage equals 2/3 V_{CC}. The comparator then resets the flip-flop which in turn discharges the capacitor and drives the output to its low state. *Figure 2* shows the waveforms generated in this mode of operation. Since the charge and the threshold level of the comparator are both directly proportional to supply voltage, the timing internal is independent of supply.



V_{CC} = 5V
TIME = 0.1 ms/DIV.
R_A = 9.1kΩ
C = 0.01μF

Top Trace: Input 5V/Div.
Middle Trace: Output 5V/Div.
Bottom Trace: Capacitor Voltage 2V/Div.

FIGURE 2. Monostable Waveforms

During the timing cycle when the output is high, the further application of a trigger pulse will not effect the circuit. However the circuit can be reset during this time by the application of a negative pulse to the reset terminal (pin 4). The output will then remain in the low state until a trigger pulse is again applied.

When the reset function is not in use, it is recommended that it be connected to V_{CC} to avoid any possibility of false triggering.

Figure 3 is a nomograph for easy determination of R, C values for various time delays.

ASTABLE OPERATION

If the circuit is connected as shown in *Figure 4* (pins 2 and 6 connected) it will trigger itself and free run as a multivibrator. The external capacitor charges through $R_A + R_B$ and discharges through R_B. Thus the duty cycle may be precisely set by the ratio of these two resistors.

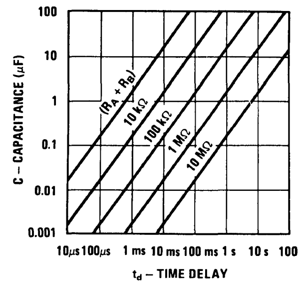


FIGURE 3. Time Delay

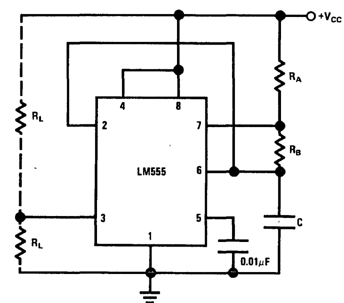
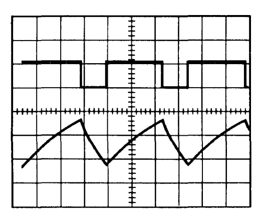


FIGURE 4. Astable

In this mode of operation, the capacitor charges and discharges between 1/3 V_{CC} and 2/3 V_{CC}. As in the triggered mode, the charge and discharge times, and therefore the frequency are independent of the supply voltage.

Figure 5 shows the waveforms generated in this mode of operation.



V_{CC} = 5V
TIME = 20μs/DIV.
R_A = 3.9 kΩ
R_B = 3 kΩ
C = 0.01μF

Top Trace: Output 5V/Div.
Bottom Trace: Capacitor Voltage 1V/Div.

FIGURE 5. Astable Waveforms

The charge time (output high) is given by:

$$t_1 = 0.693\ (R_A + R_B)\ C$$

And the discharge time (output low) by:

$$t_2 = 0.693\ (R_B)\ C$$

Thus the total period is:

$$T = t_1 + t_2 = 0.693\ (R_A + 2R_B)\ C$$

applications information (con't)

The frequency of oscillation is:

$$f = \frac{1}{T} = \frac{1.44}{(R_A + 2\,R_B)\,C}$$

Figure 6 may be used for quick determination of these RC values.

The duty cycle is: $$D = \frac{R_B}{R_A + 2R_B}$$

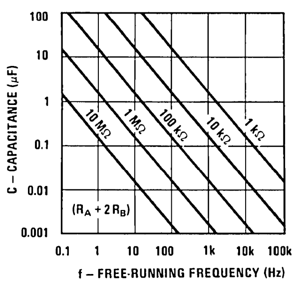
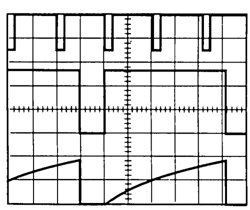


FIGURE 6. Free Running Frequency

FREQUENCY DIVIDER

The monostable circuit of *Figure 1* can be used as a frequency divider by adjusting the length of the timing cycle. *Figure 7* shows the waveforms generated in a divide by three circuit.



V_{CC} = 5V
TIME = 20μs/DIV.
R_A = 9.1 kΩ
C = 0.01μF

Top Trace: Input 4V/Div.
Middle Trace: Output 2V/Div.
Bottom Trace: Capacitor 2V/Div.

FIGURE 7. Frequency Divider

PULSE WIDTH MODULATOR

When the timer is connected in the monostable mode and triggered with a continuous pulse train, the output pulse width can be modulated by a signal applied to pin 5. *Figure 8* shows the circuit, and in *Figure 9* are some waveform examples.

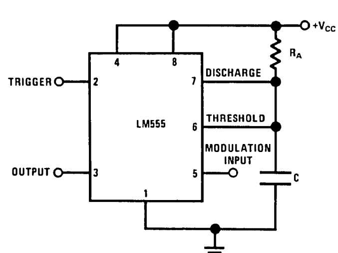
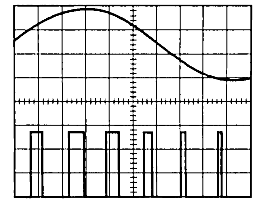


FIGURE 8. Pulse Width Modulator



V_{CC} = 5V
TIME = 0.2 ms/DIV.
R_A = 9.1 kΩ
C = 0.01μF

Top Trace: Modulation 1V/Div.
Bottom Trace: Output 2V/Div.

FIGURE 9. Pulse Width Modulator

PULSE POSITION MODULATOR

This application uses the timer connected for astable operation, as in *Figure 10*, with a modulating signal again applied to the control voltage terminal. The pulse position varies with the modulating signal, since the threshold voltage and hence the time delay is varied. *Figure 11* shows the waveforms generated for a triangle wave modulation signal.

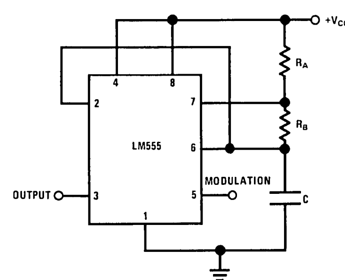
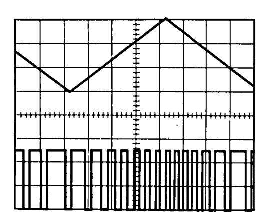


FIGURE 10. Pulse Position Modulator



V_{CC} = 5V
TIME = 0.1 ms/DIV.
R_A = 3.9 kΩ
R_B = 3 kΩ
C = 0.01μF

Top Trace: Modulation Input 1V/Div.
Bottom Trace: Output 2V/Div.

FIGURE 11. Pulse Position Modulator

LINEAR RAMP

When the pullup resistor, R_A, in the monostable circuit is replaced by a constant current source, a linear ramp is

applications information (con't)

generated. *Figure 12* shows a circuit configuration that will perform this function.

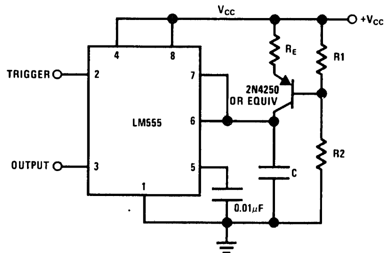


FIGURE 12.

Figure 13 shows waveforms generated by the linear ramp.

The time interval is given by:

$$T = \frac{2/3\, V_{CC}\, R_E\, (R_1 + R_2)\, C}{R_1\, V_{CC} - V_{BE}\, (R_1 + R_2)}$$

$$V_{BE} \simeq 0.6V$$

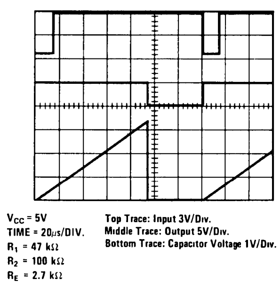


FIGURE 13. Linear Ramp

50% DUTY CYCLE OSCILLATOR

For a 50% duty cycle, the resistors R_A and R_B may be connected as in *Figure 14*. The time period for the output high is the same as previous, $t_1 = 0.693\ R_A\ C$. For the output low it is $t_2 =$

$$[(R_A\ R_B)/(R_A + R_B)]\ C \ln \left[\frac{R_B - 2R_A}{2R_B - R_A}\right]$$

Thus the frequency of oscillation is $f = \frac{1}{t_1 + t_2}$

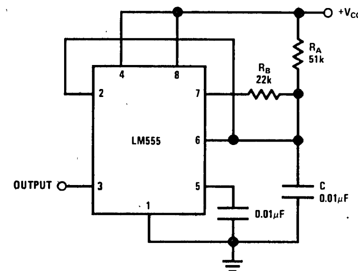


FIGURE 14. 50% Duty Cycle Oscillator

Note that this circuit will not oscillate if R_B is greater than 1/2 R_A because the junction of R_A and R_B cannot bring pin 2 down to 1/3 V_{CC} and trigger the lower comparator.

ADDITIONAL INFORMATION

Adequate power supply bypassing is necessary to protect associated circuitry. Minimum recommended is 0.1μF in parallel with 1μF electrolytic.

Lower comparator storage time can be as long as 10μs when pin 2 is driven fully to ground for triggering. This limits the monostable pulse width to 10μs minimum.

Delay time reset to output is 0.47μs typical. Minimum reset pulse width must be 0.3μs, typical.

Pin 7 current switches within 30 ns of the output (pin 3) voltage.

LM2905/LM3905 precision timer

general description

The LM3905 is a precision timer that offers great versatility with high accuracy. It operates off unregulated supplies from 4.5V to 40V while maintaining constant timing periods from milliseconds to hours. Internal logic and regulator circuits complement the basic timing function enabling the LM3905 to operate in many different applications with a minimum of external components.

The output of the timer is a floating transistor with built in current limiting. It can drive either ground referred or supply referred loads up to 40V and 50 mA. The floating nature of this output makes it ideal for interfacing, lamp or relay driving, and signal conditioning where an open collector or emitter is required. A "logic reverse" circuit can be programmed by the user to make the output transistor either "on" or "off" during the timing period.

The trigger input to the LM3905 has a threshold of 1.6V independent of supply voltage, but it is fully protected against inputs as high as ±40V – even when using a 5V supply. The circuitry reacts only to the rising edge of the trigger signal, and is immune to any trigger voltage during the timing periods.

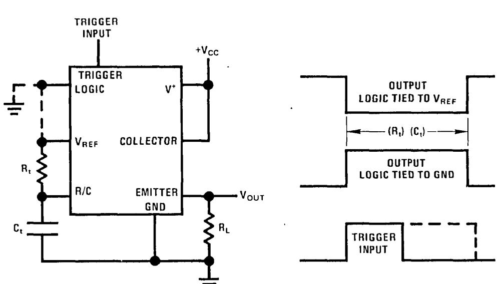
An internal 3.15V regulator is included in the timer to reject supply voltage changes and to provide the user with a convenient reference for applications other than a basic timer. External loads up to 5 mA can be driven by the regulator. An internal 2V divider between the reference and ground sets the timing period to 1 RC.

The comparator used in the LM3905 utilizes high gain PNP input transistors to achieve 300 pA typical input bias current over a common mode range of 0V to 3V.

features

- Immune to changes in trigger voltage during timing interval
- Timing periods from milliseconds to hours
- Internal logic reversal
- Immune to power supply ripple or noise during the timing interval
- Operates from 4.5V to 40V supplies
- Input protected to ±40V
- Floating transistor output with internal current limiting
- Internal regulated reference
- TTL compatible input and output

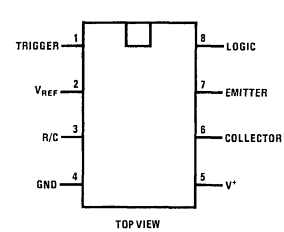
typical applications



Basic Timer-Emitter Output and Timing Chart

connection diagram

Dual-In-Line Package



Order Number LM2905N or LM3905N
See Package 20

absolute maximum ratings

Power Dissipation	500 mW
V^+ Voltage	40V
Collector Output Voltage	40V
V_{REF} Current	5 mA
Trigger Voltage	±40V
Logic Reverse Voltage	5.5V
Output Short Circuit Duration (Note 1)	
Lead Temperature (Soldering, 10 sec)	300°C

LM2905/LM3905
electrical characteristics (Note 2)

PARAMETERS	CONDITIONS	MIN	TYP	MAX	UNITS
Timing Ratio (Note 3)	$T_A = 25°C, 4.5V \le V^+ \le 40V$	.620	.632	.644	
Comparator Input Current	$T_A = 25°C, 4.5V \le V^+ \le 40V$		.3	1	nA
Trigger Voltage	$T_A = 25°C, 4.5V \le V^+ \le 40V$	1.2	1.6	2	V
Trigger Current	$T_A = 25°C, V_{TRIG} = 2V$		25		μA
Supply Current	$T_A = 25°C, 4.5V \le V^+ \le 40V$		2.5	4.5	mA
Timing Ratio	$4.5V \le V^+ \le 40V$	.610		.654	
Comparator Input Current (Note 4)	$4.5V \le V^+ \le 40V$	−2		2	nA
Trigger Voltage	$4.5V \le V^+ \le 40V$	.8		2.5	V
Trigger Current	$V_{TRIG} = 2.5V$			200	μA
Output Leakage Current	$V_{CE} = 40V$			5	μA
Capacitor Saturation Voltage	$R_t \ge 1\ M\Omega$ $R_t = 10\ k\Omega$		2.5 25		mV mV
Reset Resistance			150		Ω
Reference Voltage	$T_A = 25°C$	3	3.15	3.3	V
Reference Regulation	$0 \le I_{OUT} \le 3\ mA$ $4.5V \le V^+ < 40V$		20 6	50 25	mV mV
Collector Saturation Voltage	$I_L = 8\ mA$ $I_L = 50\ mA$		.25 .7	.4 1.4	V V
Emitter Saturation Voltage	$I_L = 3\ mA$ $T_A = 25°C$ $I_L = 50\ mA$		1.8 2.1	2.2 3	V V
Average Temperature Coefficient of Timing Ratio			.003		%/°C
Minimum Trigger Width	$V_{TRIG} = 2.5V$		.25		μs

Note 1: Continuous output shorts are not allowed. Short circuit duration at ambient temperatures of 40°C may be calculated from $t = 50/V_{CE}$ seconds, where V_{CE} is the collector to emitter voltage across the output transistor during the short.

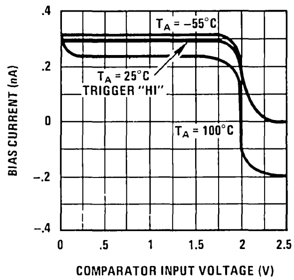
Note 2: Specifications include the temperature range $-40°C \le T_A \le +85°C$ for the LM2905 and $0°C \le T_A \le +70°C$ for the LM3905 unless otherwise noted.

Note 3: Output pulse width can be calculated from the following equation: $t = (R_t)(C_r)[1 - 2(0.632 - r) - V_C/V_{REF}]$ where r is timing ratio and V_C is capacitor saturation voltage. This reduces to $t = (R_t)(C_t)$ for all but the most critical applications.

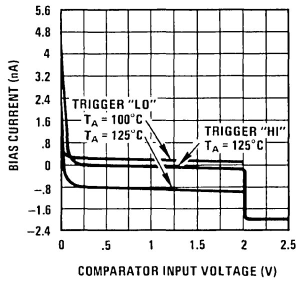
Note 4: Sign reversal may occur at high temperatures (> 70°C) where comparator input current is predominately leakage. See typical curves.

typical performance characteristics

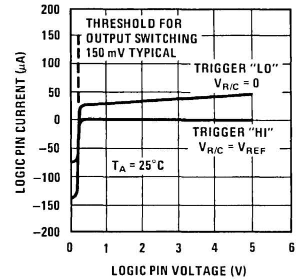
Comparator Bias Current



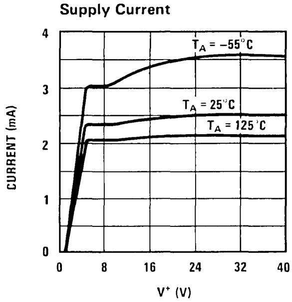
Comparator Bias Current



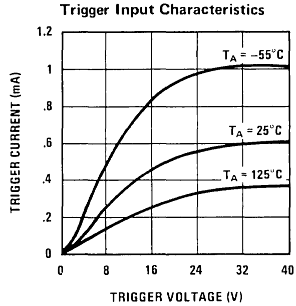
Logic Pin Characteristics



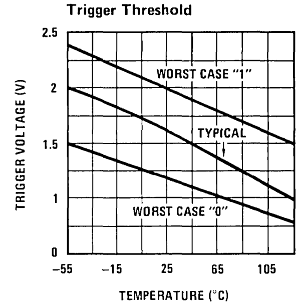
Supply Current



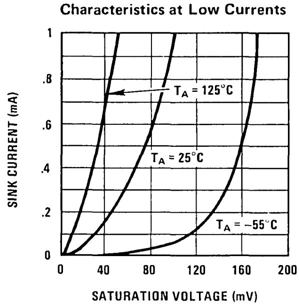
Trigger Input Characteristics



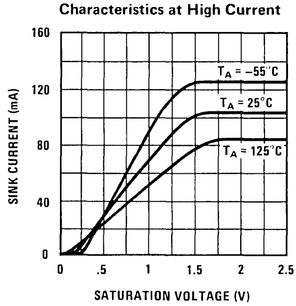
Trigger Threshold



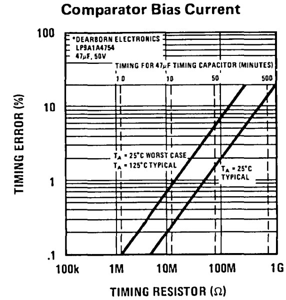
Output Transistor Saturation Characteristics at Low Currents



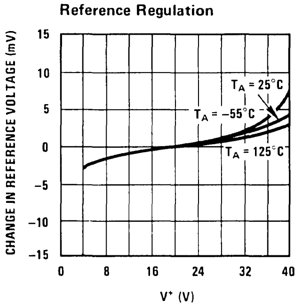
Collector Output Saturation Characteristics at High Current



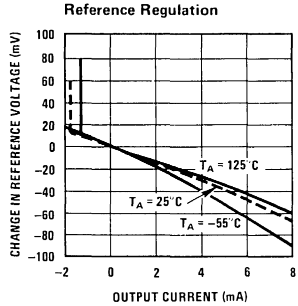
Timing Error Due to Comparator Bias Current



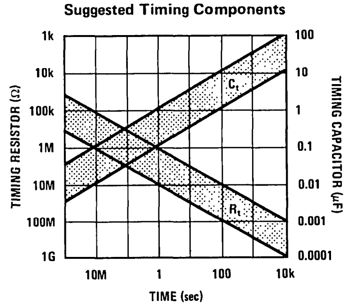
Reference Regulation



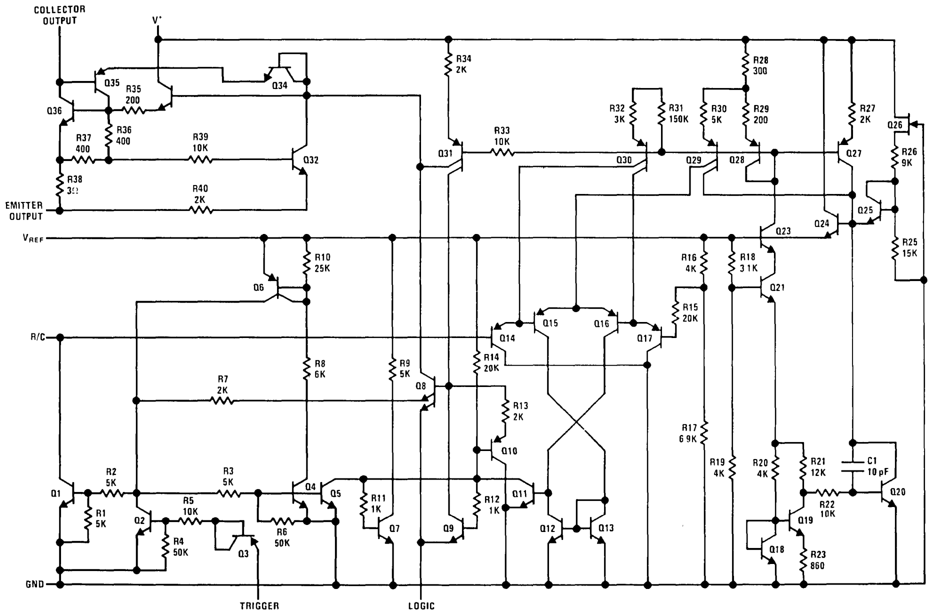
Reference Regulation



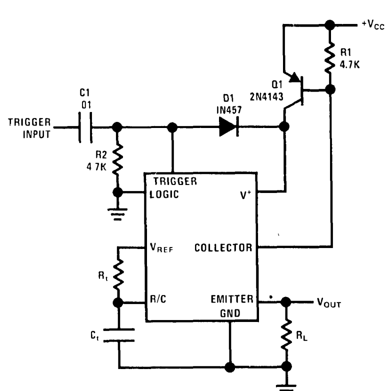
Suggested Timing Components



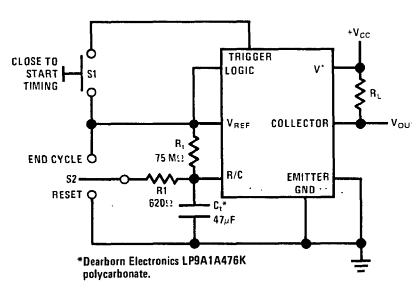
schematic diagram



typical applications(con't)

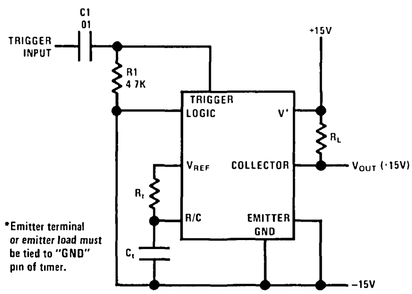


Zero Power Dissipation Between Timing Intervals

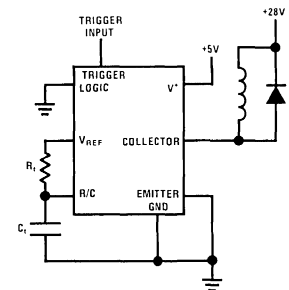


One Hour Timer with Reset & Manual Cycle End

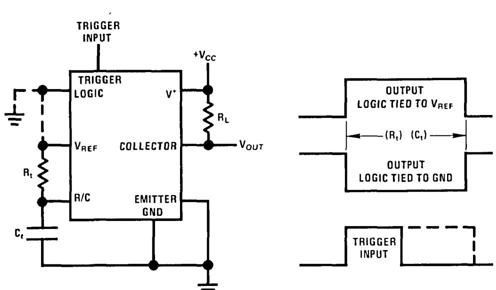
typical applications (con't)



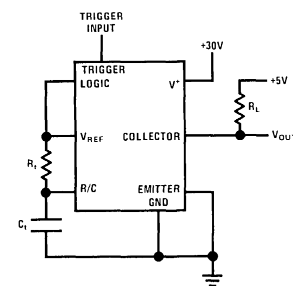
Operating off ±15V Supplies*



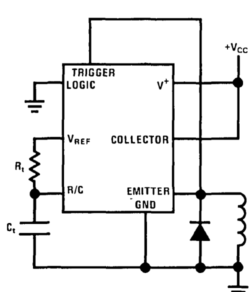
5V Logic Supply Driving 28V Relay



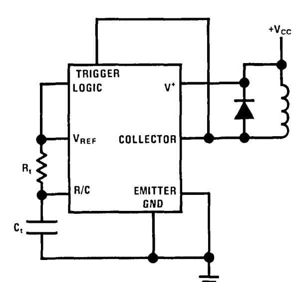
Basic Timer-Collector Output and Timing Chart



30V Supply Interfacing to 5V Logic

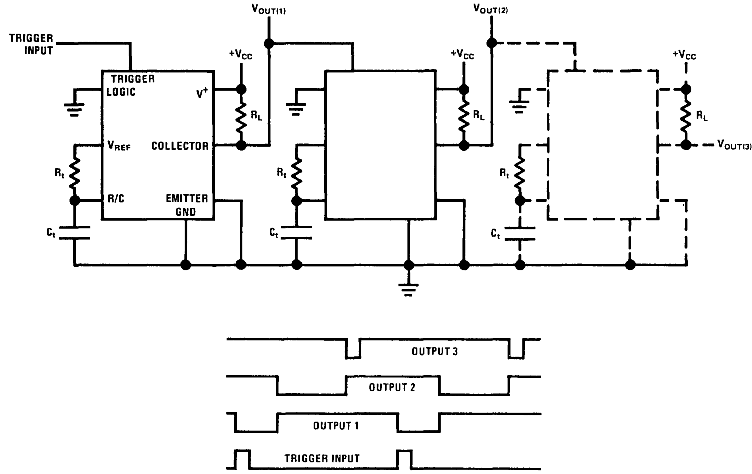


Time Out On Power Up
Relay Energized Until R_t C_t Seconds After V_{CC} is Applied

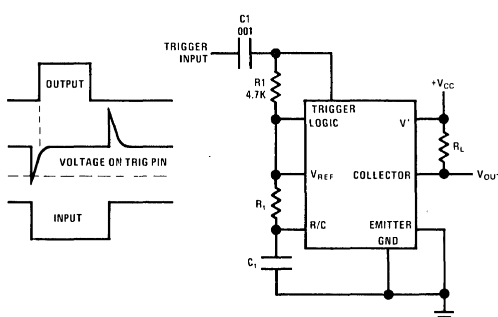


Time Out On Power Up
Relay Energized R_t C_t Seconds After V_{CC} is Applied

typical applications (con't)



Chain of Timers and Timing Chart



Timer Triggered by Negative Edge of Input Pulse

LM170/LM270/LM370 agc/squelch amplifier

general description

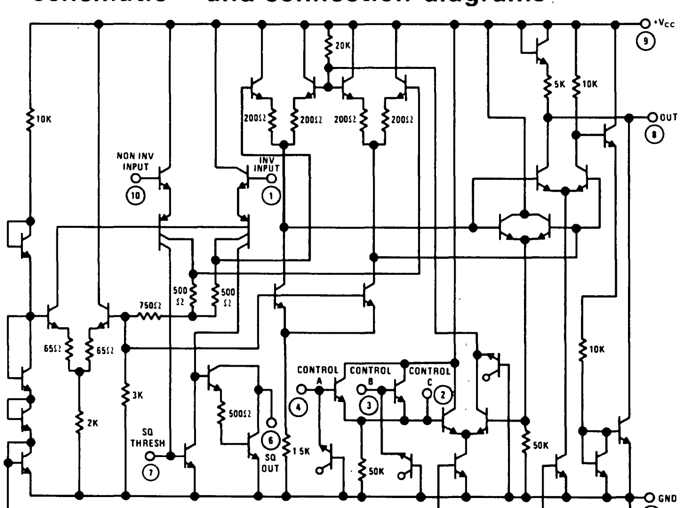
The LM170 is a direct coupled monolithic amplifier whose voltage gain is controlled by an external DC voltage. The device features:

- Large Gain Control Range
- Self-contained AGC/Squelch system, with fast-attack, slow-release.
- Low Distortion
- Minimum DC output shift as gain is varied
- Differential inputs, with large common-mode input range
- Outputs of several amplifiers may be directly summed in multichannel systems.
- Dissipates only 18 mW from +4.5V supply, usable with supply up to +24V.
- Sensitive squelch threshold set by single external resistor.

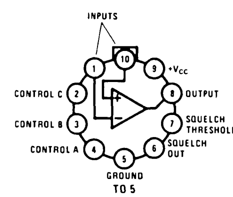
In addition to communication system squelch and AGC applications, the LM170 is useful as constant-amplitude audio oscillator, linear low frequency modulator, single-sideband automatic load control, and as a variable DC gain element in analog computation.

The LM170 is specified for operation over the −55°C to +125°C military temperature range. The LM270 is specified for operation over the −25°C to +75°C temperature range. The LM370 is specified for operation over the 0°C to +70°C temperature range.

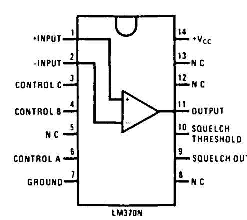
schematic** and connection diagrams



Circled numbers are pin connections.



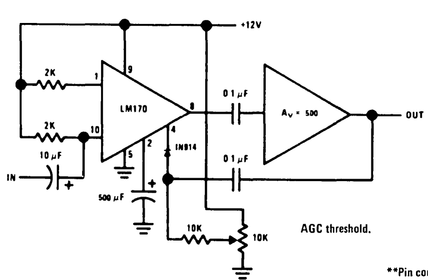
Order Number LM170H or LM270H or LM370H
See Package 14



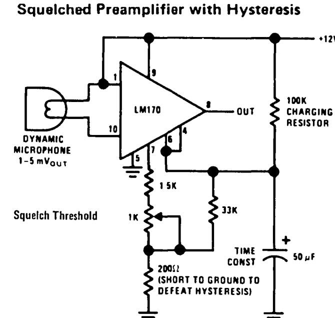
Order Number LM370N
See Package 22

typical applications**

AGC Using Built-in Detection, Driven By Additional System Gain



Squelched Preamplifier with Hysteresis



**Pin connections shown are for metal can.

absolute maximum ratings

Supply Voltage	24V
Storage Temperature	-65°C to +150°C
Operating Temperature LM170	-55°C to +125°C
LM270	-25°C to +75°C
LM370	0°C to +70°C
Differential Input Voltage	±19.5V
Common-mode Input Voltage	(V_{CC} + 0.4)V
Output Short Circuit Duration	Indefinite
Voltage applied to Pin 3 or 4	+6.0V
Voltage applied to Pin 2	+12.0V
Surge power into Pin 6 (1 second max.)	1000 mW
Continuous power into Pin 6	100 mW

electrical characteristics (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DC CHARACTERISTICS						
DC Output Voltage	$V_O(DC)$	V_{IN} (dd) = 0, V (gain control) = 0	+5.0	+6.0	+7.0	V
DC Output Voltage	$V_O(DC)$	V_{IN} (dd) = 0 V (gain control) = +3.0	+5.0	+6.0	+7.0	V
DC Output Shift	$\Delta V_O(DC)$	V_{IN} (dd) = 0 V (gain control) changed from 0 to +3.0V				
		LM170	-200	0	+200	mV
		LM270	-500	0	+500	mV
		LM370	-1000	0	1000	
Power Supply Drain	I_{PS}	V_{CC} = +24V		13.5		mA
		V_{CC} = +4.5V		4.0		
		V_{CC} = +12V LM170, 270		8.0	10.0	mA
		LM370		8.0	12.0	mA
Input Bias Current	I_{IB}	LM170, 270		5.0	10.0	μA
		LM370		5.0	12.0	
AC CHARACTERISTICS						
Voltage Gain	A_V	V (gain control) = 0				
		LM170, 270	37.5	40.0		
		LM370	35.0	40.0		dB
		f = 1 KHz				
Gain Reduction Range	ΔA_V	V (gain control) changed from 0 to +3.0V. Gain reduction occurs for control voltages between +2.1 and +2.5 volts, pin 3 or pin 4. f = 1 KHz		-80.0		dB

Note 1: T_A = 25°C, V_{CC} = +12V, $V_{IN(cm)}$ = +6V.

operating notes

Voltage gain is continuously variable from a maximum value, dependent upon supply voltage, to a minimum value, by application of a DC control voltage at Pin 3 or 4. DC output voltage is substantially independent of gain changes, provided that differential DC input voltage is minimized, so that direct-coupled or fast gain-control operation is possible with minimum disturbance of succeeding amplifiers.

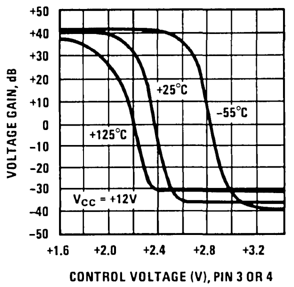
Input characteristics are similar to those of an operational amplifier, with common-mode input range extending from +4.5 volts up to and including the positive supply voltage. Lowest distortion occurs at input levels of 20 mV p-p or less. Outputs of several amplifiers, which will have quiescent DC levels approximately half of the positive supply, may be directly connected together in multi-channel summing systems, without damage.

Emitter-follower control inputs, Pins 3 and 4, may be used as positive peak detectors by connecting a smoothing capacitor at Pin 2, in AGC applications.

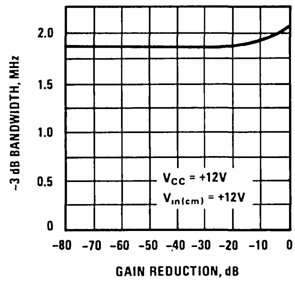
A sensitive squelch detector, independent of the amplifier's gain, provides fast-attack, slow release control at Pin 6, with threshold set by an external resistance from Pin 7 to ground. Injecting a portion of the control voltage at Pin 6 into this threshold results in a hysteresis, reducing response to erratic inputs. Since threshold is dependent on DC levels, differential DC input voltage should be held constant for squelch operation.

variable gain characteristics

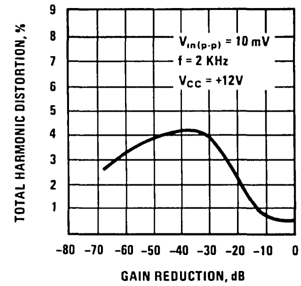
Voltage Gain vs Control Voltage



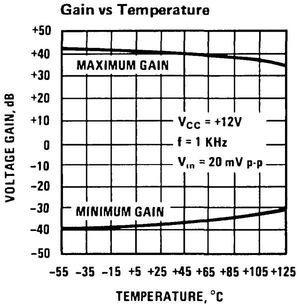
Bandwidth vs Gain Reduction



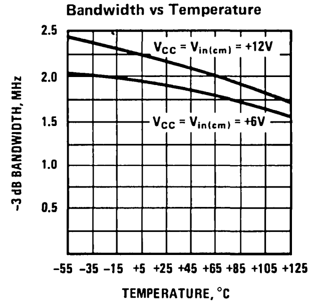
Total Harmonic Distortion vs Gain Reduction



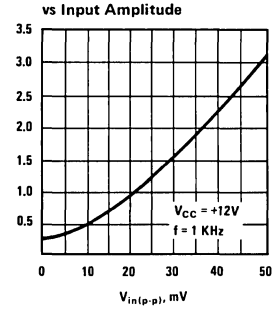
Maximum and Minimum Voltage Gain vs Temperature



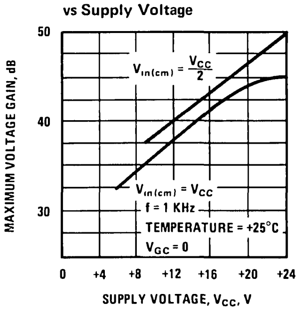
Bandwidth vs Temperature



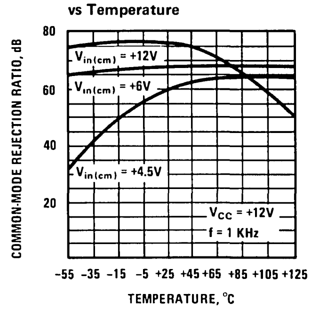
Total Harmonic Distortion vs Input Amplitude



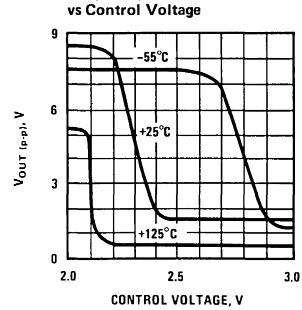
Maximum Voltage Gain vs Supply Voltage



Common-Mode Rejection Ratio vs Temperature

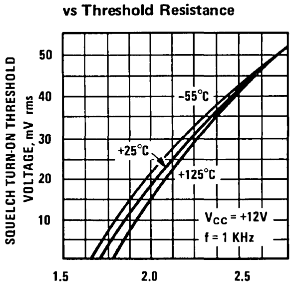


Output Dynamic Range vs Control Voltage

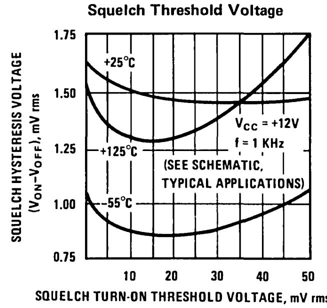


squelch characteristics

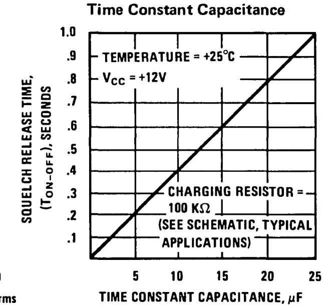
Squelch Threshold Voltage vs Threshold Resistance



Squelch Hysteresis Voltage vs Squelch Threshold Voltage



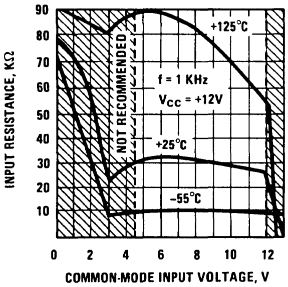
Squelch Release Time vs Time Constant Capacitance



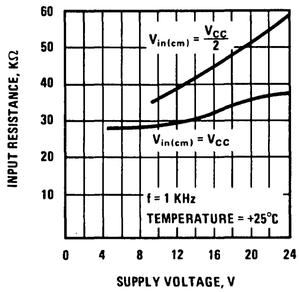
5

input and output characteristics

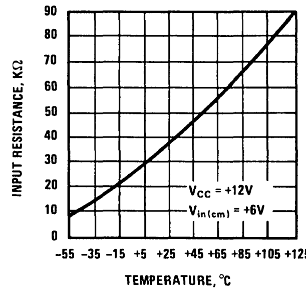
Input Resistance vs Common-Mode Input Voltage



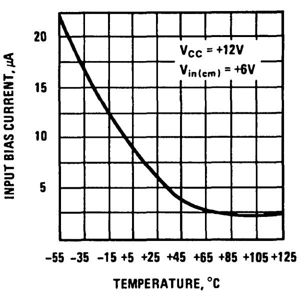
Input Resistance vs Supply Voltage



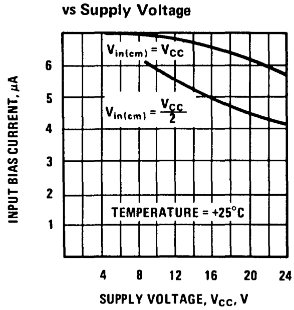
Input Resistance vs Temperature



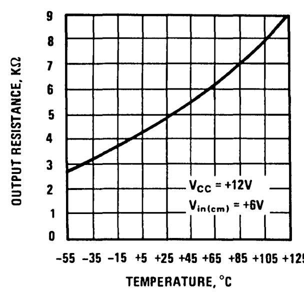
Input Bias Current vs Temperature



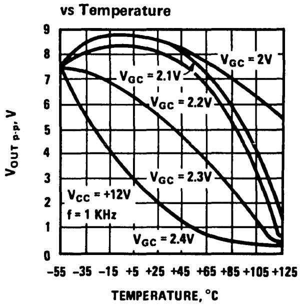
Input Bias Current vs Supply Voltage



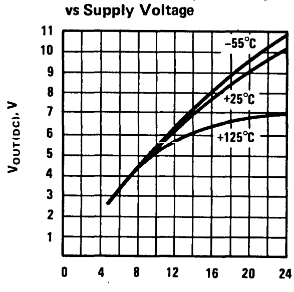
Output Resistance vs Temperature



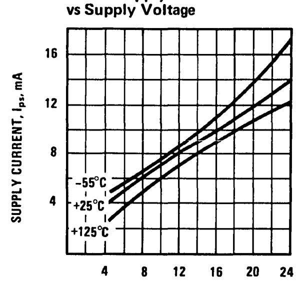
Output Dynamic Range vs Temperature



Quiescent DC Output Voltage vs Supply Voltage



Power Supply Current vs Supply Voltage



Consumer Circuits

LM171/LM271/LM371 integrated rf/if amplifier

general description

The LM171/LM271/LM371 is a monolithic RF-IF amplifier capable of emitter coupled or cascode operation from DC to 250 MHz. Wide versatility is offered by having all inputs and outputs brought out so many circuit configurations are possible.

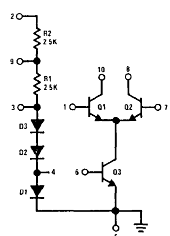
features

- Low internal feedback, allowing high stability-limited gain
- Versatility through user-connected configurations
- As emitter coupled amplifier, symmetrical, non-saturated limiting
- As cascode, wide AGC range with constant input admittance
- As differential DC amplifier, low input offset voltage and wide dynamic range
- As video amplifier, externally selected gain, and high gain-bandwidth product
- 100 MHz tuned power gain

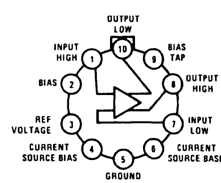
(Emitter Coupled)	24.6 dB
(Cascode)	27.5 dB

In addition to amplifier service, the circuit is useful in mixer, oscillator, detector, modulator, and numerous other applications. The LM271 is a plug-in replacement for the 911C type.

schematic and connection diagrams



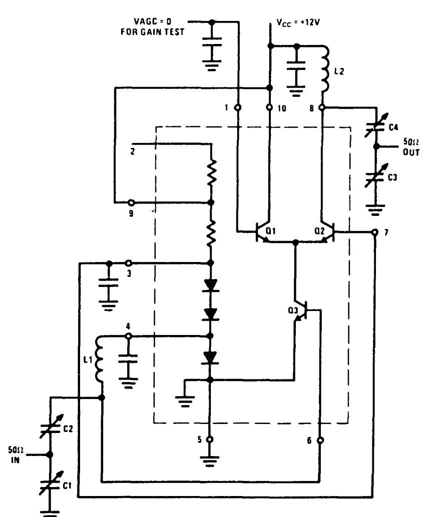
Metal Can Package



Order Number LM171H
or LM271H or LM371H
See Package 14

typical applications

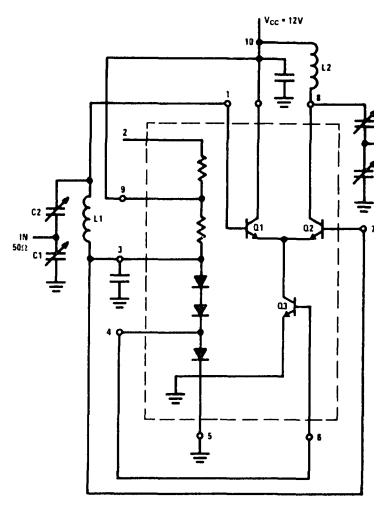
100 MHz Cascode Test Circuit



C1 = C3 = 9-36 pF trimmer. L1 = L2 = 7 t. #16 a.w.g.
C2 = C4 = 2-8 pF trimmer. Spaced 1 turn, 1/4" inside diam.

FIGURE 1

100 MHz Emitter Coupled Test Circuit



C1 = C3 = 9-36 pF trimmer. L1 = L2 7 t. #16 a.w.g.
C2 = C4 = 2-8 pF trimmer. Spaced 1 turn, 1/4" inside diag.

FIGURE 2

Note: All unmarked bypass capacitors 1000 pF.

absolute maximum ratings

Supply Surge Voltage		30V
Supply Operating Voltage		24V
Storage Temperature		−65°C to +150°C
Operating Temperature	LM171	−55°C to +125°C
	LM271	0°C to +100°C
Power Dissipation		230 mW
Voltage Between 1 and 7		±5V
Voltage Between 4 and 6		±5V

electrical characteristics These specifications apply for $V^+ = +12V$ and $T_A = 25°C$

PARAMETER	CONDITIONS	LM171			LM271			LM371			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
DC CHARACTERISTICS											
Input Offset Voltage (V_{OS})	$I_8 = I_{10} = 500\ \mu A$			3			3			10	mV
Input Bias Current (I_{BIAS})		1.30		2.65	1.3		2.65	1.3		2.65	mA
Ratio of R1/R2		0.895		1.12	0.895		1.12	0.895		0.895	
Voltage at Pin 3 (V_3)	$V_2 = +12V$	2.0			2.0			2.0			V
Current Through Current Source Q3 (I_C)	$I_C = I_8 + I_{10}$	2.45		5.70	2.45		5.70	2.45		5.70	mA
Current Gain (β)		40			40			40			
Power Supply Current Drain (I_{PS})	$I_{PS} = I_{BIAS} + I_8 + I_{10}$			9.0			9.0			10.5	mA

EMITTER COUPLED CHARACTERISTICS (Input Signal < 10 mVrms) LM171, LM271, LM371

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Conductance (G_{11})	455 kHz		0.30	0.40	mmhos
Output Conductance (G_{22})	455 kHz		0.01	0.04	mmhos
Magnitude of Forward Transadmittance ($\|Y_{21}\|$)	455 kHz	17.0	27.0		mmhos
Magnitude of Reverse Transadmittance ($\|Y_{12}\|$)	200 MHz		0.1		mmhos
Tuned Power Gain (A_P)	10.7 MHz BW = 470 kHz		24.6		dB
Tuned Power Gain (A_P)	100 MHz BW = 5 MHz		22.7		dB

CASCODE CHARACTERISTICS (Input Signal < 10 mVrms) LM171, LM271, LM371

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Conductance (G_{11})	455 kHz		1.1	2.5	mmhos
Output Conductance (G_{22})	455 kHz Connect Pin 1 to 7		0.01	0.04	mmhos
Magnitude of Forward Transadmittance ($\|Y_{21}\|$)	455 kHz Pin 1 GND	25.0	50.0		mmhos
Magnitude of Reverse Transadmittance ($\|Y_{12}\|$)	200 MHz 100 MHz		0.001		mmhos
Tuned Power Gain (A_P)	Pin 1 GND BW = 5 MHz		27.5		dB
Tuned Power Gain (A_P)	Pin 1 GND BW = 6 MHz		25.0		dB

THE FOLLOWING PARAMETERS APPLY FOR THE LM171 FOR $-55°C < T_A < +125°C$

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Magnitude of Forward Transadmittance (Emitter Coupled) ($\|Y_{21}\|$)	455 kHz e_{in} < 10 mV rms	17.0			mmhos
Magnitude of Forward Transadmittance (Cascode) ($\|Y_{21}\|$)	455 kHz e_{in} < 10 mV rms Pin 1 GND	21.0			mmhos

biasing considerations

The active portion of the 171 is biased by monolithic matching of constant-current transistor Q3 and diode D1. R1 and R2 may be connected in one of four ways to force a current from V_{CC} through three diodes. Alternatively, an external resistor may be used. If pin 4 is connected to pin 6, directly, or through an inductor or resistor having less than 100 ohms DC resistance, the current drawn by Q3 will approximately equal that forced through D1.

Pin 3 may be used as a DC reference voltage, to bias pins 1 and 7, and is approximately the minimum voltage required to guarantee proper current source collector characteristics.

Typical Biasing for Emitter Coupled Amplifier

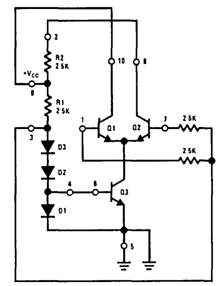
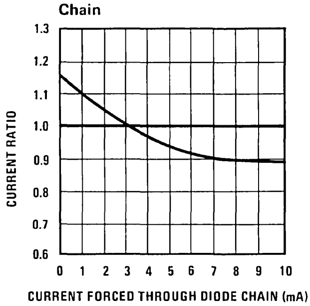
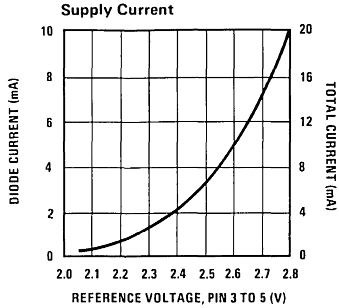


FIGURE 3

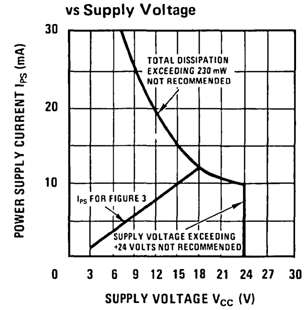
Current Source – Diode Current Ratio vs Current Forced Through Diode Chain



DC Reference Voltage (3 to 5) vs Diode Chain Current and Supply Current

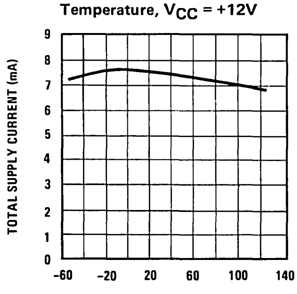


Total Supply Current vs Supply Voltage

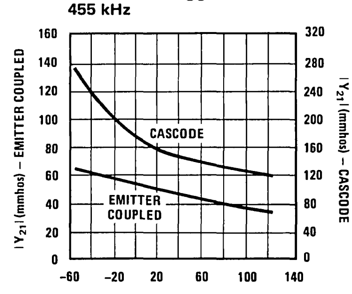


typical temperature characteristics

Total Supply Current vs Temperature, V_{CC} = +12V



Magnitude of Forward Transadmittance vs Temperature, V_{CC} = +12V, 455 kHz



cascode configuration

The common-emitter, common-base, or cascode, configuration is useful as a tuned RF or IF amplifier to 250 MHz. Two common-base stages are formed by the differential pair, Q1 and Q2, which may be used as a gain control system by applying a differential gain oontrol voltage between pins 1 and 7. With Q1 cut off, maximum gain is obtained, being reduced as Q1 is progressively turned on and Q2 turned off. The input common-emitter transistor presents a nearly constant input admittance as AGC is applied.

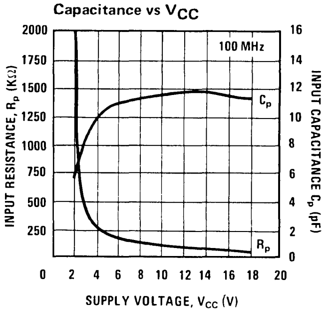
DC input bias is obtained through the input inductor from the bias chain, pin 4.

Pin 3 may be used as the DC reference for the AGC input, to assure adequate bias voltage for the collector of Q3. Where large AGC voltages are used, an external resistive divider, from pin 3 to 1 to the

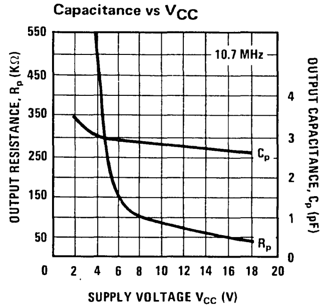
AGC voltage may be used to optimize the DC AGC requirements. VAGC is defined as the voltage between pin 1 and 7.

At some frequencies, bypassing may be required at pins 1, 3, 4 or the V_{CC} connection.

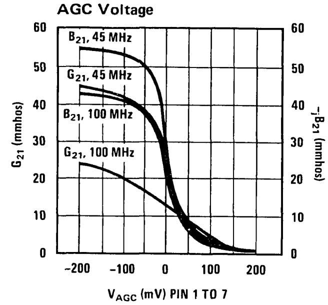
Input Resistance and Capacitance vs V_{CC}



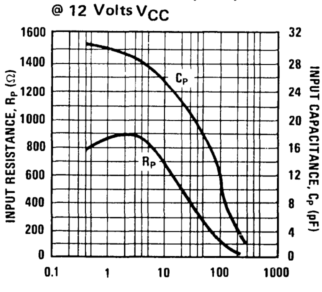
Output Resistance and Capacitance vs V_{CC}



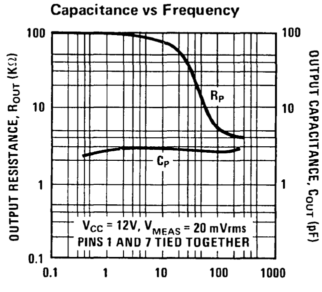
Forward Transadmittance vs AGC Voltage



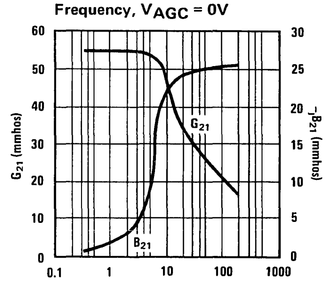
Input Resistance and Capacitance vs Frequency @ 12 Volts V_{CC}



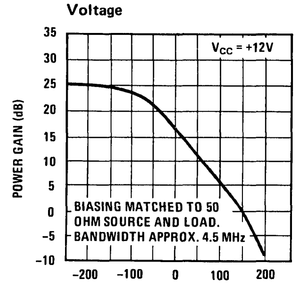
Output Resistance and Capacitance vs Frequency



Forward Transadmittance vs Frequency, V_{AGC} = 0V



Tuned Power Gain vs AGC Voltage



emitter coupled configuration

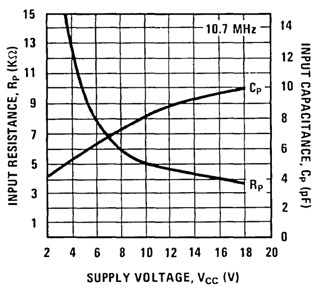
The common-collector, common-base, or emitter-coupled configuration is useful as a symmetrically non-saturated limiting RF or IF amplifier to 150 MHz. Basically a differential amplifier, this configuration is especially suited to FM IF strips using conventional interstage tuning. While available gain is lower and noise figure higher than the cascode, emitter coupled operation may be considered wherever fast recovery from large-signal overdrive or excellent AM rejection is required.

Q3 is used as a current source, obtaining its bias from the diode chain. Current available from Q3 is shunted through Q1 or Q2, depending on input signal, and is equally divided when no signal is present, assuring inherently symmetrical operation. DC bias for pin 7 is obtained from the divider chain, and through the input inductor, the same bias is applied to pin 1.

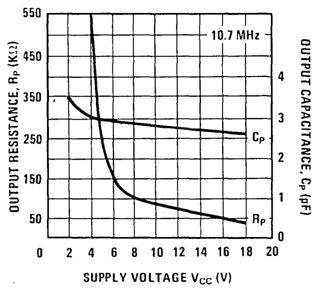
For non-saturated operation, the output load must be chosen so that the collector voltage of the output transistor is higher than the DC reference voltage, with all source current shunted into the output, for the particular bias levels used.

At some frequencies, bypassing of pins 3, 6, 7, or the V_{CC} connection may be required.

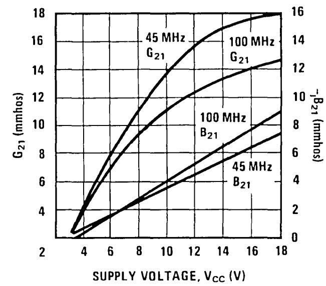
Input Resistance and Capacitance vs V_{CC}



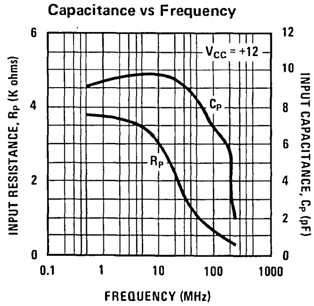
Output Resistance and Capacitance vs V_{CC}



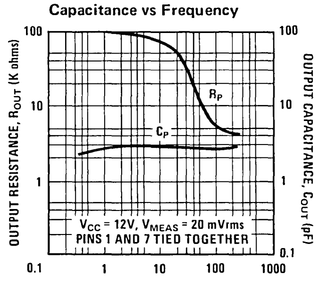
Forward Transadmittance vs V_{CC}



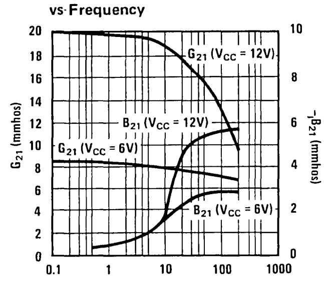
Input Resistance and Capacitance vs Frequency



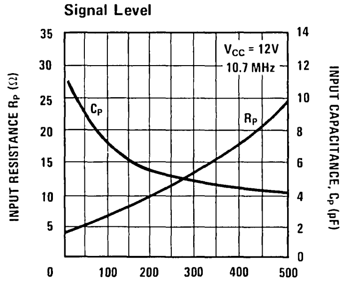
Output Resistance and Capacitance vs Frequency



Forward Transadmittance vs Frequency



Input Resistance and Capacitance vs Input Signal Level



dc, audio and video configuration

Convenient self-contained biasing, excellent monolithic matching, and high gain-bandwidth product make a wide variety of applications possible using resistive loads.

The biasing shown in Figure 3 uses R2 as collector load for a single-ended output, differential input amplifier. By choosing the proper external load resistor, bias configuration, and supply voltage, video amplifiers may be constructed to meet specific gain and bandwidth requirements, in either cascode or emitter coupled form.

With matched pairs of external load resistors, true differential DC amplifiers may be constructed, with large common-mode input range, input offset voltages typically 0.3 mV, and monolithically matched, self-contained current sources easily tailored to specific operating point requirements.

Direct Coupled Test Circuit (Connect R_L Between Pins 8 and 10, or Connect Pin 2 to 8 for Internal R_L)

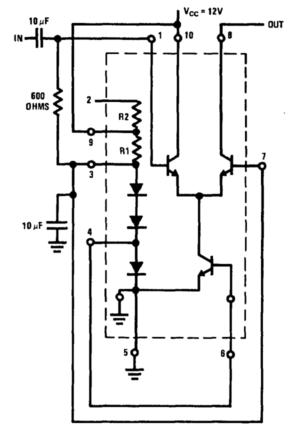
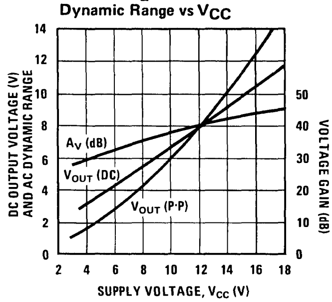
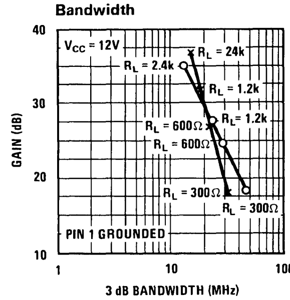


FIGURE 4

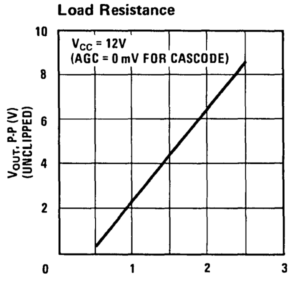
Voltage Gain, DC Output Voltage (R_L = R2) & Dynamic Range vs V_{CC}



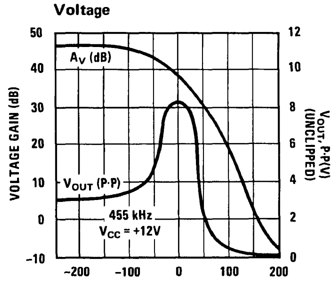
Cascode and Emitter Coupled Video Amplifiers Voltage Gain and Load Resistance vs Bandwidth



Cascode & Emitter Coupled Video Amplifiers Dynamic Range vs Load Resistance



Cascode Video Amplifier Voltage Gain & Dynamic Range vs AGC Voltage



Consumer Circuits

LM172/LM272/LM372 am if strip

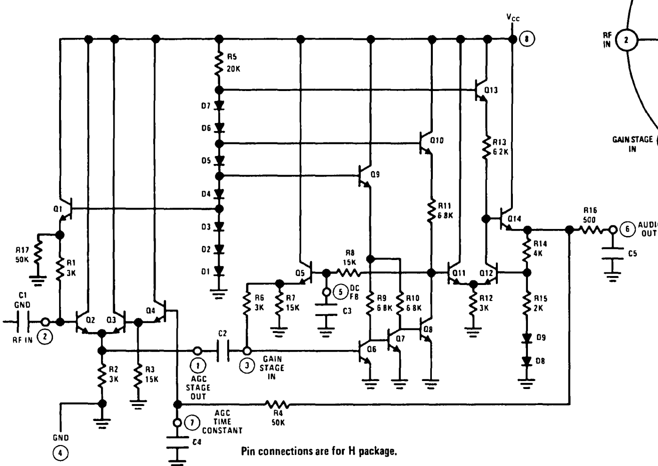
general description

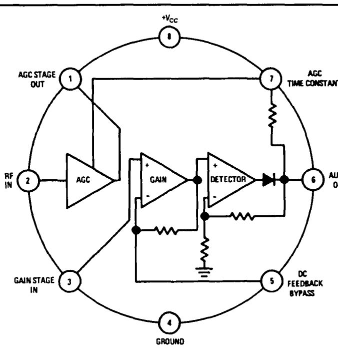
The LM172/LM272/LM372 is a broadband AM receiver subsystem, including a high gain amplifier, an active detector, and self-contained automatic gain control. It is intended for IF or TRF applications from 50 kHz to 2 MHz. Bandpass shaping is performed by a single, external filter, which may be ceramic, crystal, mechanical, or LC, having single or multiple poles. The IF strip features:

- AGC Range: 60 dB
- Audio Output of 0.8V p-p for 80% modulated inputs, at carrier levels as low as 50 μV rms.
- Total dissipation only 8.4 mW from +6V supply, usable with supply up to +15V.
- AGC time constant and audio frequency response selected by choice of external capacitors.
- Internal supply regulators eliminate individual stage decoupling.
- AGC voltage available to drive receiver "front end."

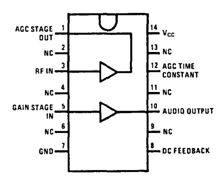
The LM172 is specified for operation over the −55°C to +125°C military temperature range. The LM272 is specified for operation over the −25°C to +75°C temperature range. The LM372 is specified for operation over the 0°C to +70°C temperature range.

schematic and connection diagrams



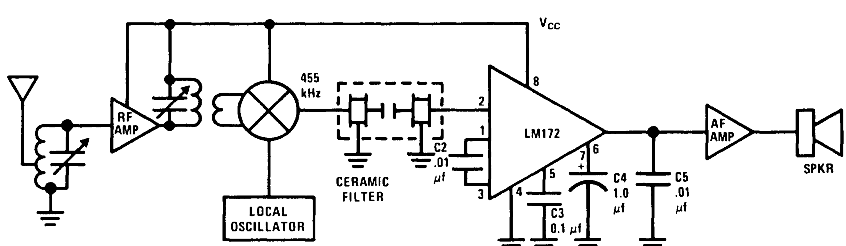


Order Number LM172H or LM272H or LM372H
See Package 11



Order Number LM272N or LM372N
See Package 22

typical application



5

absolute maxium ratings

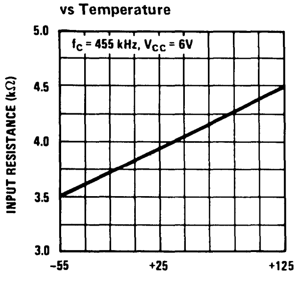
Supply Voltage Range		+6V to +15V
Storage Temperature		$-65^\circ C$ to $+150^\circ C$
Operating Temperature	LM172	$-55^\circ C$ to $+125^\circ C$
	LM272	$-25^\circ C$ to $+75^\circ C$
	LM372	$0^\circ C$ to $+70^\circ C$
RF Input Level, Pin 2		500 mV rms

electrical characteristics ($T_A = 25^\circ C$)

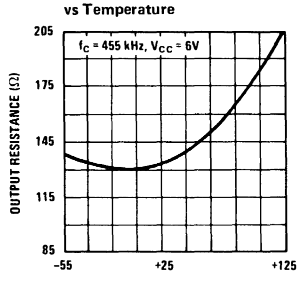
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Power Supply Drain	I_{ps}	V_{CC} = 6V, Input = 50 mV f = 455 kHz		1.4		mA
		V_{CC} = 6V, Input = 50 μV f = 455 kHz		1.7		mA
		V_{CC} = 15V, Input = 50 mV f = 455 kHz				
		LM172/272		2.5	2.65	mA
		LM372		2.5	3.2	mA
AGC Range	AGCR	V_{CC} = 6V, f = 455 kHz				
		LM172/272	50	69		dB
		LM372	47	69		dB
AGC Threshold	V_{IN}(th)	V_{CC} = 6V, f = 455 kHz		50		μV, rms
Maximum Usable Frequency	MUF	V_{CC} = 6V		2.0		MHz
Audio Output Voltage	V_{OUT}	V_{IN} Between 50 μV and 50 mV, 455 kHz, 80% modulated by 100 Hz,				
		V_{CC} = 6V				
		LM172/272	0.4	0.8		V, p-p
		LM372	0.35	0.8		V, p-p
		V_{CC} = 15V				
		LM172/272	0.45	0.9		V, p-p
		LM372	0.40	0.9		V, p-p

input-output impedance characteristics

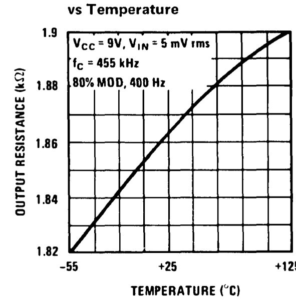
AGC Stage Input Resistance vs Temperature



AGC Stage Output Resistance vs Temperature

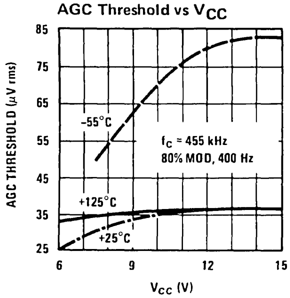


Detector Output Resistance vs Temperature

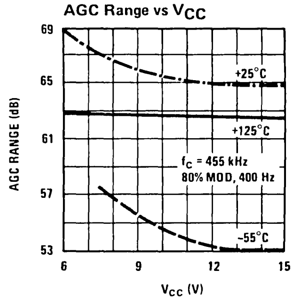


typical characteristics

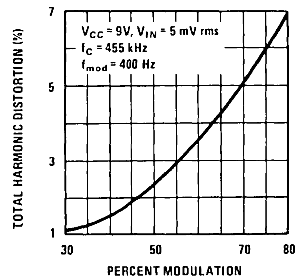
AGC Threshold vs V_{CC}



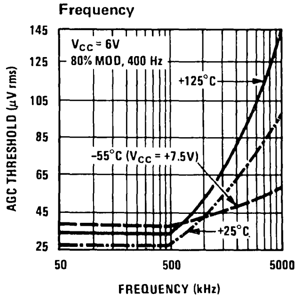
AGC Range vs V_{CC}



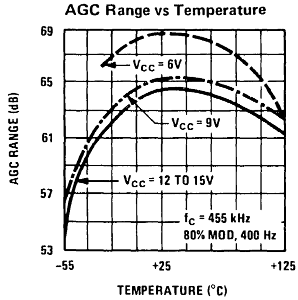
Audio Distortion vs % Modulation



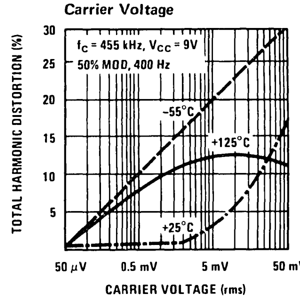
AGC Threshold vs Carrier Frequency



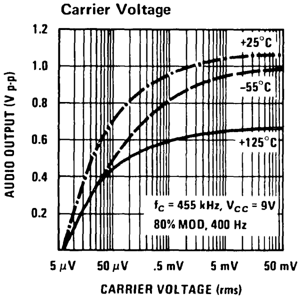
AGC Range vs Temperature



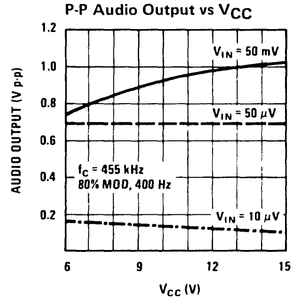
Audio Distortion vs Input Carrier Voltage



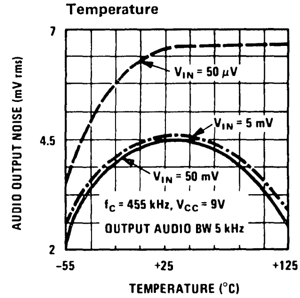
P-P Audio Output vs Input Carrier Voltage



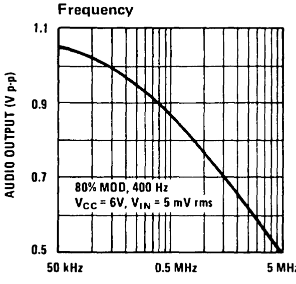
P-P Audio Output vs V_{CC}



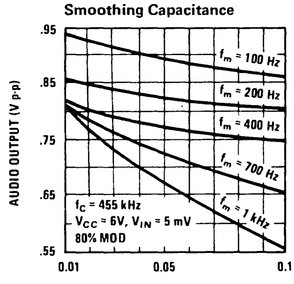
Audio Output Noise vs Temperature



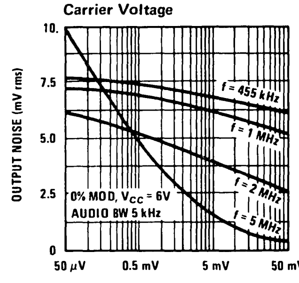
P-P Audio Output vs Carrier Frequency



P-P Audio Output vs Output Smoothing Capacitance

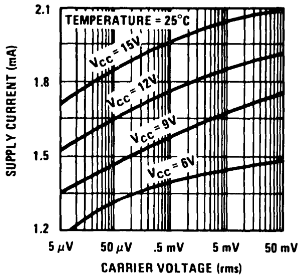


Audio Output Noise vs Input Carrier Voltage

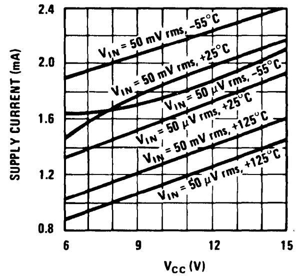


power supply characteristics

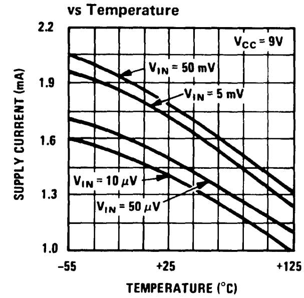
Power Supply Current vs Input Carrier Voltage



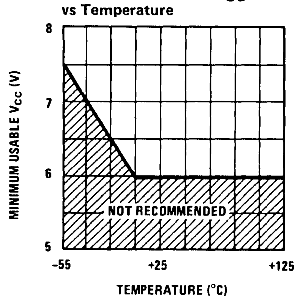
Power Supply Current vs V_{CC}



Power Supply Current vs Temperature



Minimum Operating V_{CC} vs Temperature



Consumer Circuits

LM273/LM373 am/fm/ssb if amp/detector
LM274/LM374 am/fm/ssb if video amp/detector

general description

The LM273/LM373 and LM274/LM374 are broadband communications subsystems, capable of performing the diverse functions required in AM, FM or single sideband receivers and transmitters. In addition, the LM274/LM374 may operate as high gain AGC'd video amplifier. Bandpass shaping may be performed by a single external filter, connected between amplifier sections, at frequencies from audio up to 30 MHz. The first section of the LM273/LM373 is optimized to drive low impedance loads, such as mechanical or ceramic filters. The LM274/LM374 has a high output impedance, ideal for high-Z crystal, LC or ceramic filters.

The LM273 and LM274 are specified for operation over the −25°C to +100°C military temperature range. The LM373 and LM374 are specified for operation over the 0°C to +70°C temperature range.

features

CONNECTED FOR AM OPERATION

- High gain; typical sensitivity of 10 μV at 455 kHz
- Wide bandwidth; 30 MHz capability
- Self-contained detector and AGC system
- Wide AGC range, greater than 60 dB for a 10 dB output change at 27 MHz
- Less than ±1 dB change in audio output −20°C to +100°C, typically
- Access to detector input for S/N improvement
- No DC paths required through external filters
- Low feedthrough between amplifier sections, typically better than 65 dB

CONNECTED FOR FM OPERATION

- Three emitter coupled limiting stages and simple quadrature detector
- Detection of ±5 kHz deviation FM at either 455 kHz or 10.7 MHz
- Two separated amplifier blocks, allowing filtering in two or more blocks
- No DC paths required through external filters or through quadrature network

CONNECTED FOR SSB OPERATION

- Double balanced product detector
- Self contained audio peak AGC system
- Easy external tailoring of AGC characteristic for desired AGC figure of merit

CONNECTED FOR VIDEO AMPLIFIER OPERATION

- Internal video peak detector for video AGC
- High and low level video outputs
- Gated video AGC capability

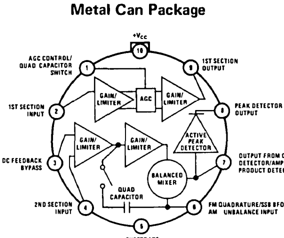
In addition, these versatile microcircuits may be used as:

- Constant amplitude or amplitude modulated RF oscillator
- Synchronous demodulating IF strip
- Mixer and IF, using AGC section as a mixer
- Double sideband modulator with audio AGC

5

connection diagrams

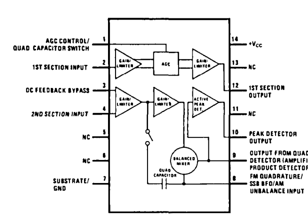
Metal Can Package



TOP VIEW

Order Number LM273H or LM373H
LM274H or LM374H
See Package 14

Dual-In-Line Package



TOP VIEW

Order Number LM373N or LM374N

See Package 22

absolute maximum ratings

Supply Voltage, Operating	18V	DC Voltage Applied to Any Other Pin	+8V, −0.5V
Supply Voltage, Surge (100 ms max)	24V	Junction Temperature (Note 1)	150°C
AC Voltage Applied to Any Pin	$1.4V_{p\text{-}p}$	Storage Temperature Range	−65°C to +150°C
DC Voltage Applied to AGC Section Output Pin		Operating Temperature Range	
LM273/LM373	+10V, −0.5V	LM273, LM274	−25°C to +100°C
LM274/LM374	+18V, −0.5V	LM373, LM374	0°C to +70°C

electrical characteristics

(T_A = 25°C, V_{CC} = +12V unless otherwise noted) (Subscript numbers in parentheses are DIP pin numbers)

DC CHARACTERISTICS

PARAMETER	SYMBOL	CONDITIONS	LM273/LM274			LM373/LM374			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Power Supply Current	$I_{10(14)}$	V_{CC} = 12V, AM Mode		14	20		14	20	mA
		$-20°C \leq T_A \leq +100°C$			21				mA
AGC Input Current	I_1	$V_{AGC} \leq 5V$		50	110		50	110	µA
		$-20°C \leq T_A \leq +100°C$			110				µA
AGC Section Quiescent Output	$V_{9(12)}$	V_{AGC} = 0V, LM273/LM373		4.75			4.75		V
	$I_{9(12)}$	V_{AGC} = 0V, LM274/LM374	0.5	0.7	1.0	0.5	0.7	1.0	mA
AGC Section Output Shift		V_{AGC} = 0V to V_{AGC} = 5V							
	$\Delta V_{9(12)}$	LM273/LM373		0.1			0.1		V
	$\Delta I_{9(12)}$	LM274/LM374		−0.1			−0.1		mA
Second Section Quiescent Output Voltage	$V_{7(9)}$			3.8			3.8		V
Peak Detector Quiescent Output Voltage	$V_{8(10)}$			3.8			3.8		V

VIDEO CHARACTERISTICS

PARAMETER	SYMBOL	CONDITIONS	LM273/LM274 MIN	TYP	MAX	LM373/LM374 MIN	TYP	MAX	UNITS
AGC Section Voltage Gain	$A_{2-9(11)}$	V_{AGC} = 0V, f = 455 kHz	30	32		29	32		dB
		V_{AGC} = 4.5V			−40			−40	dB
		$-20°C \leq T_A \leq 100°C$ LM273/LM373	28						dB
AGC Section Transconductance	$g_{m2-9(11)}$	V_{AGC} = 0V, f = 455 kHz	28	40		28	40		mmhos
		$-20°C \leq T_A \leq 100°C$ LM274/LM374	28						mmhos
AGC Section Bandwidth	BW_{AGC}	Z_L = 1k∥3 pF		30			30		MHz
AGC Section Output Swing	$V_{9(12)}\ max_{p\text{-}p}$	R_L = 1k, V_{AGC} = 0V, V_2 = ±300 mV,	0.95	1.4		0.78	1.4		$V_{p\text{-}p}$
		$-20°C \leq T_A \leq 100°C$	0.7						$V_{p\text{-}p}$
AGC Section Conversion Voltage Gain	$A_{C,AGC}$	f_1 = 30 MHz, f_2 = 30.455 MHz, e_2 = 800mVrms (See Figure 8)		22			22		dB
Second Section Voltage Gain	$A_{4-7(11)}$	f = 455 kHz	32.5	37	39	29.5	37	–	dB
		T_A = 100°C		31					
Second Section Bandwidth	BW_2	Z_L = 100k ∥3 pF		20			20		MHz
Second Section Output Swing	$V_{7(11)}\ max_{p\text{-}p}$	V_{3-4} = ±100 $mV_{p\text{-}p}$	0.93	1.4		.83	1.4		$V_{p\text{-}p}$
		$-20°C \leq T_A \leq 100°C$	0.75						$V_{p\text{-}p}$

AC PORT PARAMETERS (Typical, e_{IN} = 20 mVrms)

TERMINAL	LM273/LM373			LM274/LM374		
	f = 455 kHz	f = 10.7 MHz	f = 27 MHz	f = 455 kHz	f = 10.7 MHz	f = 27 MHz
2 (V_{AGC} = 0V)	1.2k ∥2.5 pF	1.2k ∥2.5 pF	1.15k ∥2.6 pF	1.2k ∥2.5 pF	1.2k ∥2.5 pF	1.15k ∥2.6 pF
2 (V_{AGC} = 5V)	1.18k ∥3 pF	1.18k ∥3 pF	1.1k ∥2.7 pF	1.18k ∥3 pF	1.18k ∥3 pF	1.1k ∥2.7 pF
4	4.5k ∥4 pF	5k ∥5 pF	4.3k ∥5.5 pF	4.5k ∥4 pF	5k ∥5 pF	4.3k ∥5.5 pF
6(8)	3.0k ∥7.7 pF	3.0k ∥7.7 pF	3.0k ∥8.0 pF	3.0k ∥7.7 pF	3.0k ∥7.7 pF	3.0k ∥8.0 pF
7(9)	1.0k ∥6 pF	1.0k ∥6 pF	1.0k ∥5 pF	1.0k ∥6 pF	1.0k ∥6 pF	1.0k ∥5 pF
9(12)	70Ω ∥−100 pF	60Ω ∥5 pF	200Ω ∥−90 pF	600k ∥5.5 pF	100k ∥3.3 pF	10k ∥3.5 pF

Note 1: For operation at elevated temperatures, derate devices based on 150°C maximum junction temperature and 150°C/W junction to ambient or 45°C/W junction to case thermal coefficients for the metal can.

electrical characteristics (con't)

TYPICAL AM PERFORMANCE (See Figures 1 and 2)

PARAMETER	CONDITIONS	f = 455 kHz	f = 10.7 MHz	f = 27 MHz	UNITS
Sensitivity	(Signal + Noise)/Noise = 10 dB	10	15	30	μVrms
AGC Threshold	Output 3 dB below extrapolated low level gain curve value for same input	35	55	110	μVrms
AGC Figure of Merit	Number (dB) input change from 100 mVrms for 10 dB output change	68	63	60	dB
Gain Control Range	V_1 = 0 to V_1 = +5V	80	70	66	dB
Audio Output	R_{AGC} = 2.4k, V_{IN} 100 mVrms f_m = 1 kHz, m = 0.7	100	100	100	mVrms
	As above, T_A = 100°C LM273 and LM274 only	90	90	90	mVrms
Signal to Noise Ratio	M = 0.7 to M = 0 e_{IN} = 30 mVrms	42	38	40	dB
Audio Distortion	M = 0.7, f_m = 1 kHz, e_{IN} = 10 mV	5	3.5	2.8	%

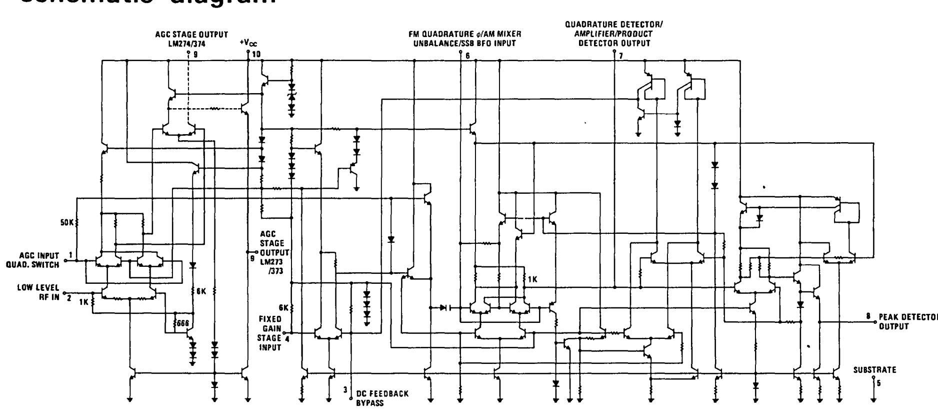
TYPICAL FM PERFORMANCE (See Figures 3 and 4)

PARAMETER	CONDITIONS	f = 455 kHz	f = 10.7 MHz	f = 27 MHz	UNITS
Limiting Threshold	e_O = 3 dB from value at e_{IN} = 100 mVrms				
	Δf = ±75 kHz		800	–	μVrms
	Δf = ±5 kHz	800	800	–	μVrms
AM Rejection Ratio	M_{fm} = 1, M_{am} = 0.3 e_{IN} = 10 mVrms				
	Δf = ±75 kHz		45	–	dB
	Δf = ±5 kHz	35		–	dB
Audio Output	e_{IN} = 10 mVrms				
	Δf = ±75 kHz		80	–	mVrms
	Δf = ±5 kHz	70	38	–	mVrms
	@ T_A = 100°C, Δf = ±75 kHz		50	–	mVrms
	@ T_A = 100°C, Δf = ±5 kHz LM273 and LM274 only	40	19	–	mVrms
Audio Distortion	e_{IN} = 10 mVrms				
	Δf = ±75 kHz		1.5	–	%
	Δf = ±5 kHz	2	1.0	–	%

TYPICAL SSB PERFORMANCE (See Figures 5 and 6)

PARAMETER	CONDITIONS	f = 455 kHz	f = 10.7 MHz	f = 27 MHz	UNITS
Sensitivity	(Signal + Noise)/Noise = 10 dB e_{LO} = 60 mVrms	25	30	60	μVrms
AGC Threshold	Same as AM	300	300	500	μVrms
AGC Figure of Merit	Same as for AM	60	60	50	dB
Audio Output Voltage	e_{IN} = 100 mVrms	60	80	85	mVrms
	T_A = 100°C LM273 and LM274 only	40	55	60	mVrms

schematic diagram

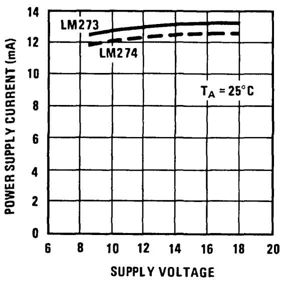


Pin connections shown are for TO-5 package only.

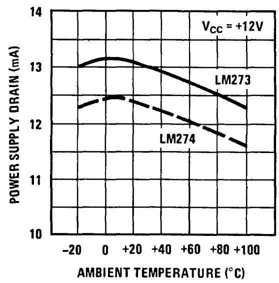
5

typical performance characteristics

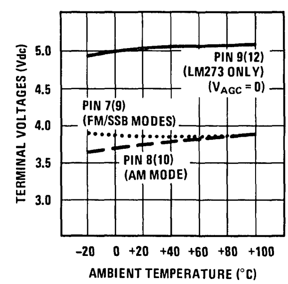
Power Supply Current vs Supply Voltage



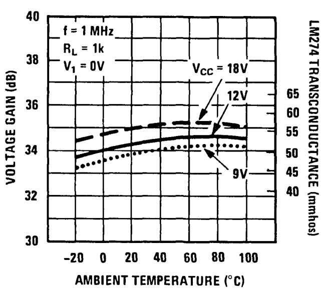
Power Supply Current vs Ambient Temperature



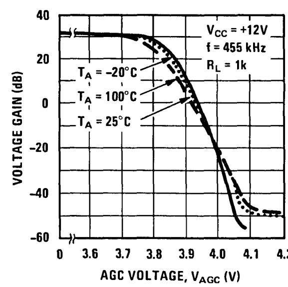
Output Terminal Voltage vs Temperature



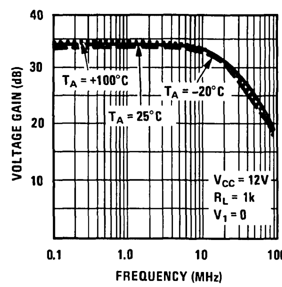
First Section Voltage Gain or Transconductance vs Temperature



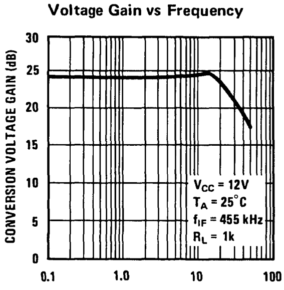
First Section Voltage Gain vs AGC Voltage



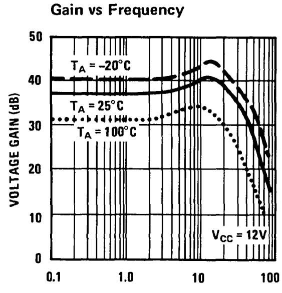
First Section Voltage Gain vs Frequency



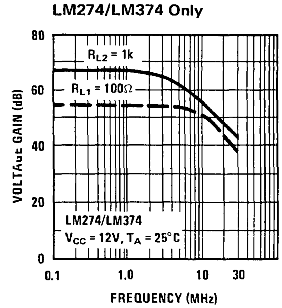
First Section Conversion Voltage Gain vs Frequency



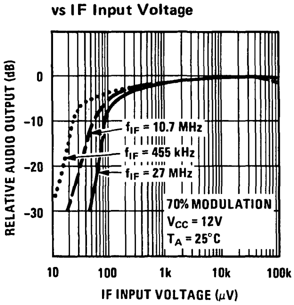
Second Section Voltage Gain vs Frequency



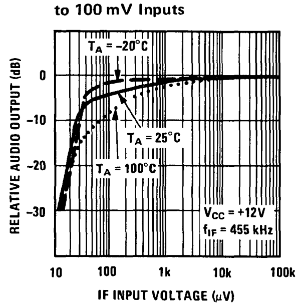
Cascaded Sections Video Gain vs Frequency, LM274/LM374 Only



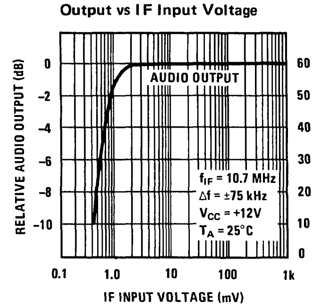
AM IF Audio Output vs IF Input Voltage



Relative AM Audio Output vs IF Input Voltage, Referred to 100 mV Inputs

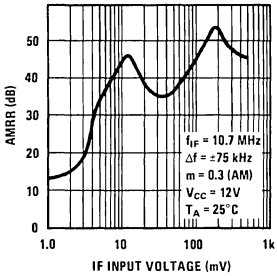


Wide Band FM Audio Output vs IF Input Voltage

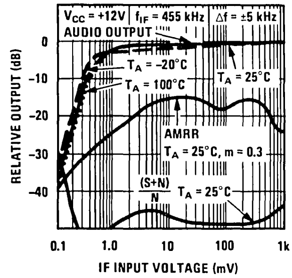


typical performance characteristics (con't)

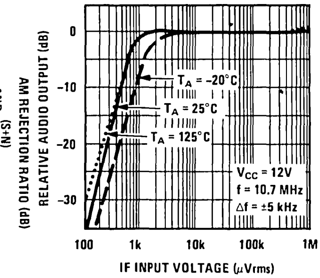
AM Rejection Ratio vs IF Input Voltage for Wide Band FM



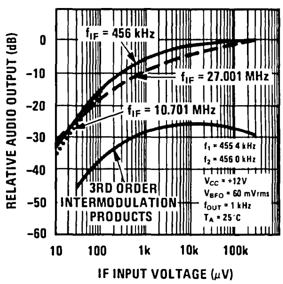
455 kHz NFM IF Audio Output, AM Rejection Ratio, and Signal to Noise vs IF Input Voltage



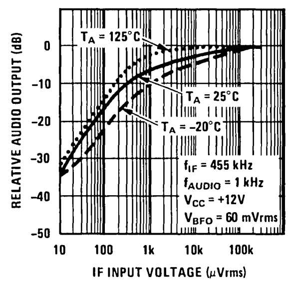
10.7 MHz NFM IF Audio Output vs IF Input Voltage



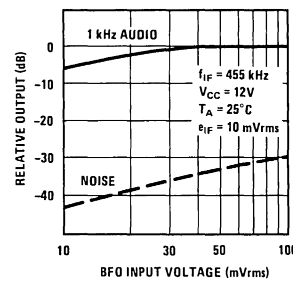
SSB IF Audio Output and Intermodulation Products vs IF Input Level



SSB IF Audio Output vs IF Input Voltage



SSB IF Audio Output vs BFO Voltage



APPLICATION HINTS

The LM273/LM373 and LM274/LM374 devices have been designed for stability and minimum usage of external components, while at the same time offering wide versatility through access to inputs and outputs of nearly every major functional block of the device. This makes possible the detection of AM, FM,and SSB signals with a single device with a minimum of circuitry switching. Experience has shown that for optimum performance of the multiple mode IF strip, the following suggestions should be noted.

First, as with any radio frequency gain device, proper layout and minimum lead length should be observed. The first gain block, Pin 2 to Pin 9, shows a typical gain of 32 dB and the second gain block, Pin 4 to Pin 7, shows a typical gain of 37 dB so it is clear why any stray coupling or long leads should be kept clear from any of the gain input pins. Despite it's high gain, however, the device does not require any shielding between stages. Construction on a copperclad printed circuit type board is more than adequate. It should also be observed that good power supply bypassing directly at Pin 10 and DC feedback bypassing at Pin 3 is always necessary.

The devices can be wide-band coupled to provide video gain response up to approximately 50 MHz. For AM operation, however, it is much more desirable to limit the IF bandwidths. This will greatly increase both input sensitivity and AGC figure of merit by preventing the device from AGCing on wideband detected noise. There are two ways of accomplishing this. One is to insert filtering from the first gain block to the second, Pin 9 to Pin 4, but the most effective way is to AC couple an L-C tank from the input of the active peak detector to ground. A lossy filter from Pin 9 to Pin 4 should be avoided as this will greatly reduce the audio output and AGC figure merit. In addition the tank on Pin 7 should have high enough Q to limit noise yet low enough to pass the full IF signal. It should also have a high enough impedance (>5k) to avoid affecting the gain of that stage. Proper audio output is attained by a small capacitor at Pin 8 to peak detect the RF envelope, followed by a series RC roll off to shape the audio response. Here again excessive loading will reduce available output. There is a trade off available between audio level out and AGC range so the feedback resistor from Pin 8 to the AGC feedback, Pin 1, should be adjusted to give the desired results. Pin 1 must be filtered well with approximately 15 μF capacitor or larger to prevent any AC variation from causing erratic AGC action.

For proper FM operation, the input level needs to be larger, on the order of 1 mV to give full limiting which is necessary for good AM rejection. Here again low loss coupling from Pin 9 to Pin 4 is desired. The phase shift network on Pin 6 should be shielded to prevent any extraneous RF pickup or radiation. Also the Q of the network should be adjusted to give the proper bandwidth for the type of signal to be detected, whether wideband or narrowband FM. Obviously, it should be tuned to the same center frequency as the IF input and the Pin 9 to Pin 4 filtering so that detection takes place symmetrically around the resonant frequency of the tank. Since the audio output for FM is at Pin 7, it should be RF bypassed along with audio rolloff and de-emphasis.

For SSB operation, the devices operate almost the same as in the AM mode, with the exception that the product detector which was unbalanced and used as a simple gain stage for AM is now balanced and used for detection. The local oscillator signal is fed into Pin 6 at an optimum level around 60 mVrms. For better AGC, a capacitor may be added to Pin 8 in addition to the one already at Pin 1 to provide even more filtering for AGC feedback voltage. The output level and AGC figure of merit is still adjusted by the feedback resistors from Pin 8 to Pin 1.

typical applications

*Capacitors noted by asterisk are 0.1 at 455 kHz. L is Miller No. 43A105CBI for 455 kHz; 8 turns No. 26 AWG on Micrometals T25-2 Carbonyle Core (0.255 OD x 0.180 ID x 0.096W) for 10.7 MHz; 3 1/2 turns No. 20 AWG 5/16" dia x 1/4" long for 27 MHz.

f	C1	C2	C3	C4	L
455 kHz	.01	1000	.012	.001	10.5 μH
10.7 MHz	1000	250	1000	500	.22 μH
27 MHz	1000	180	300	500	.12 μH

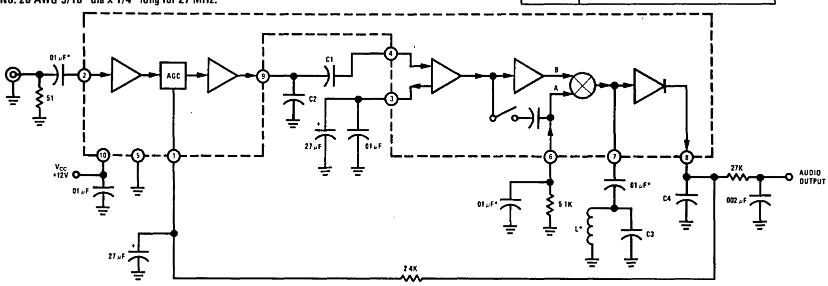
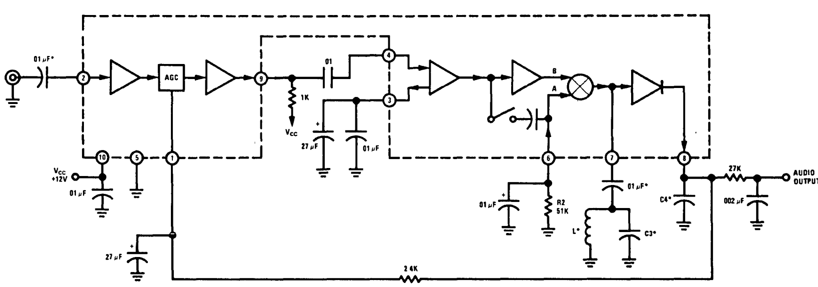


FIGURE 1. LM273/LM373 AM IF Connection



*See Figure 1 for component values.

FIGURE 2. LM274/LM374 AM IF Connection

T Pri 5 turns No. 32, sec. 30 turns No. 32, Core Micrometals T25-2 (Ref. Figure 1).

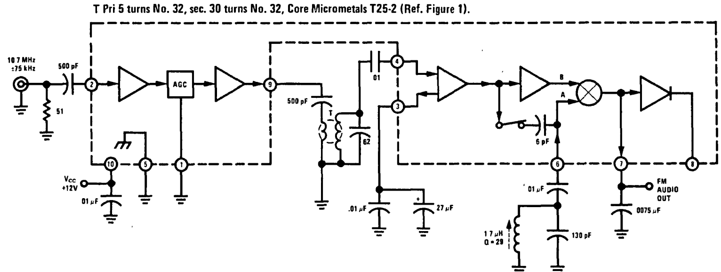


FIGURE 3. LM273/LM373 Wide Band FM IF Connection

typical applications (con't)

*For 455 kHz, T is 8t & 60t No. 36 AWG on Micrometals T25-3 Core (Carbonyl HP, 0.255 OD x 0.120 ID x 0.096W); L is 680 turns universal wound No. 38 enamel with 10-32 x 1/4" Carbonyl HP core. For 10.7 MHz, T is 5t & 30t of No. 32 AWG on Micrometals T25-2 core; L is 37t No. 36 AWG on 0.200 dia form with 10-32 x 1/4" Carbonyl E Core (Q_{AV} = 170).

f	C1	R	C2	C3	C4	C5	C6
455 kHz	500	0	1	.05	5000	33	150
10 7 MHz	.01	300	.01	500	43	47	82

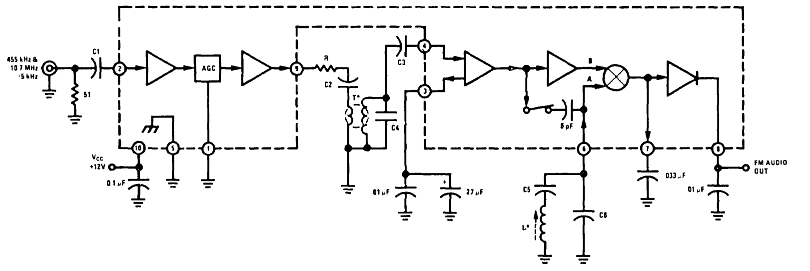


FIGURE 4. LM273/LM373 Narrow Band FM IF Connection

f	C1	C2
455 kHz	1000	.005
10 7 MHz	250	1000
27 MHz	180	1000

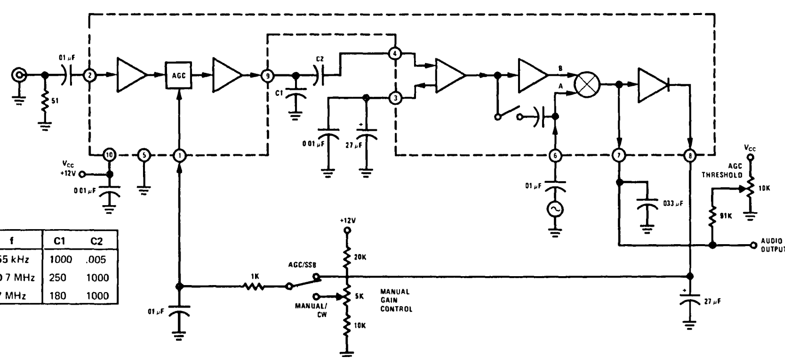


FIGURE 5. LM273/LM373 SSB & CW IF Connection

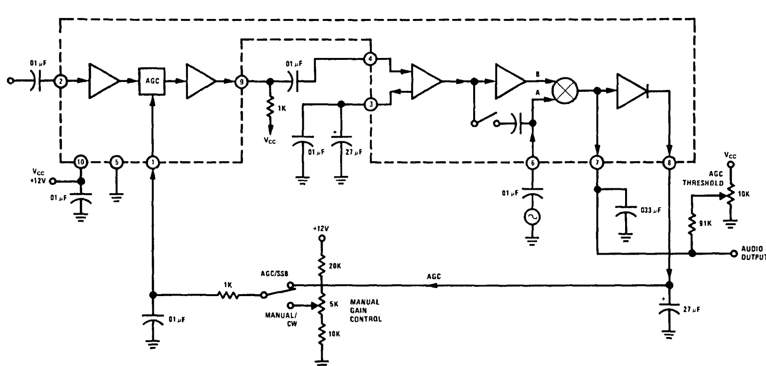


FIGURE 6. LM274/LM374 SSB & CW IF Connection

typical applications (con't)

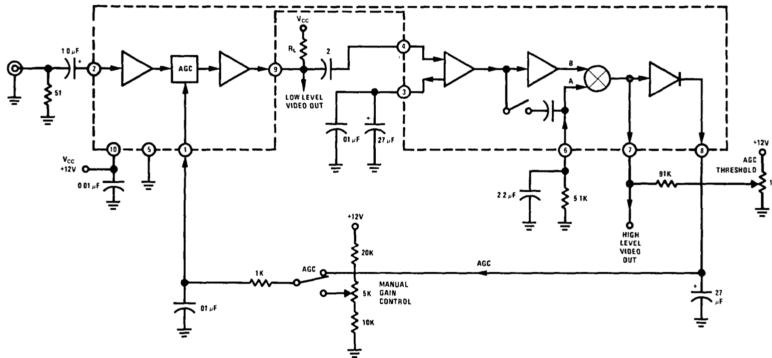


FIGURE 7. LM274/LM374 Video Amplifier Configuration

*Capacitors noted by asterisk are 0.1 at 455 kHz. L is Miller No. 43A105CBI for 455 kHz; 8 turns No. 26 AWG on Micrometals T25-2 Carbonyle Core (0.255 OD x 0.180 ID x 0.096W) for 10.7 MHz; 3-1/2 turns No. 20 AWG 5/16" dia x 1/4" long for 27 MHz.

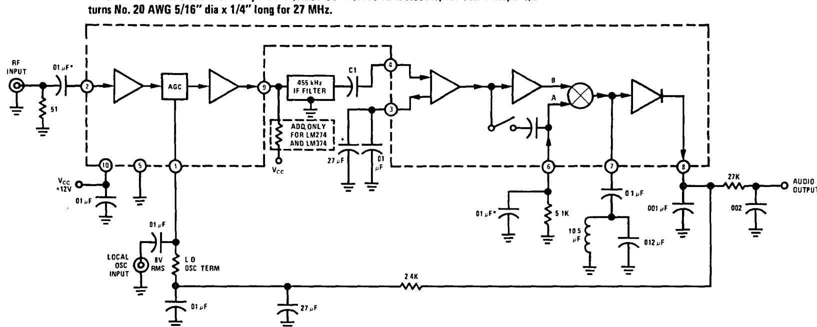


FIGURE 8. LM274/LM374, LM273/LM373 First Stage Converter Operation for AM Signal Detection @ 455 kHz

Consumer Circuits

LM175/LM275/LM375 oscillator and buffer with TTL output

general description

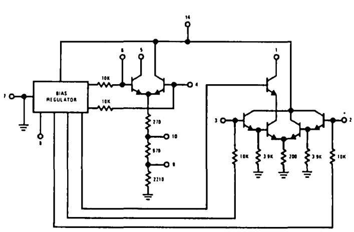
The LM175/LM275/LM375 is a monolithic, differential pair, general purpose oscillator. It may be used with crystal control or with LC or RC tanks. Two output configurations are possible. It may be connected to the internal isolating buffer to provide sine or square wave outputs, or to the internal logic buffer with output levels and switching times compatible with TTL and DTL logic circuitry. It provides extremely high temperature and power supply versus frequency rejection.

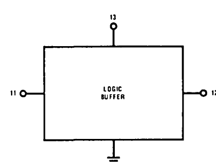
The LM175 is specified for operation over the −55°C to +125°C military temperature range. The LM275 is specified for operation over the −25°C to +85°C temperature range. The LM375 is specified for operation over the 0°C to +70°C temperature range.

features

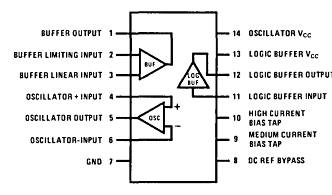
- Oscillation up to 200 MHz
- Operation from supplies from 4.5V to 24V (Logic buffer maximum supply at 7.0V)
- High supply voltage rejection, typically 0.1 ppm/V
- Low temperature coefficient, typically 0.05 ppm/°C
- Variable drive to crystal to limit dissipation
- Capable of fundamental or overtone, series or parallel mode of operation
- Separate power supply lead for logic buffer for noise isolation
- Low power dissipation

schematic and connection diagrams





Dual-In-Line Package



TOP VIEW

Order Number LM175D or LM275D or LM375D
See Package 1

Order Number LM375N
See Package 22

typical applications

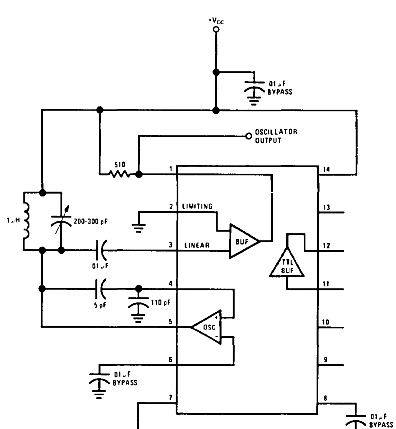


FIGURE 1. 10 MHz L–C Sine Wave Oscillator

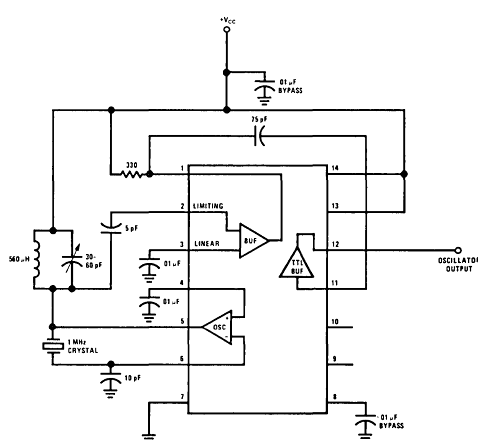


FIGURE 2. 1 MHz Crystal Oscillator with TTL Output

absolute maximum ratings

Supply Operating Voltage (Pin 14)	24V	Storage Temperature Range	-65°C to +150°C
Supply Operating Voltage (Pin 13)	7V	Operating Temperature Range LM175	-55°C to +125°C
Differential Input Voltage ΔV P_4 to Pin 6	5V	LM275	-25°C to +85°C
ΔV P_2 to Pin 3	5V	LM375	0°C to 70°C
Power Dissipation (Note 1)	500 mW	Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (T_A = 25°C, V_{CC} = 5V unless otherwise noted)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DC CHARACTERISTICS						
Power Supply Current (Pin 14)	I_{PS14}	V_{CC} = 24V	4.0	6.0	12.0	mA
Power Supply Current (Pin 13)	I_{PS13}	No Load at Pin 12	4.0	6.0	14.0	mA
Oscillator Output Current	I_{OSC}	R_L (Pin 5) = 1 kΩ				
		Pin 9 Open, Pin 10 Open	120	140		μA_{p-p}
		Pin 9 Tied to Pin 10	160	190		μA_{p-p}
		Pin 9 Grounded, Pin 10 Open	300	360		μA_{p-p}
		Pin 10 Grounded, Pin 9 Open	750	1000		μA_{p-p}
Buffer Output Current	I_{BUF}		2.5	3.0		mA_{p-p}
Logic Buffer Output Voltage	V_{TTL}	Input LOW	2.1	2.7		
		Input HIGH				
		I_{SINK} = 1.6 mA		200	400	mV
The Following Specifications apply to −55°C < T_A < +125°C						
Oscillator Output Current	I_{OSC}	R_L (Pin 5) = 1 kΩ				
		Pin 9 Open, Pin 10 Open	100			μA_{p-p}
		Pin 9 Tied to Pin 10	130			μA_{p-p}
		Pin 9 Grounded, Pin 10 Open	250			μA_{p-p}
		Pin 10 Grounded, Pin 9 Open	600			μA_{p-p}
Buffer Ouptut Current	I_{BUF}		2.0			mA_{p-p}
AC CHARACTERISTICS						
Oscillator Gain (at 1 kHz)	gm_{OSC}	Pin 9 Open, Pin 10 Open		1.4		mmhos
		Pin 9 Tied to Pin 10		1.9		mmhos
		Pin 9 Grounded, Pin 10 Open		3.6		mmhos
		Pin 9 Open, Pin 10 Grounded		10.0		mmhos
Oscillator 3 dB Bandwidth	BW_{OSC}	$R_S = R_L$ (Pin 5) = 50Ω		200		MHz
Buffer Gain (at 1 kHz)	gm_{BUF}	R_L (Pin 1) = 500Ω				
		Linear Mode		8		mmhos
		Limiting Mode		30		mmhos
Buffer 3 dB Bandwidth	BW_{BUF}	$R_S = R_L$ (Pin 1) = 50Ω				
		Linear Mode		200		MHz
		Limiting Mode		80		MHz
Logic Buffer Rise Time				20	50	ns
Logic Buffer Fall Time				20	50	ns

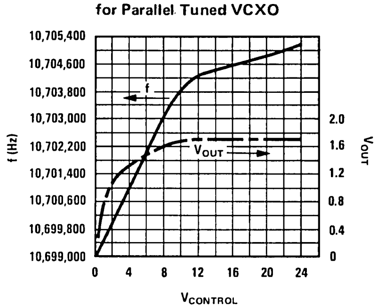
Note 1: For operation at elevated temperatures, the device must be operated based on a 150°C maximum junction temperature with a thermal resistance of 140°C/W for the metal DIP package and 100°C maximum junction temperature with a thermal resistance of 150°C/W for the plastic DIP package.

electrical characteristics (con't)

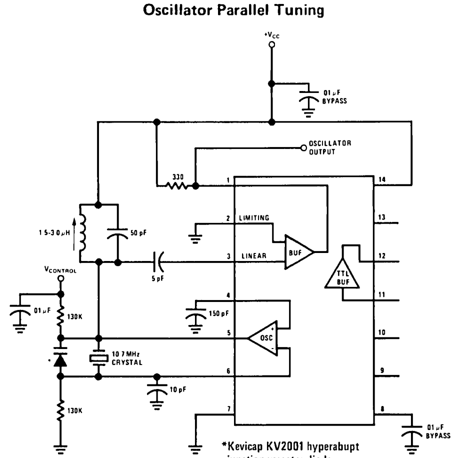
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
OSCILLATOR CHARACTERISTICS (See Oscillator Circuit)						
Frequency vs Power Supply Rejection		$5V < V_{CC} < 10V$		0.1		ppm/V
Frequency vs Temperature Rejection		$-55°C < T_A < +125°C$		0.05		ppm/°C
Load Pull (Change in Frequency vs Change in Buffer Load Impedance)		$0 \leq R_{L\ BUF} \leq \infty$		0.01		ppm
INPUT-OUTPUT TERMINAL CHARACTERISTICS						
Oscillator Input Resistance	R_4	Minimum Current		10		kΩ
		Maximum Current		4.5		kΩ
	R_6	Minimum Current		10		kΩ
		Maximum Current		4.5		kΩ
Oscillator Input Capacitance	C_4			3		pF
	C_6			3		pF
Oscillator Output Resistance	R_5	Minimum Current		100		kΩ
		Maximum Current		30		kΩ
Oscillator Output Capacitance	C_5			3		pF
Buffer Input Resistance	R_2			10		kΩ
	R_3			10		kΩ
Buffer Input Capacitance	C_2			2		pF
	C_3			2		pF
Buffer Output Resistance	R_1			100		kΩ
Buffer Output Capacitance	C_1			5		pF
Logic Buffer Input Resistance	R_{11}			1.2		kΩ
Logic Buffer Input Capacitance	C_{11}			4		pF

typical oscillator circuit connections

Frequency and Output Voltage for Parallel Tuned VCXO

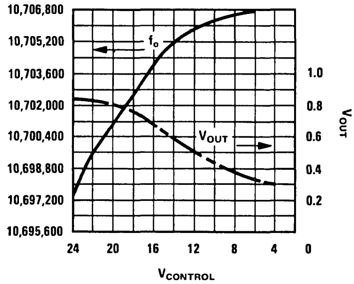


10.7 MHz Voltage-Controlled Crystal Oscillator Parallel Tuning

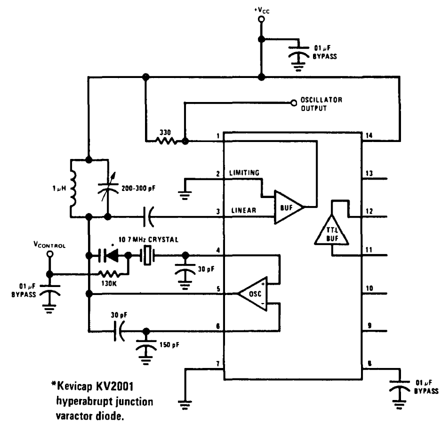


typical oscillator circuit connections (con't)

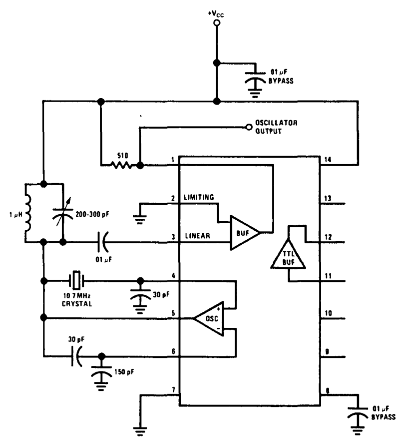
Frequency and Output Voltage for Series Tuned VCXO



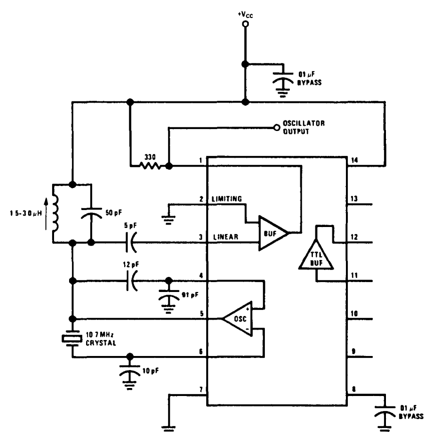
10.7 MHz Voltage Controlled Crystal Oscillator Series Tuning



10.7 MHz Series Resonant Crystal Oscillator

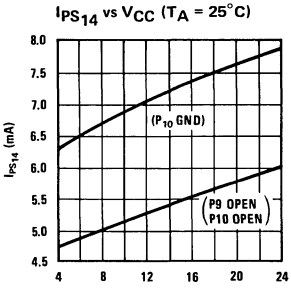


10.7 MHz Parallel Resonant Crystal Oscillator

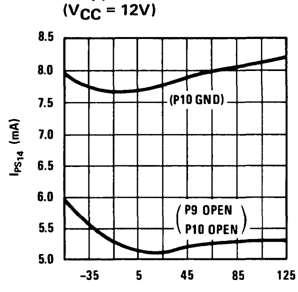


typical performance characteristics

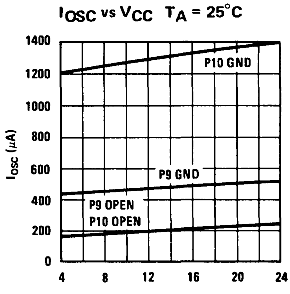
I_{PS14} vs V_{CC} (T_A = 25°C)



I_{PS14} vs Temperature (V_{CC} = 12V)

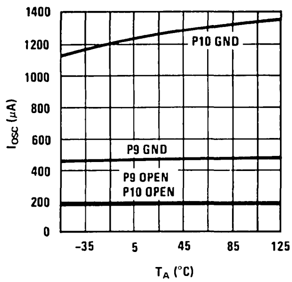


I_{OSC} vs V_{CC} T_A = 25°C

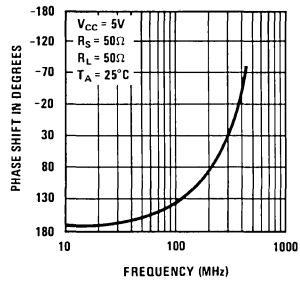


typical performance characteristics (con't)

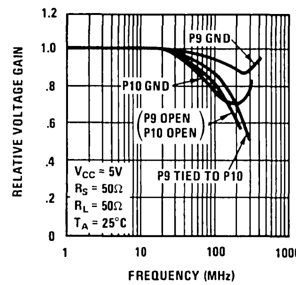
I_{OSC} vs Temperature V_{CC} = 12V



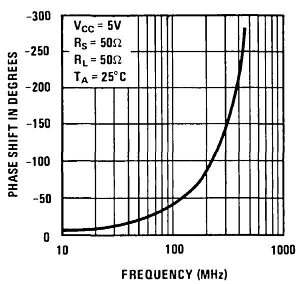
Phase Shift from Pin 6 to Pin 5



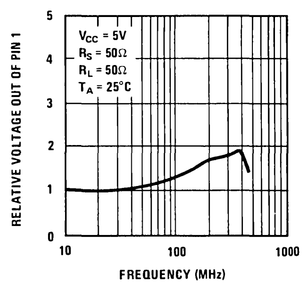
OSC Stage Bandwidth



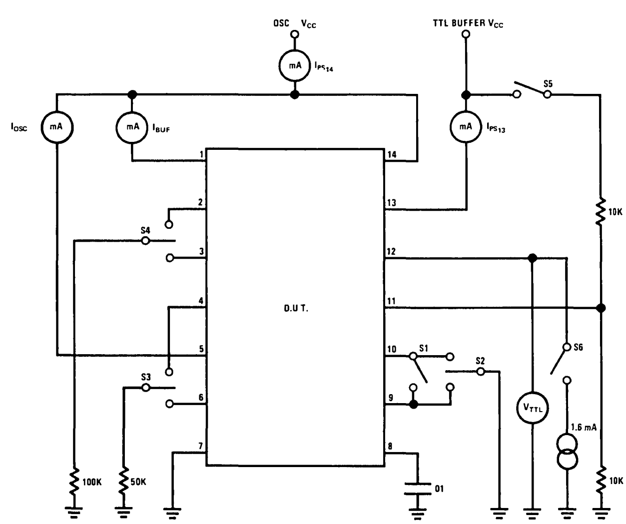
Phase Shift from Pin 4 to Pin 5



OSC Buffer Bandwidth



dc test circuit



S1, S2 Used to select desired oscillator current.
S3 Used to swing oscillator output and measure I_{OSC}.
S4 Used to swing buffer output and measure I_{BUF}.
S5 Used to switch TTL buffer to high and low states.
S6 Switches in maximum guaranteed TTL load to measure V_{TTL} in the low state.

5

Consumer Circuits

LM377 dual 2 watt audio amplifier

general description

The LM377 is a monolithic dual power amplifier which offers high quality performance for stereo phonographs, tape players, recorders, and AM-FM stereo receivers, etc.

The LM377 will deliver 2W/channel into 8 or 16Ω loads. The amplifier is designed to operate with a minimum of external components and contains an internal bias regulator to bias each amplifier. Device overload protection consists of both internal current limit and thermal shutdown.

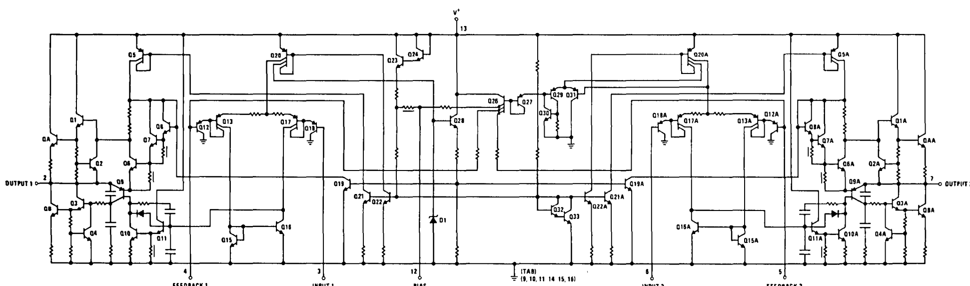
features

- A_{VO} typical 90 dB
- 2W per channel
- 70 dB ripple rejection
- 75 dB channel separation
- Internal stabilization
- Self centered biasing
- 3 MΩ input impedance
- 10–26V operation
- Internal current limiting
- Internal thermal protection

applications

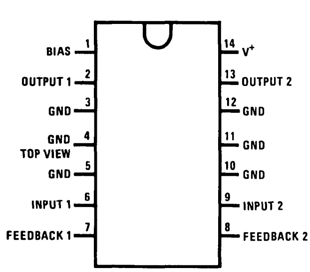
- Multi-channel audio systems
- Tape recorders and players
- Movie projectors
- Automotive systems
- Stereo phonographs
- Bridge output stages
- AM-FM radio receivers
- Intercoms
- Servo amplifiers
- Instrument systems

schematic diagram



connection diagram

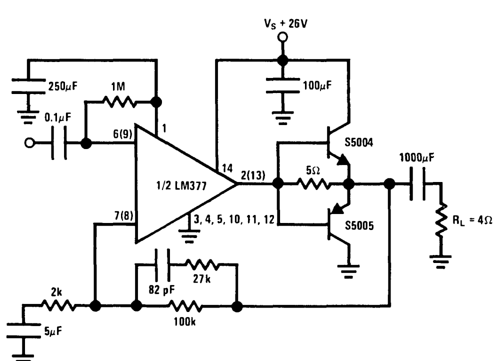
Dual-In-Line Package



TOP VIEW

Order Number LM377N
See Package 22

typical applications



15W Per Channel Audio Amplifier

absolute maximum ratings

Supply Voltage	26V
Input Voltage	0V – V_{SUPPLY}
Operating Temperature	0°C to +70°C
Storage Temperature	−65°C to +150°C
Junction Temperature	150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

V_S = 20V, T_{TAB} = 25°C, R_L = 8Ω, A_V = 50 (34 dB), unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Total Supply Current	P_{OUT} = 0W		15	50	mA
	P_{OUT} = 1.5W/Channel		430	500	mA
DC Output Level			10		V
Supply Voltage		10		26	V
Output Power	T.H.D. = < 5%	2	2.5		W
T.H.D.	P_{OUT} = 0.05W/Channel, f = 1 kHz		0.25		%
	P_{OUT} = 1W/Channel, f = 1 kHz		0.07	1	%
	P_{OUT} = 2W/Channel, f = 1 kHz		0.10		%
Offset Voltage			15		mV
Input Bias Current			100		nA
Input Impedance		3			MΩ
Open Loop Gain	R_S = 0Ω	66	90		dB
Output Swing			V_S–6		V_{P-P}
Channel Separation	C_F = 250µF, f = 1 kHz	50	70		dB
Ripple Rejection	f = 120 Hz, C_F = 250µF	60	70		dB
Current Limit			1.5		A
Slew Rate			1.4		V/µs
Equivalent Input Noise Voltage	R_S = 600Ω, 100 Hz – 10 kHz		3		µVrms

Note 1: For operation at ambient temperatures greater than 25°C the LM377 must be derated based on a maximum 150°C junction temperature using a thermal resistance which depends upon device mounting techniques.

Note 2: Dissipation characteristics are shown for four mounting configurations.

a. Infinite sink – 13.4°C/W

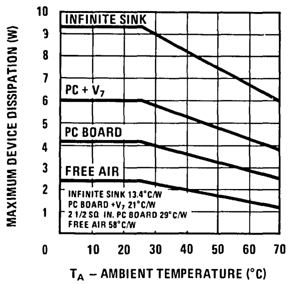
b. P.C. board +V_7 sink – 21°C/W. P.C. board is 2 1/2 square inches. Staver V_7 sink is 0.02 inch thick copper and has a radiating surface area of 10 square inches.

c. P.C. board only – 29°C/W. Device soldered to 2 1/2 square inch P.C. board.

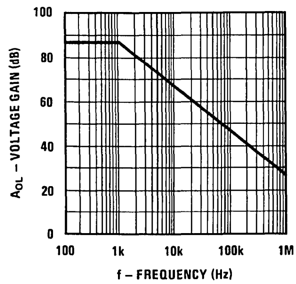
d. Free air – 58°C/W.

typical performance characteristics

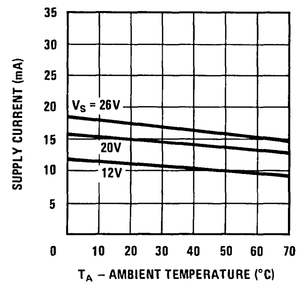
Maximum Dissipation vs Ambient Temperature



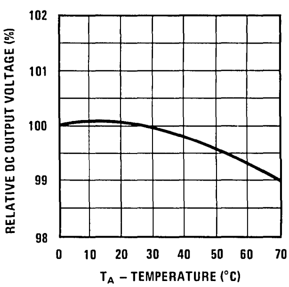
Open Loop Gain



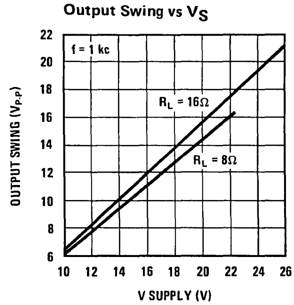
Supply Current vs Temperature



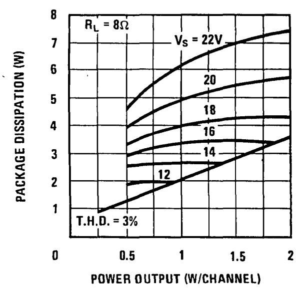
DC Output Level vs Temperature



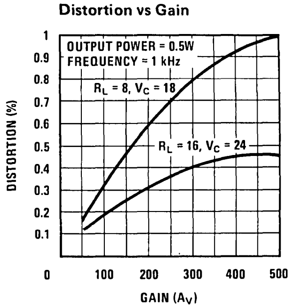
Output Swing vs V_S



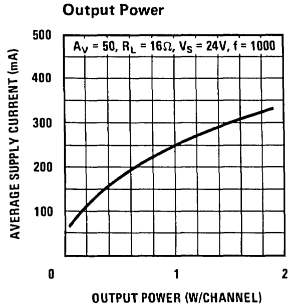
Power Dissipation vs Power Output



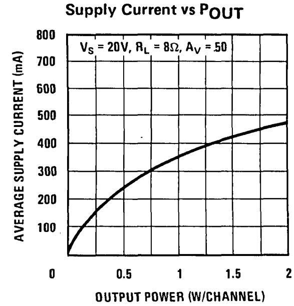
Distortion vs Gain



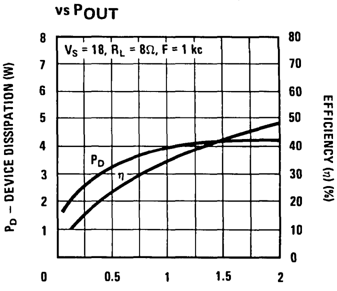
Supply Current vs Output Power



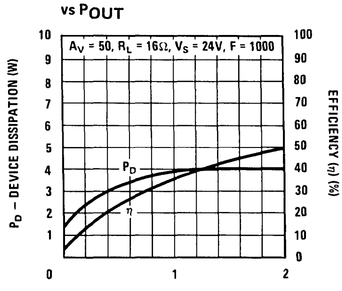
Supply Current vs P_{OUT}



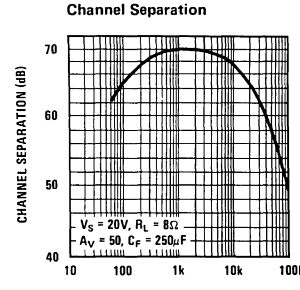
Dissipation and Efficiency vs P_{OUT}



Dissipation and Efficiency vs P_{OUT}

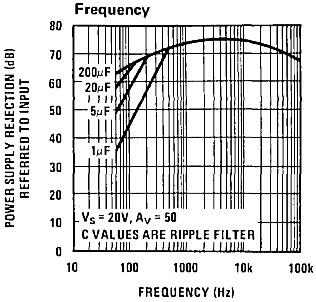


Channel Separation

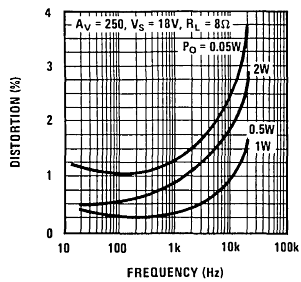


typical performance characteristics (con't)

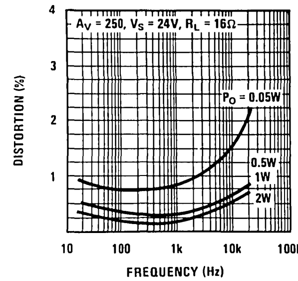
Supply Rejection vs Frequency



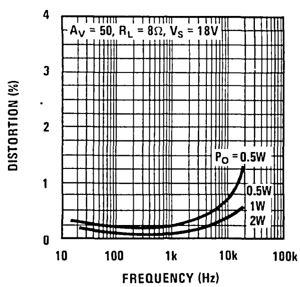
Distortion vs Frequency



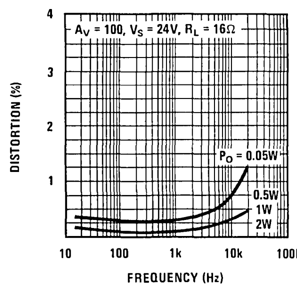
Distortion vs Frequency



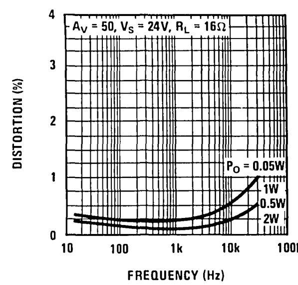
Distortion vs Frequency



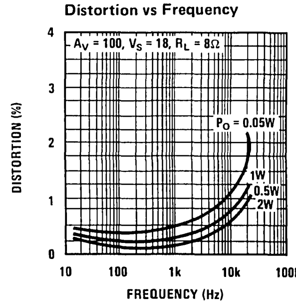
Distortion vs Frequency



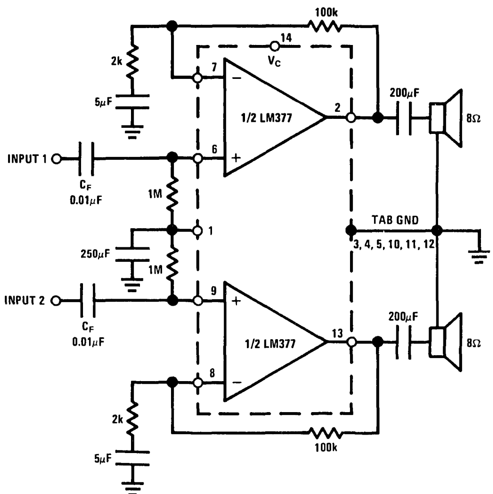
Distortion vs Frequency



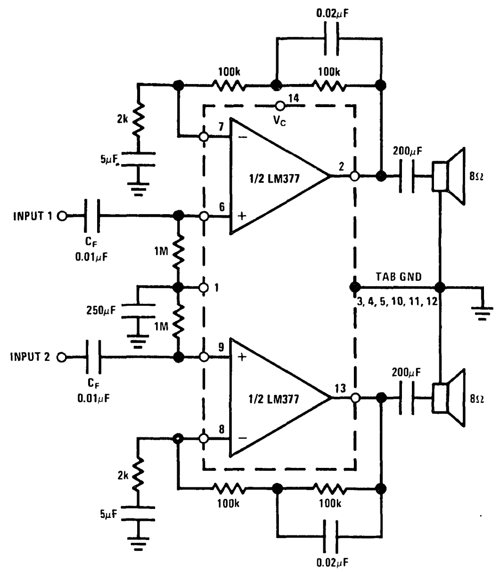
Distortion vs Frequency



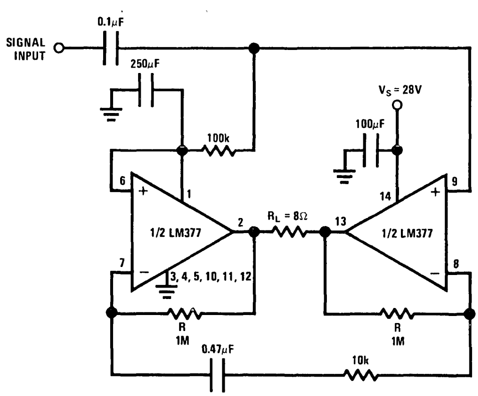
typical applications



Simple Stereo Amplifier



Simple Stereo Amplifier with Bass Boost



4W Bridge Amplifier

Consumer Circuits

LM378 dual 4 watt audio amplifier

general description

The LM378 is a monolithic dual power amplifier which offers high quality performance for stereo phonographs, tape players, recorders, and AM-FM stereo receivers, etc.

The LM378 will deliver 4W channel into 8 or 16Ω loads. The amplifier is designed to operate with a minimum of external components and contains an internal bias regulator to bias each amplifier. Device overload protection consists of both internal current limit and thermal shutdown.

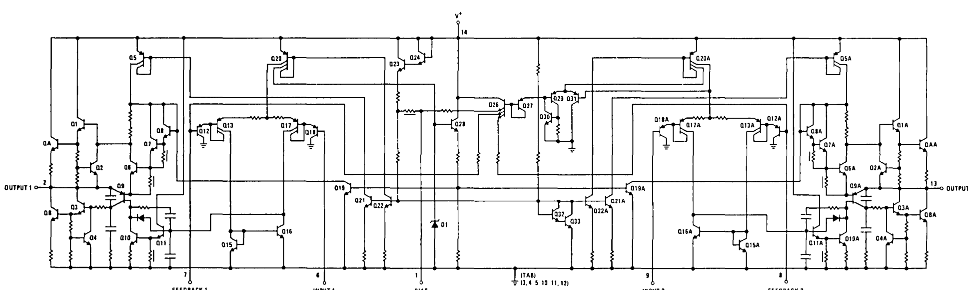
features

- A_{VO} typical 90 dB
- 4W per channel
- 70 dB ripple rejection
- 75 dB channel separation
- Internal stabilization
- Self centered biasing
- 3 MΩ input impedance
- Internal current limiting
- Internal thermal protection

applications

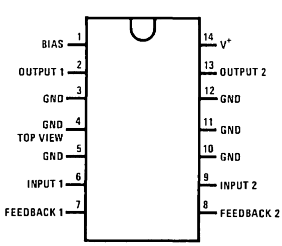
- Multi-channel audio systems
- Tape recorders and players
- Movie projectors
- Automotive systems
- Stereo phonographs
- Bridge output stages
- AM-FM radio receivers
- Intercoms
- Servo amplifiers
- Instrument systems

schematic diagram



connection diagram

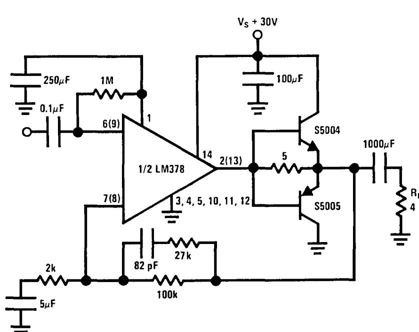
Dual-In-Line Package



TOP VIEW

Order Number LM378N
See Package 22

typical applications



15W Per Channel Audio Amplifier

absolute maximum ratings

Supply Voltage	35V
Input Voltage	0V – V_{SUPPLY}
Operating Temperature	0°C to +70°C
Storage Temperature	–65°C to +150°C
Junction Temperature	150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

V_S = 24V, T_{TAB} = 25°C, R_L = 8Ω, A_V = 50 (34 dB), unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Total Supply Current	P_{OUT} = 0W P_{OUT} = 1.5W/Channel		15 430	50 500	mA mA
DC Output Level			12		V
Supply Voltage		10			V
Output Power	T.H.D. = < 5%, R_L = 8Ω T.H.D. = < 5%, R_L = 16Ω	4 4	5 5		W W*
T.H.D.	P_{OUT} = 0.05W/Channel, f = 1 kHz P_{OUT} = 1W/Channel, f = 1 kHz P_{OUT} 2W/Channel, f = 1 kHz		0.25 0.07 0.10	 1 	% % %
Offset Voltage			15		mV
Input Bias Current			100		nA
Input Impedance		3			MΩ
Open Loop Gain	R_S = 0Ω	66	90		dB
Channel Separation	C_F = 250μF, f = 1 kHz	50	70		dB
Ripple Rejection	f = 120 Hz, C_F = 250μF	60	70		dB
Current Limit			1.5		A
Slew Rate			1.4		V/μs
Equivalent Input Noise Voltage	R_S = 600Ω, 100 Hz – 10 kHz		3		μVrms

Note 1: For operation at ambient temperatures greater than 25°C the LM378 must be derated based on a maximum 150°C junction temperature using a thermal resistance which depends upon device mounting techniques.

Note 2: Dissipation characteristics are shown for four mounting configurations.

a. Infinite sink – 13.4°C/W

b. P.C. board +V_7 sink – 21°C/W. P.C. board is 2 1/2 square inches. Staver V_7 sink is 0.02 inch thick copper and has a radiating surface area of 10 square inches.

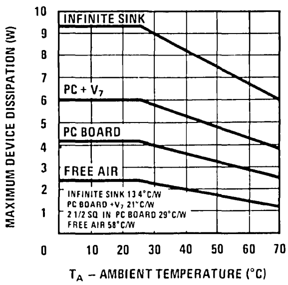
c. P.C. board only – 29°C/W. Device soldered to 2 1/2 square inch P.C. board.

d. Free air – 58°C/W.

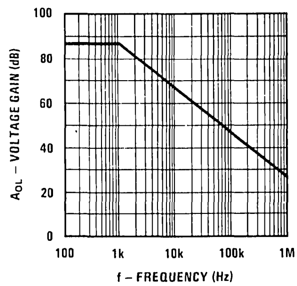
*Tested at V_S = 30V.

typical performance characteristics

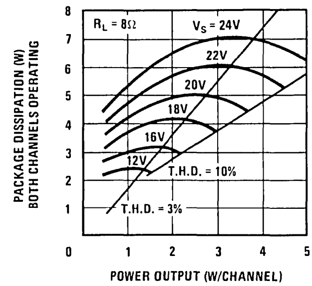
Maximum Dissipation vs Ambient Temperature



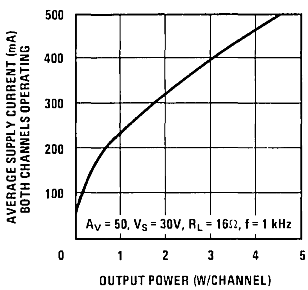
Open Loop Gain



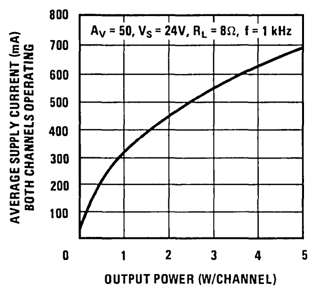
Power Dissipation vs Power Output



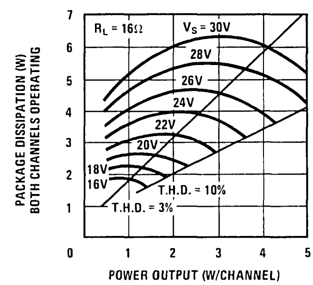
Supply Current vs Output Power



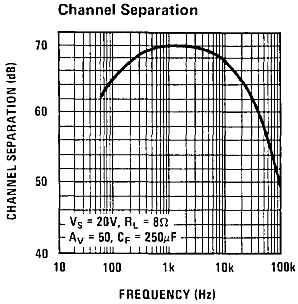
Supply Current vs Output Power



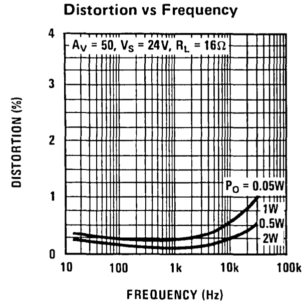
Power Dissipation vs Power Output



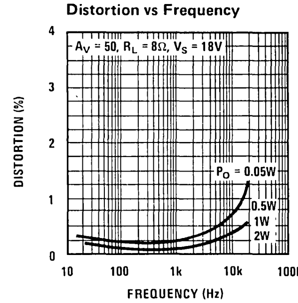
Channel Separation



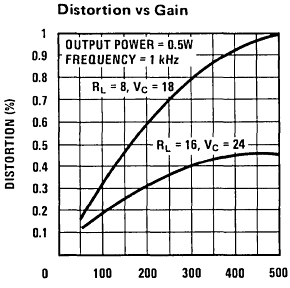
Distortion vs Frequency



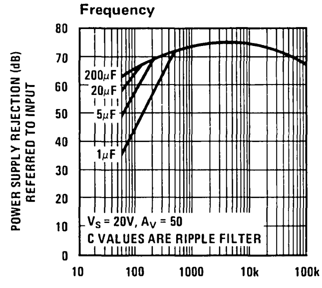
Distortion vs Frequency



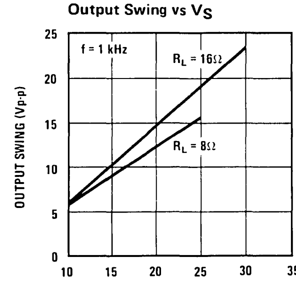
Distortion vs Gain



Supply Rejection vs Frequency



Output Swing vs V_S



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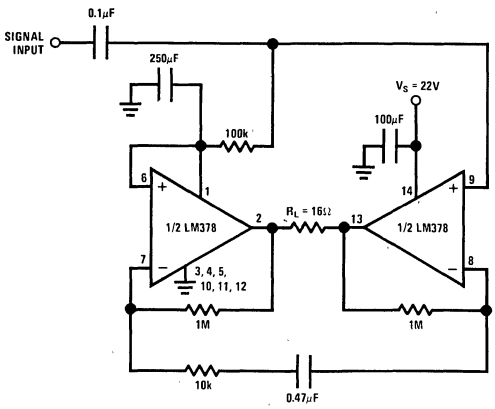
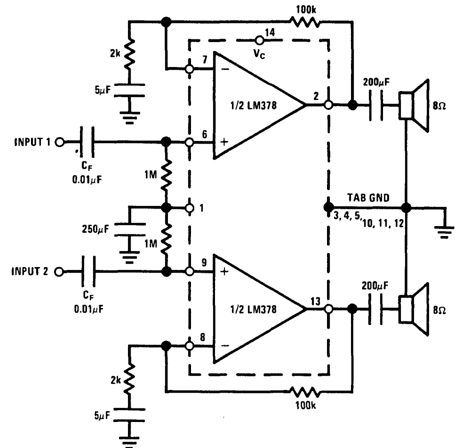
typical applications (con't)



8W Bridge Amplifier



Simple Stereo Amplifier

Consumer Circuits

LM379 dual 6 watt audio amplifier

general description

The LM379 is a monolithic dual power amplifier which offers high quality performance for stereo phonographs, tape players, recorders, and AM-FM stereo receivers, etc.

The LM379 will deliver 7W/channel to an 8Ω load. The amplifier is designed to operate with a minimum of external components and contains an internal bias regulator to bias each amplifier. Device overload protection consists of both internal current limit and thermal shutdown.

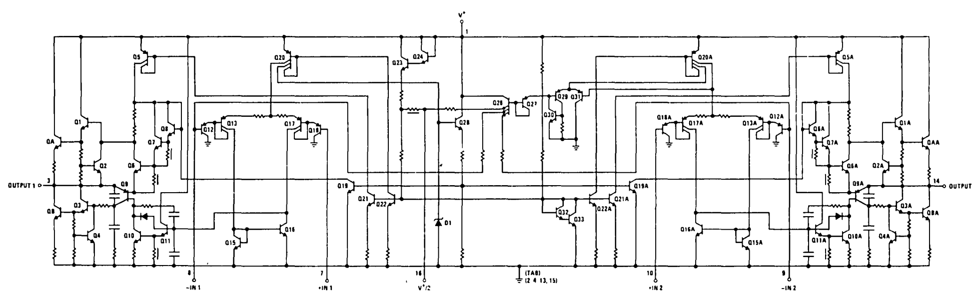
features

- A_{VO} typical 90 dB
- 7W per channel
- 70 dB ripple rejection
- 75 dB channel separation
- Internal stabilization
- Self centered biasing
- 3 MΩ input impedance
- Internal current limiting
- Internal thermal protection

applications

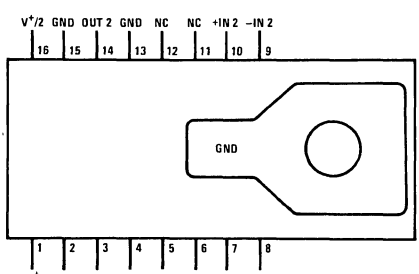
- Multi-channel audio systems
- Tape recorders and players
- Movie projectors
- Automotive systems
- Stereo phonographs
- Bridge output stages
- AM-FM radio receivers
- Intercoms
- Servo amplifiers
- Instrument systems

schematic diagram



connection diagram

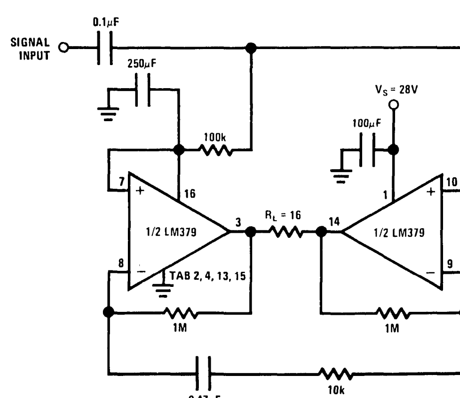
Dual-In-Line Package



TOP VIEW

Order Number LM379M
See Package 36

typical applications



14W Bridge Amplifier

absolute maximum ratings

Supply Voltage	35V
Input Voltage	0V – V_{SUPPLY}
Operating Temperature	0°C to +70°C
Storage Temperature	−65°C to +150°C
Junction Temperature	150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

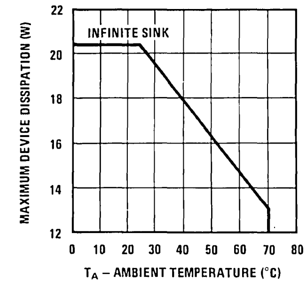
V_S = 28V, T_{TAB} = 25°C, R_L = 8Ω, A_V = 50 (34 dB), unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Total Supply Current	P_{OUT} = 0W		15	65	mA
	P_{OUT} = 1.5W/Channel		430		mA
DC Output Level			14		V
Supply Voltage		10			V
Output Power	T.H.D. = 5%		6		W
	T.H.D. = 10%	6	7		W
T.H.D.	P_{OUT} = 1W/Channel, f = 1 kHz		0.07	1	%
	P_{OUT} = 4W/Channel, f = 1 kHz		0.2		%
Offset Voltage			15		mV
Input Bias Current			100		nA
Input Impedance		3			MΩ
Open Loop Gain	R_S = 0Ω	66	90		dB
Channel Separation	C_F = 250μF, f = 1 kHz	50	70		dB
Ripple Rejection	f = 120 Hz, C_F = 250μF		70		dB
Current Limit			1.5		A
Slew Rate			1.4		V/μs
Equivalent Input Noise Voltage	R_S = 600Ω, 100 Hz – 10 kHz		3		μVrms

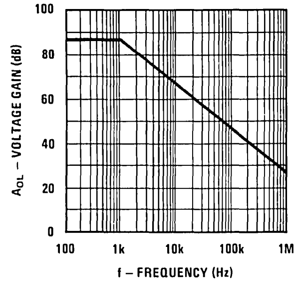
Note 1: For operation at ambient temperatures greater than 25°C the LM379 must be derated based on a maximum 150°C junction temperature using a thermal resistance which depends upon device mounting techniques.

typical performance characteristics

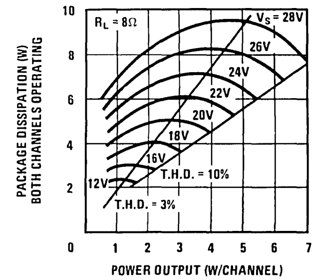
Maximum Dissipation vs Ambient Temperature



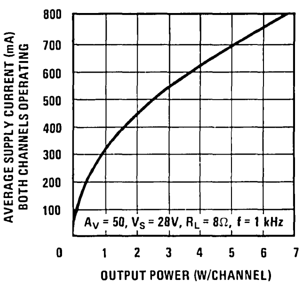
Open Loop Gain



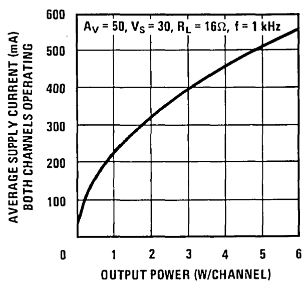
Power Dissipation vs Power Output



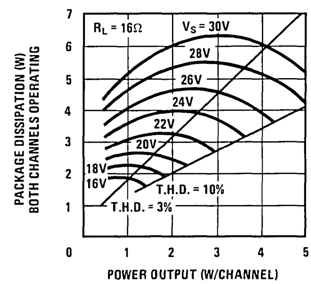
Supply Current vs Output Power



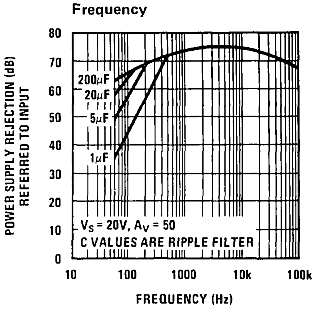
Supply Current vs P_{OUT}



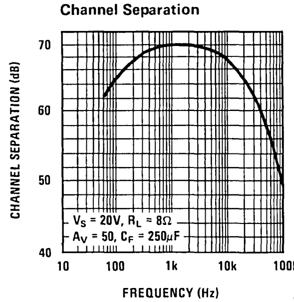
Power Dissipation vs Power Output



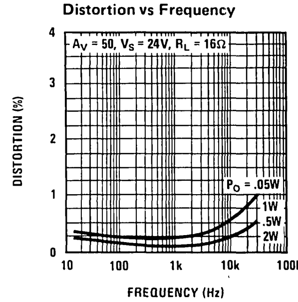
Supply Rejection vs Frequency



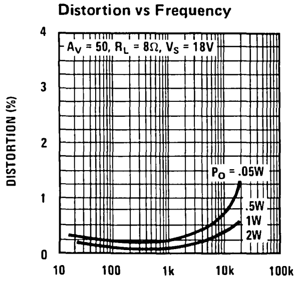
Channel Separation



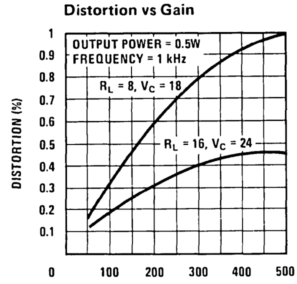
Distortion vs Frequency



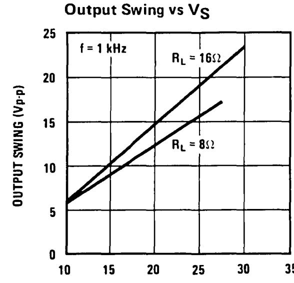
Distortion vs Frequency



Distortion vs Gain



Output Swing vs V_S



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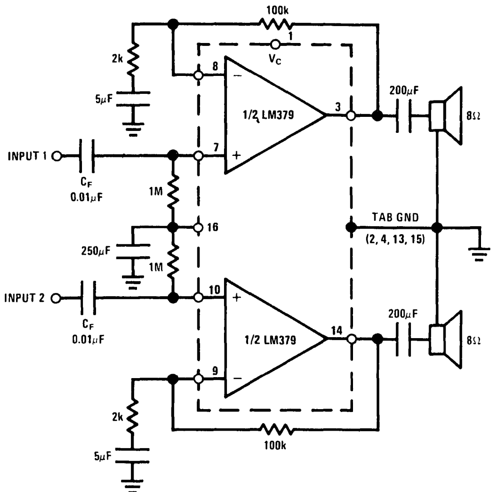
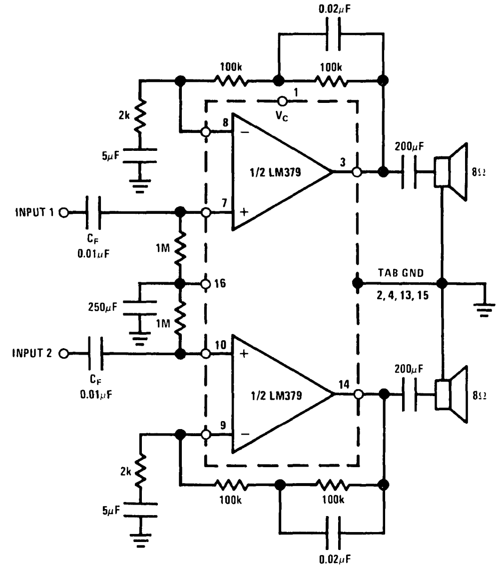
typical applications (con't)



Simple Stereo Amplifier



Simple Stereo Amplifier with Bass Boost

Consumer Circuits

LM380 audio power amplifier

general description

The LM380 is a power audio amplifier for consumer application. In order to hold system cost to a minimum, gain is internally fixed at 34 dB. A unique input stage allows inputs to be ground referenced. The output is automatically self entering to one half the supply voltage.

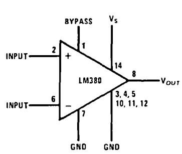
The output is short circuit proof with internal thermal limiting. The package outline is standard dual-in-line. A copper lead frame is used with the center three pins on either side comprising a heat sink. This makes the device easy to use in standard p-c layout. A mini dual-in-line package version with reduced power capability also available.

Uses include simple phonograph amplifiers, intercoms, line drivers, teaching machine outputs, alarms, ultrasonic drivers, TV sound systems, AM-FM radio, small servo drivers, power converters,etc.

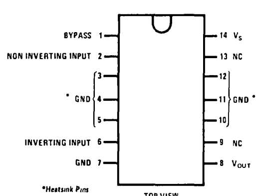
features

- Wide supply voltage range
- Low quiescent power drain
- Voltage gain fixed at 50
- High peak current capability
- Input referenced to GND
- High input impedance
- Low distortion
- Quiescent output voltage is at one-half of the supply voltage
- Standard dual-in-line package

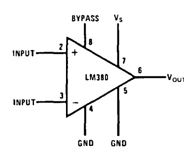
block and connection diagrams



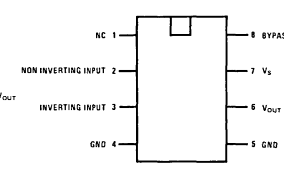
Dual-In-Line Package



Order Number LM380N
See Package 22

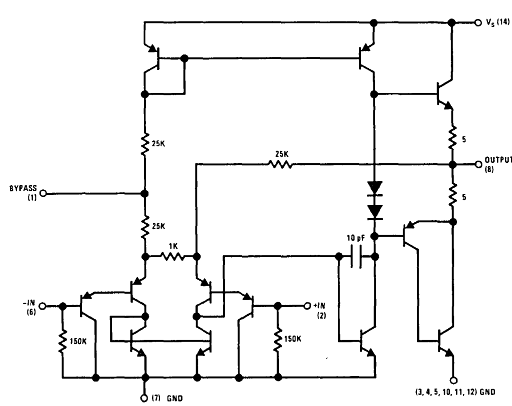


Dual-In-Line Package



Order Number LM380N-8
See Package 20

schematic diagram



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absolute maximum ratings

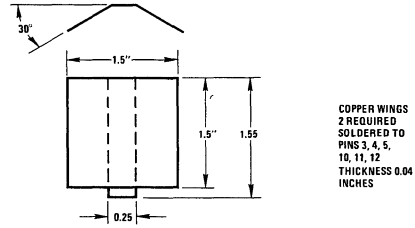
Supply Voltage	22V
Peak Current	1.3A
Package Dissipation 14 Pin DIP (Note 6)	5.0W
Package Dissipation 8 Pin DIP (Note 7)	660 mW
Input Voltage	±0.5V
Storage Temperature	−65°C to +150°C
Operating Temperature	0°C to +70°C
Junction Temperature	+150°C
Lead Temperature (Soldering, 10 sec)	+300°C

electrical characteristics (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Power	$P_{OUT(RMS)}$	(Notes 3, 4) $R_L = 8\Omega$, THD = 3%	2.5			W
Gain	A_V		40	50	60	V/V
Output Voltage Swing	V_{OUT}	$R_L = 8\Omega$		14		$V_{p\text{-}p}$
Input Resistance	Z_{IN}			150k		Ω
Total Harmonic Distortion	THD	(Note 4, 5)		0.2		%
Power Supply Rejection Ratio	PSRR	(Note 2)		38		dB
Supply Voltage	V_S		8		22	V
Bandwidth	BW	$P_{OUT} = 2W$, $R_L = 8\Omega$		100k		Hz
Quiescent Supply Current	I_Q			7	25	mA
Quiescent Output Voltage	V_{OUTQ}		8	9.0	10	V
Bias Current	I_{BIAS}	Inputs Floating		100		nA
Short Circuit Current	I_{SC}			1.3		A

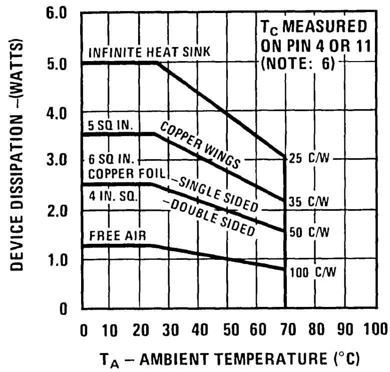
Note 1: $V_S = 18V$ and $T_A = 25°C$ unless otherwise specified.
Note 2: Rejection ratio referred to the output with $C_{BYPASS} = 5\ \mu F$.
Note 3: With device Pins 3, 4, 5, 10, 11, 12 soldered into a 1/16" epoxy glass board with 2 ounce copper foil with a minimum surface of 6 square inches.
Note 4: If oscillation exists under some load conditions, add 2.7Ω and 0.1 μfd series network from Pin 8 to Gnd.
Note 5: $C_{BYPASS} = 0.47\ \mu fd$ on Pin 1.
Note 6: Pins 3, 4, 5, 10, 11, 12 at 25°C derate 25°C/W above 25°C case.
Note 7: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 187°C/W junction to ambient.

heat sink dimensions

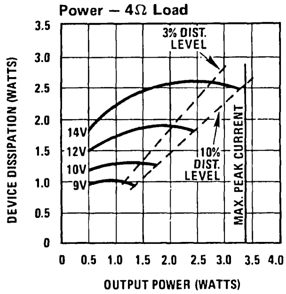


typical performance characteristics

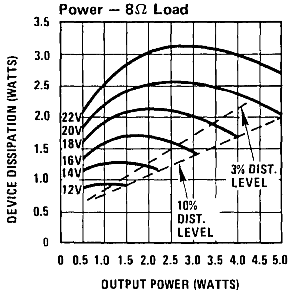
Maximum Device Dissipation vs Ambient Temperature



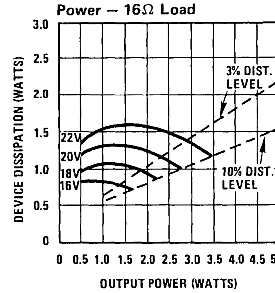
Device Dissipation vs Output Power – 4Ω Load



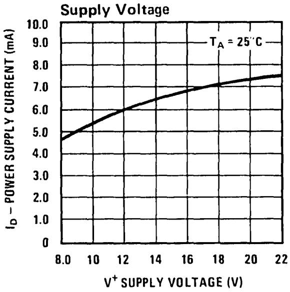
Device Dissipation vs Output Power – 8Ω Load



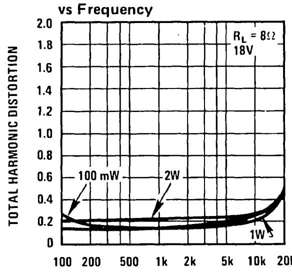
Device Dissipation vs Output Power – 16Ω Load



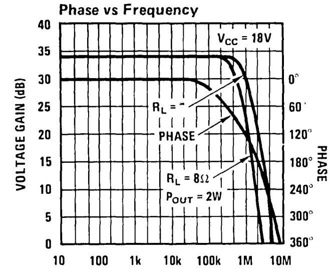
Power Supply Current vs Supply Voltage



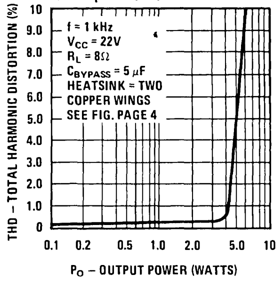
Total Harmonic Distortion vs Frequency



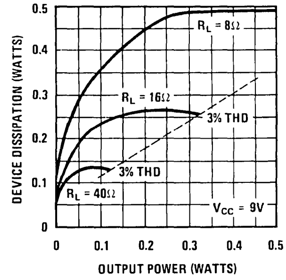
Output Voltage Gain and Phase vs Frequency



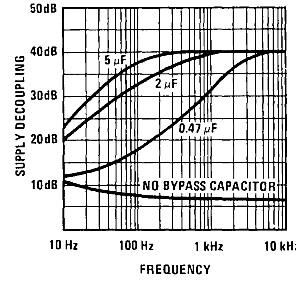
Total Harmonic Distortion vs Output Power



Device Dissipation vs Output Power

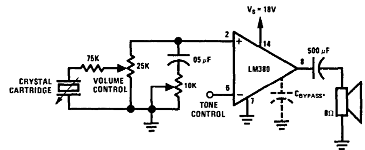


Supply Decoupling vs Frequency

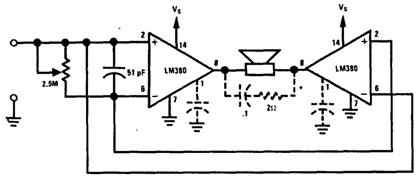


typical applications

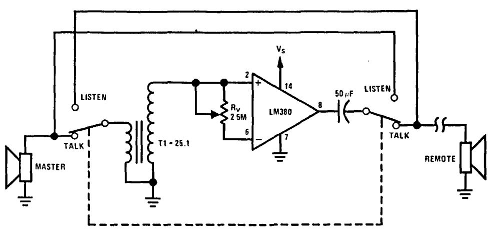
Phono Amplifier



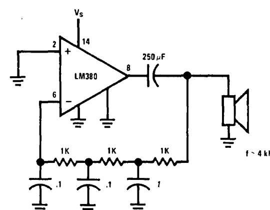
Bridge Amplifier



Intercom



Phase Shift Oscillator



Consumer Circuits

LM381/LM381A low noise dual preamplifier

general description

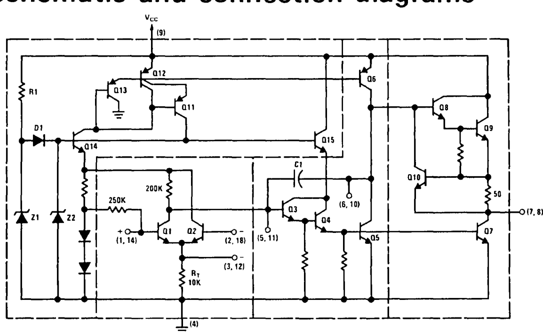
The LM381/LM381A is a dual preamplifier for the amplication of low level signals in applications requiring optimum noise performance. Each of the two amplifiers is completely independent, with individual internal power supply decoupler-regulator, providing 120 dB supply rejection and 60 dB channel separation. Other outstanding features include high gain (112 dB), large output voltage swing (V_{CC} −2V) p-p, and wide power bandwidth (75 kHz, $20V_{P-P}$). The LM381/LM381A operates from a single supply across the wide range of 9 to 40V.

Either differential input or single ended input configurations may be selected. The amplifier is internally compensated with the provision for additional external compensation for narrow band applications.

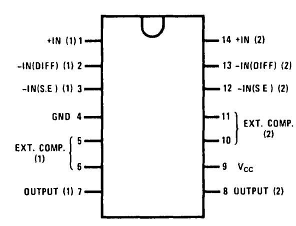
features

- Low Noise — .5 μV total input noise
- High Gain — 112 dB open loop
- Single Supply Operation
- Wide supply range 9–40V
- Power supply rejection 120 dB
- Large output voltage swing (V_{CC} −2V)$_{p-p}$
- Wide bandwidth 15 MHz unity gain
- Power bandwidth 75 kHz, 20 V_{p-p}
- Internally compensated
- Short circuit protected

schematic and connection diagrams

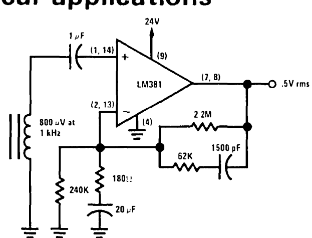


Dual-In-Line Package

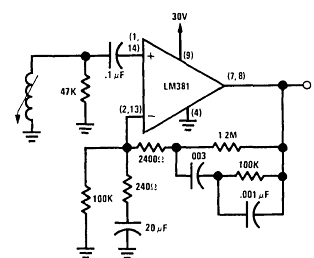


Order Number LM381N, LM381AN
See Package 22

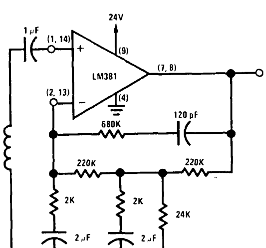
typical applications



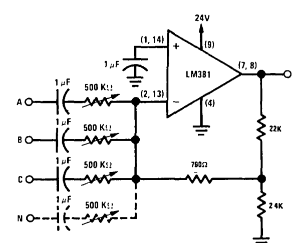
Typical Tape Playback Amplifier



Typical Magnetic Phono Preamp.



Two-Pole Fast Turn-On NAB Tape Preamp



Audio Mixer

absolute maximum ratings

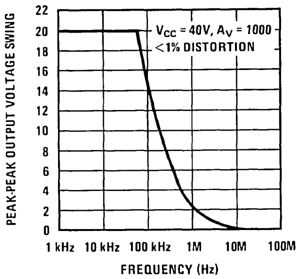
Supply Voltage	+40V
Power Dissipation	800 mW
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics T_A = 25°C, V_{CC} = 14V, unless otherwise stated.

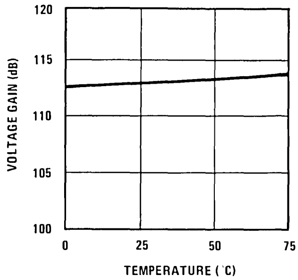
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Voltage Gain	Open Loop (Differential Input)		160,000		V/V
	Open Loop (Single Ended)		320,000		V/V
Supply Current	V_{CC} 9 to 40V, $R_L = \infty$		10		mA
Input Resistance					
(Positive Input)			100		kΩ
(Negative Input)			200		kΩ
Input Current					
(Negative Input)			0.5		μA
Output Resistance	Open Loop		150		Ω
Output Current	Source		8		mA
	Sink		2		mA
Output Voltage Swing	Peak-to-Peak		$V_{CC} - 2$		V
Small Signal Bandwidth			15		MHz
Power Bandwidth	20 V_{p-p} (V_{CC} = 24V)		75		kHz
Maximum Input Voltage	Linear Operation			300	mVrms
Supply Rejection Ratio	f = 1 kHz		120		dB
Channel Separation	f = 1 kHz		60		dB
Total Harmonic Distortion	75 dB Gain, f = 1 kHz		0.1		%
Total Equivalent Input Noise	R_S = 600Ω, 10 – 10,000 Hz (Single Ended Input)				
LM381A			0.5	0.7	μVrms
LM381			0.5	1.0	μVrms
Noise Figure	50 kΩ, 10 – 10,000 Hz (Single Ended Input)		1.0		dB
	10 kΩ, 10 – 10,000 Hz (Single Ended Input)		1.3		dB
	5 kΩ, 10 – 10,000 Hz (Single Ended Input)		1.6		dB

typical performance characteristics

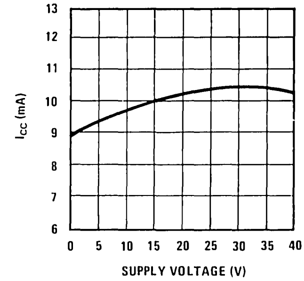
Large Signal Frequency Response



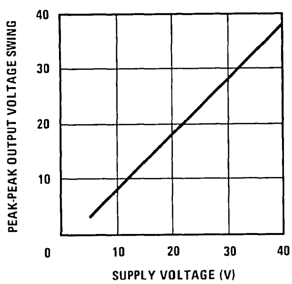
Gain vs Temperature



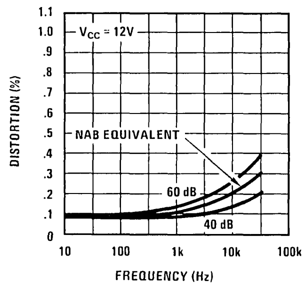
V_{CC} vs I_{CC}



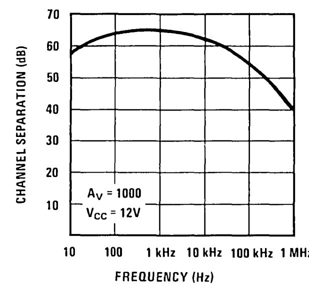
P–P Output Voltage Swing vs V_{CC}



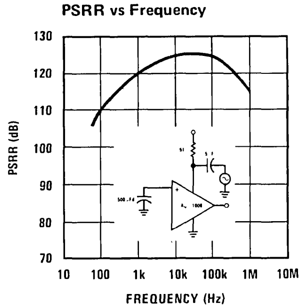
% Distortion



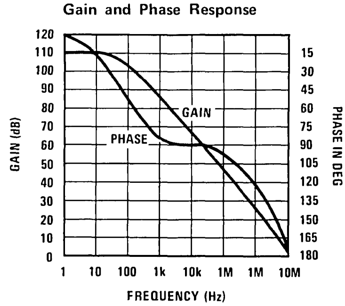
Channel Separation



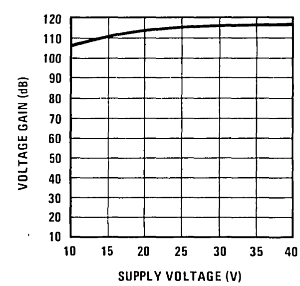
PSRR vs Frequency



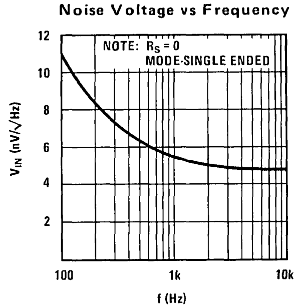
Gain and Phase Response



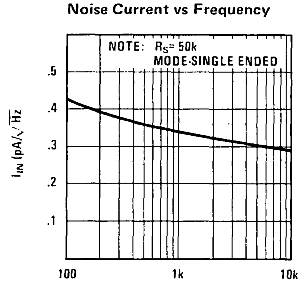
Voltage Gain vs Supply Voltage



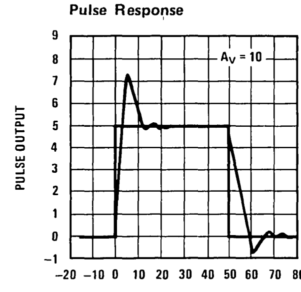
Noise Voltage vs Frequency



Noise Current vs Frequency



Pulse Response



Consumer Circuits

LM382 low noise dual preamplifier general description

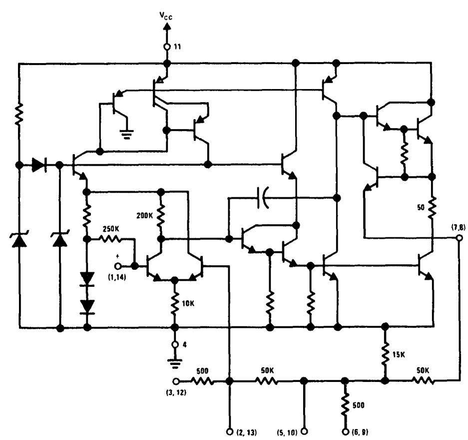
The LM382 is a dual preamplifier for the amplification of low level signals in applications requiring optimum noise performance. Each of the two amplifiers is completely independent, with individual internal power supply decoupler-regulator, providing 120 dB supply rejection and 60 dB channel separation. Other outstanding features include high gain (100 dB), large output voltage swing (V_{CC} −2V) p-p, and wide power bandwidth (75 kHz, 20 V_{p-p}). The LM382 operates from a single supply across the wide range of 9 to 40V.

A resistor matrix is provided on the chip to allow the user to select a variety of closed loop gain options and frequency response characteristics such as flat-band, NAB or RIAA equalization. The circuit is supplied in the 14 lead dual-in-line package.

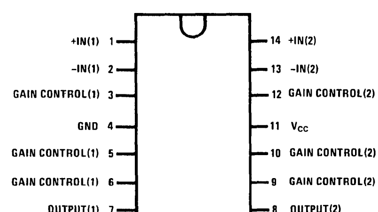
features

- Low noise – 0.8 μV total equivalent input noise
- High gain – 100 dB open loop
- Single supply operation
- Wide supply range 9 to 40V
- Power supply rejection – 120 dB
- Large output voltage swing
- Wide bandwidth – 15 MHz unity gain
- Power bandwidth – 75 kHz, 20 V_{p-p}
- Internally compensated
- Short circuit protected.

schematic and connection diagrams



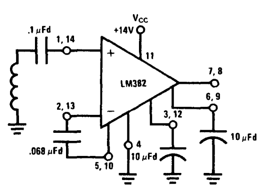
Dual-In-Line Package



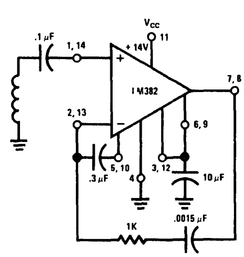
TOP VIEW

Order Number LM382N
See Package 22

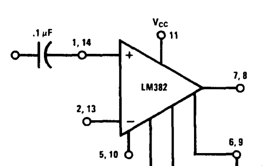
typical applications



Tape Reamplifier (NAB Equilization)



Phono Pre-Amp (RIAA Equilization)



CAPACITOR	GAIN
C1 Only	40 dB
C2 Only	55 dB
C1 & C2	80 dB

Flat Response – Fixed Gain Configuration

absolute maximum ratings

Supply Voltage	+40V
Power Dissipation	800 mW
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	–65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

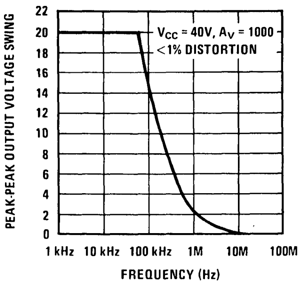
electrical characteristics T_A = 25°C, V_{CC} = 14V, unless otherwise stated.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Voltage Gain	Open Loop (Differential Input)		100,000		V/V
Supply Current	V_{CC} 9 to 40V, $R_L = \infty$		10	16	mA
Input Resistance					
(Positive Input)			100		kΩ
(Negative Input)			200		kΩ
Input Current					
(Negative Input)			0.5		μA
Output Resistance	Open Loop		150		Ω
Output Current	Source		8		mA
	Sink		2		mA
Output Voltage Swing	Peak-to-Peak, R = 10k		V_{CC} - 2		V
Small Signal Bandwidth			15		MHz
Power Bandwidth	20 $V_{p\text{-}p}$ (V_{CC} = 24V)		75		kHz
Maximum Input Voltage	Linear Operation			300	mVrms
Supply Rejection Ratio	f = 1 kHz		120		dB
Channel Separation	f = 1 kHz	40	60		dB
Total Harmonic Distortion	60 dB Gain, f = 1 kHz		0.1	0.3	%
Total Equivalent Input Noise	R_S = 600Ω, 100 – 10,000 Hz		0.8	1.2	μVrms
Noise Figure	50 kΩ, 100 – 10,000 Hz		1.0		dB
	10 kΩ, 100 – 10,000 Hz		1.6		dB
	5 kΩ, 100 – 10,000 Hz		2.8		dB

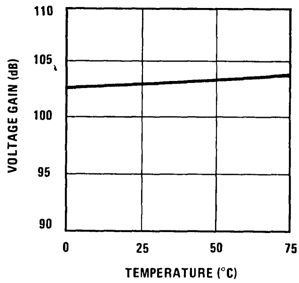
5

typical performance characteristics

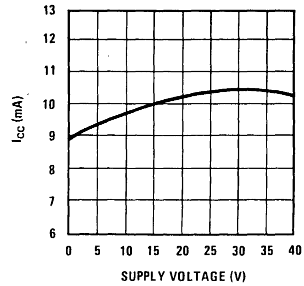
Large Signal Frequency Response



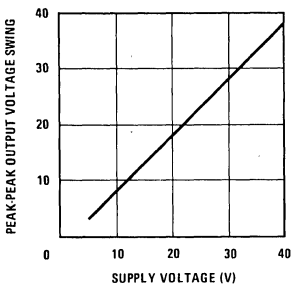
Gain vs Temperature



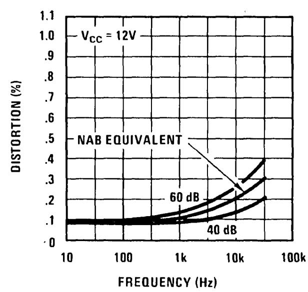
V_{CC} vs I_{CC}



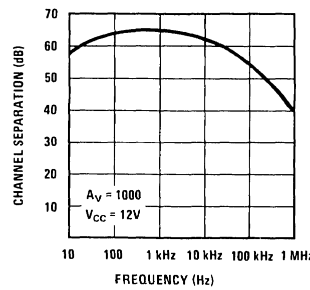
P–P Output Voltage Swing vs V_{CC}



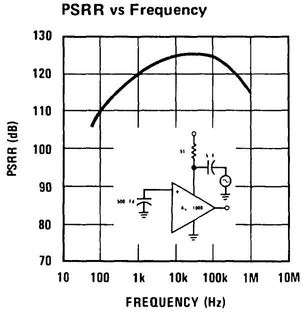
% Distortion



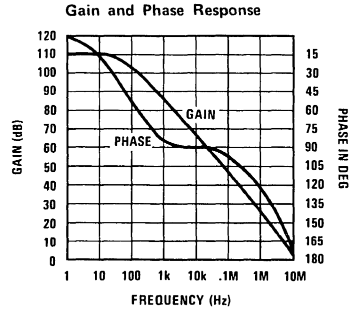
Channel Separation



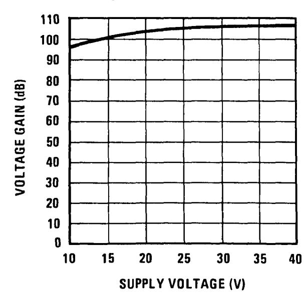
PSRR vs Frequency



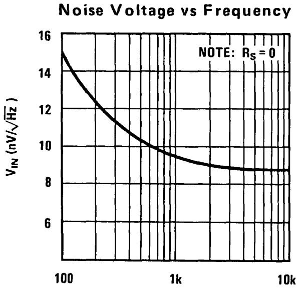
Gain and Phase Response



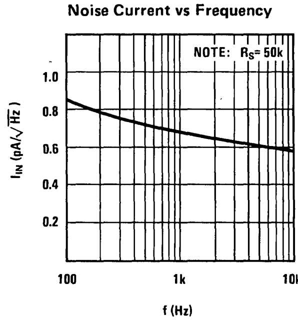
Voltage Gain vs Supply Voltage



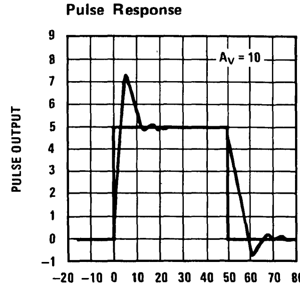
Noise Voltage vs Frequency



Noise Current vs Frequency



Pulse Response



Consumer Circuits

LM386 low voltage audio power amplifier

general description

The LM386 is a power amplifier designed for use in low voltage consumer applications. The gain is internally set to 20 to keep external part count low, but the addition of an external resistor and capacitor between pins 1 and 8 will increase the gain to any value up to 200.

The inputs are ground referenced while the output is automatically biased to one half the supply voltage. The quiescent power drain is only 18 milliwatts when operating from a 6 volt supply, making the LM386 ideal for battery operation.

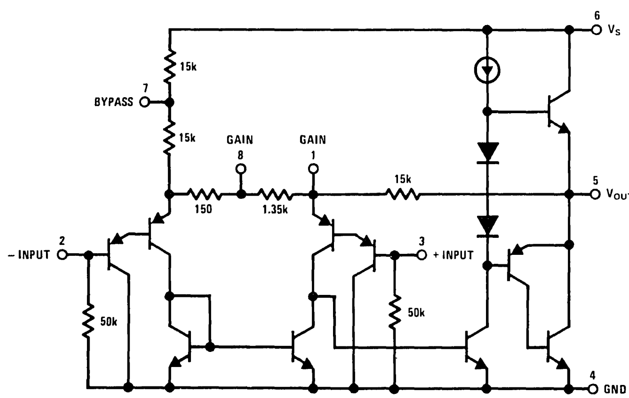
features

- Battery operation
- Minimum external parts
- Wide supply voltage range 4–12 Volts
- Low quiescent current drain 3 mA
- Voltage gains from 20 to 200
- Ground referenced input
- Self-centering output quiescent voltage
- Low distortion
- Eight pin dual-in-line package

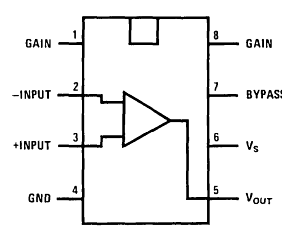
applications

- AM-FM radio amplifiers
- Portable tape player amplifiers
- Intercoms
- TV sound systems
- Line drivers
- Ultrasonic drivers
- Small servo drivers
- Power converters

equivalent schematic and connection diagrams



Dual-In-Line Package

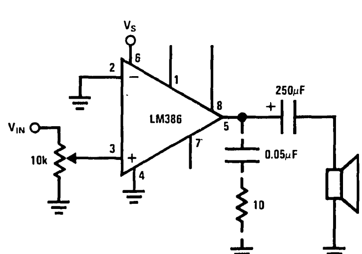


TOP VIEW

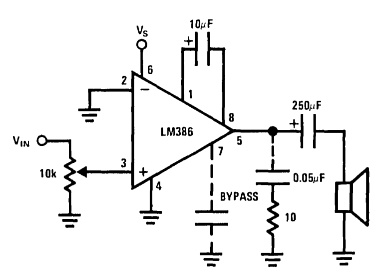
Order Number LM386N
See Package 20

typical applications

Amplifier with Gain = 20
Minimum Parts



Amplifier with Gain = 200



absolute maximum ratings

Supply Voltage	15V
Package Dissipation 8 Pin DIP (Note 1)	660 mW
Input Voltage	±0.4V
Storage Temperature	−65°C to +150°C
Operating Temperature	0°C to +70°C
Junction Temperature	+150°C
Lead Temperature (Soldering, 10 seconds)	+300°C

electrical characteristics T_A = 25°C

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Supply Voltage (V_S)		4		12	V
Quiescent Current (I_Q)	V_S = 6V, V_{IN} = 0		3	8	mA
Output Power (P_{OUT}) (Note 2)	V_S = 6V, R_L = 8Ω, THD = 10%, V_S = 9V, R_L = 16Ω, THD = 10%	250	325 500		mW mW
Voltage Gain (A_V)	V_S = 6V, f = 1 kHz 10μF from Pin 1 to 8		26 46		dB dB
Bandwidth (BW)	V_S = 6V, Pins 1 and 8 Open		300		kHz
Total Harmonic Distortion (THD)	V_S = 6V, R_L = 8Ω, P_{OUT} = 125 mW f = 1 kHz, Pins 1 and 8 Open		0.2		%
Power Supply Rejection Ratio (PSRR)	V_S = 6V, f = 1 kHz, C_{BYPASS} = 10μF Pins 1 and 8 Open, Referred to Output		50		dB
Input Resistance (R_{IN})			50		kΩ
Input Bias Current (I_{BIAS})	V_S = 6V, Pins 2 and 3 Open		250		nA

Note 1: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 187°C/W junction to ambient.

Note 2: If oscillation exists under some load conditions, add 10Ω and 0.05μF series network from pin 5 to ground.

application hints

GAIN CONTROL

To make the LM386 a more versatile amplifier, two pins (1 and 8) are provided for gain control. With pins 1 and 8 open the 1.35 kΩ resistor sets the gain at 20 (26 dB). If a capacitor is put from pin 1 to 8, bypassing the 1.35 kΩ resistor, the gain will go up to 200 (46 dB). If a resistor is placed in series with the capacitor, the gain can be set to any value from 20 to 200. Gain control can also be done by capacitively coupling a resistor (or FET) from pin 1 to ground.

Additional external components can be placed in parallel with the internal feedback resistors to tailor the gain and frequency response for individual applications. For example, we can compensate poor speaker bass response by frequency shaping the feedback path. This is done with a series RC from pin 1 to 5 (paralleling the internal 15kΩ resistor). For 6 dB effective bass boost: R ≅ 15 kΩ, the lowest value for good stable operation is R = 10 kΩ if pin 8 is open. If pins 1 and 8 are bypassed then R as low as 2 kΩ can be used. This restriction is because the amplifier is only compensated for closed-loop gains greater than 9.

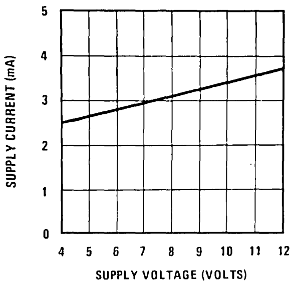
INPUT BIASING

The schematic shows that both inputs are biased to ground with a 50 kΩ resistor. The base current of the input transistors is about 250 nA, so the inputs are at about 12.5 mV when left open. If the dc source resistance driving the LM386 is higher than 250 kΩ it will contribute very little additional offset (about 2.5 mV at the input, 50 mV at the output). If the dc source resistance is less than 10 kΩ, then shorting the unused input to ground will keep the offset low (about 2.5 mV at the input, 50 mV at the output). For dc source resistances between these values we can eliminate excess offset by putting a resistor from the unused input to ground, equal in value to the dc source resistance. Of course all offset problems are eliminated if the input is capacitively coupled.

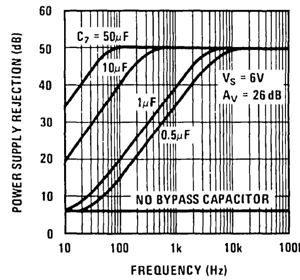
When using the LM386 with higher gains (bypassing the 1.35 kΩ resistor between pins 1 and 8) it is necessary to bypass the unused input, preventing degradation of gain and possible instabilities. This is done with a 0.1μF capacitor or a short to ground depending on the dc source resistance on the driven input.

typical performance characteristics

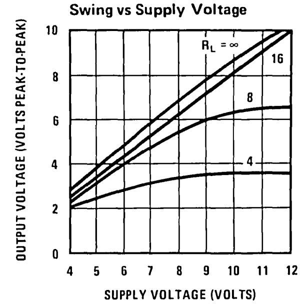
Quiescent Supply Current vs Supply Voltage



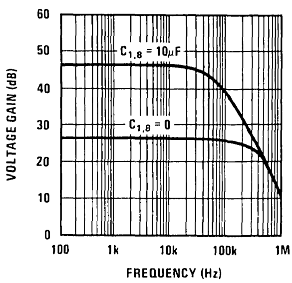
Power Supply Rejection Ratio (Referred to the Output) vs Frequency



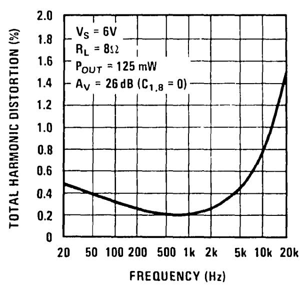
Peak-to-Peak Output Voltage Swing vs Supply Voltage



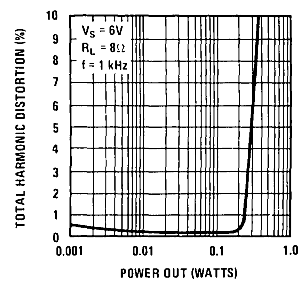
Voltage Gain vs Frequency



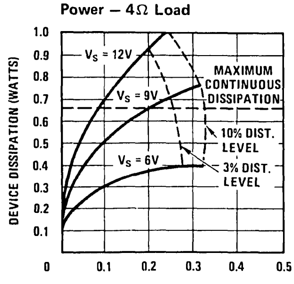
Distortion vs Frequency



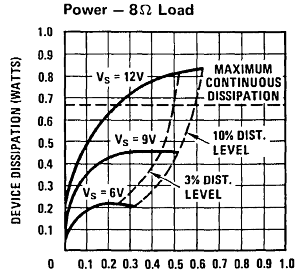
Distortion vs Output Power



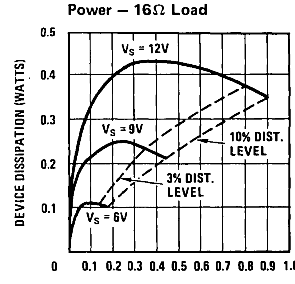
Device Dissipation vs Output Power — 4Ω Load



Device Dissipation vs Output Power — 8Ω Load

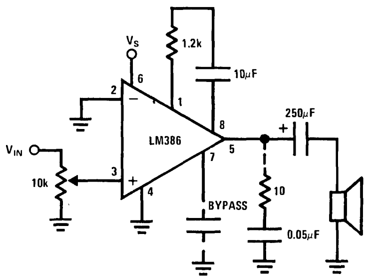


Device Dissipation vs Output Power — 16Ω Load

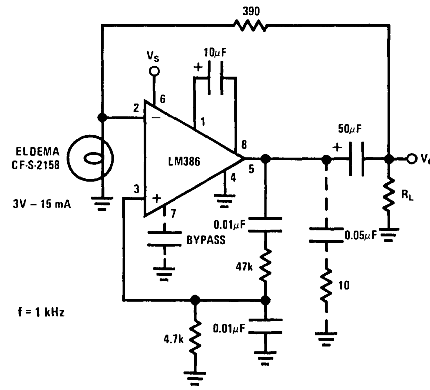


typical applications (con't)

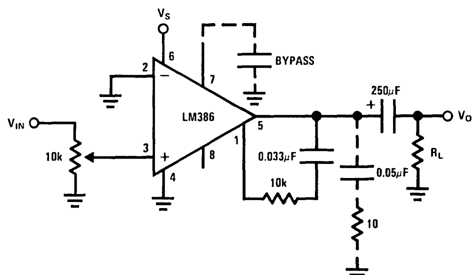
Amplifier with Gain = 50



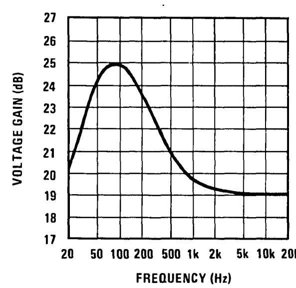
Low Distortion Power Wienbridge Oscillator



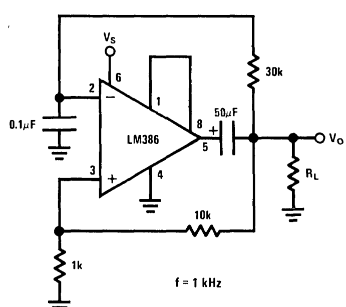
Amplifier with Bass Boost



Frequency Response with Bass Boost



Square Wave Oscillator



LM387 low noise dual preamplifier

general description

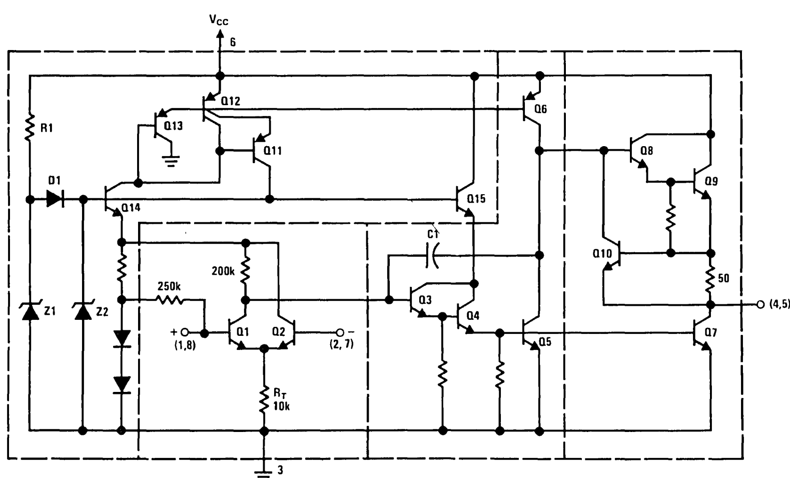
The LM387 is a dual preamplifier for the amplication of low level signals in applications requiring optimum noise performance. Each of the two amplifiers is completely independent, with an internal power supply decoupler-regulator, providing 110 dB supply rejection and 60 dB channel separation. Other outstanding features include high gain (104 dB), large output voltage swing (V_{CC}−2V)p-p, and wide power bandwidth (75 kHz, 20 Vp-p). The LM387 operates from a single supply across the wide range of 9 to 40V.

The amplifiers are internally compensated for. All gains greater than 10. The LM387 is available in an 8 lead dual-in-line package.

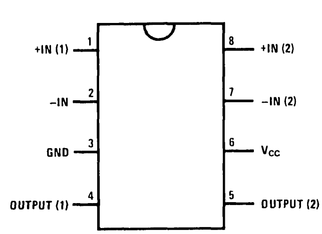
features

- Low noise 0.8μV total input noise
- High gain 104 dB open loop
- Single supply operation
- Wide supply range 9 to 40V
- Power supply rejection 110 dB
- Large output voltage swing (V_{CC}−2V)p-p
- Wide bandwidth 15 MHz unity gain
- Power bandwidth 75 kHz, 20 Vp-p
- Internally compensated
- Short circuit protected

schematic and connection diagrams



Dual-In-Line Package



TOP VIEW

Order Number LM387N

See Package 20

absolute maximum ratings

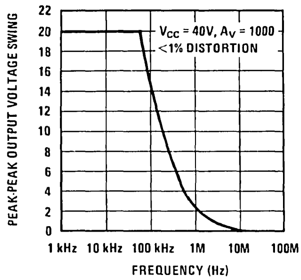
Supply Voltage	+40V
Power Dissipation	660 mW
Operating Temperature Range	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics T_A = 25°C, V_{CC} = 14V, unless otherwise stated.

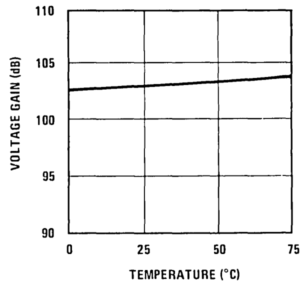
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Voltage Gain	Open Loop		160,000		V/V
Supply Current	V_{CC} 9 to 40V, $R_L = \infty$		10		mA
Input Resistance					
Positive Input			100		kΩ
Negative Input			200		kΩ
Input Current					
Negative Input			0.5		μA
Output Resistance	Open Loop		150		Ω
Output Current	Source		8		mA
	Sink		2		mA
Output Voltage Swing	Peak-to-Peak		$V_{CC}-2$		V
Small Signal Bandwidth			15		MHz
Power Bandwidth	20 Vp-p (V_{CC} = 24V)		75		kHz
Maximum Input Voltage	Linear Operation			300	mVrms
Supply Rejection Ratio	f = 1 kHz		110		dB
Channel Separation	f = 1 kHz		60		dB
Total Harmonic Distortion	75 dB Gain, f = 1 kHz		0.1		%
Total Equivalent Input Noise	R_S = 600Ω, 100 – 10,000 Hz		0.8	1.4	μVrms
Noise Figure	50 kΩ, 10 – 10,000 Hz		1.0		dB
	10 kΩ, 10 – 10,000 Hz		1.6		dB
	5 kΩ, 10 – 10,000 Hz		2.8		dB

typical performance characteristics

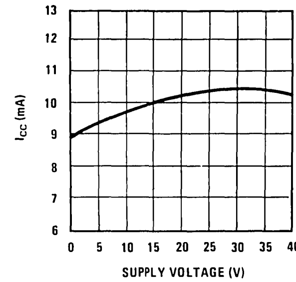
Large Signal Frequency Response



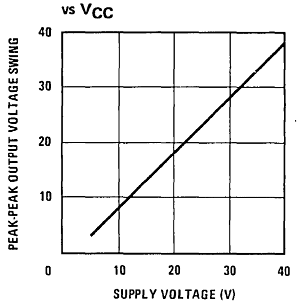
Gain vs Temperature



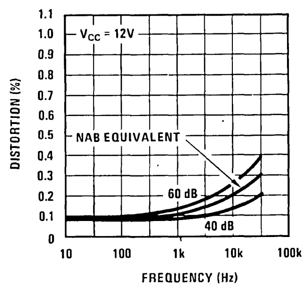
V_{CC} vs I_{CC}



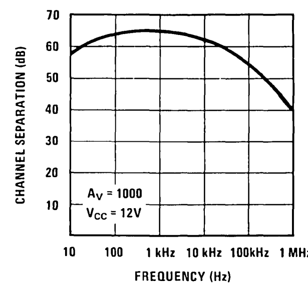
P-P Output Voltage Swing vs V_{CC}



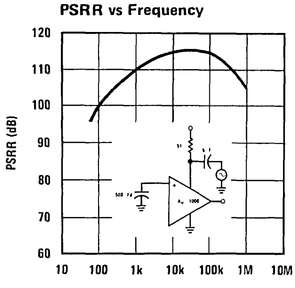
% Distortion



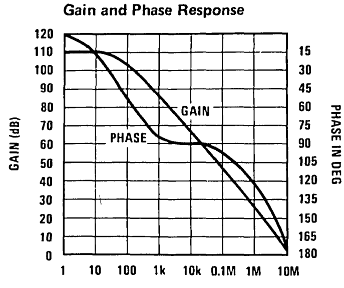
Channel Separation



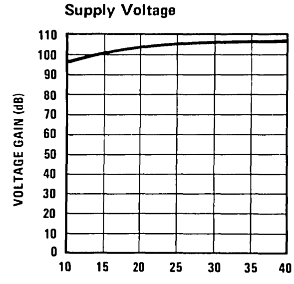
PSRR vs Frequency



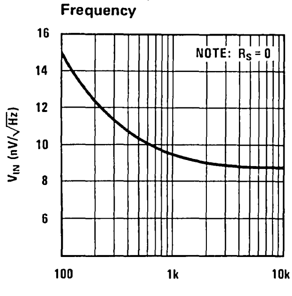
Gain and Phase Response



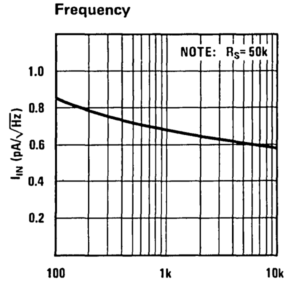
Voltage Gain vs Supply Voltage



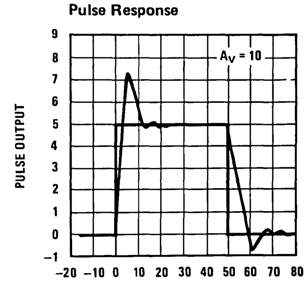
Noise Voltage vs Frequency



Noise Current vs Frequency

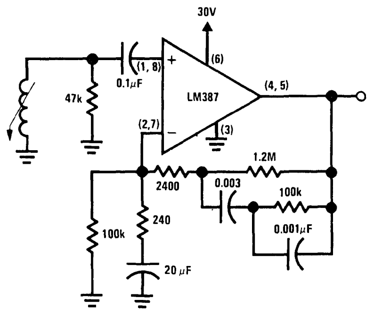


Pulse Response

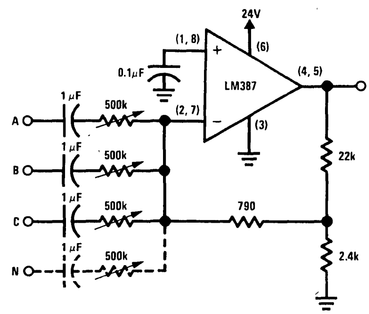


5

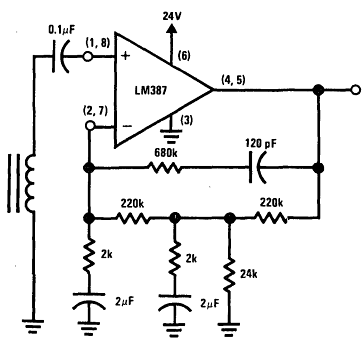
typical applications



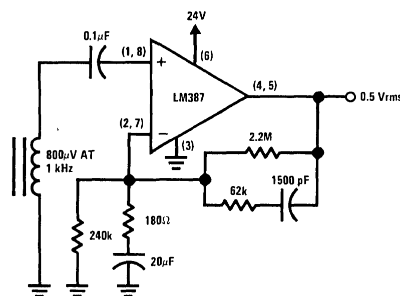
Typical Magnetic Phono Preamplifier



Audio Mixer



Two-Pole Fast Turn-On NAB Tape Preamplifier



Typical Tape Playback Amplifier

Consumer Circuits

LM565/LM565C phase locked loop

general description

The LM565 and LM565C are general purpose phase locked loops containing a stable, highly linear voltage controlled oscillator for low distortion FM demodulation, and a double balanced phase detector with good carrier suppression. The VCO frequency is set with an external resistor and capacitor, and a tuning range of 10:1 can be obtained with the same capacitor. The characteristics of the closed loop system—bandwidth, response speed, capture and pull in range—may be adjusted over a wide range with an external resistor and capacitor. The loop may be broken between the VCO and the phase detector for insertion of a digital frequency divider to obtain frequency multiplication.

The LM565H is specified for operation over the −55°C to +125°C military temperature range. The LM565CH and LM565CN are specified for operation over the 0°C to +70°C temperature range.

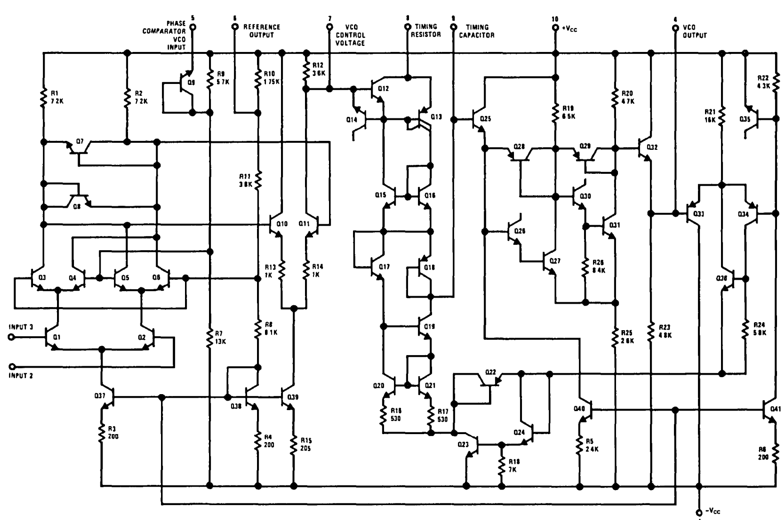
features

- 200 ppm/°C frequency stability of the VCO
- Power supply range of ±5 to ±12 volts with 100 ppm/% typical
- 0.2% linearity of demodulated output
- Linear triangle wave with in phase zero crossings available
- TTL and DTL compatible phase detector input and square wave output
- Adjustable hold in range from ±1% to > ±60%.

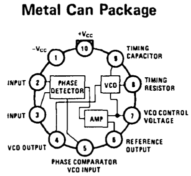
applications

- Data and tape synchronization
- Modems
- FSK demodulation
- FM demodulation
- Frequency synthesizer
- Tone decoding
- Frequency multiplication and division
- SCA demodulators
- Telemetry receivers
- Signal regeneration
- Coherent demodulators.

schematic and connection diagrams

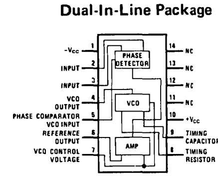


Metal Can Package



Order Number LM565H or LM565CH
See Package 14

Dual-In-Line Package



Order Number LM565CN
See Package 22

absolute maximum ratings

Supply Voltage		±12V
Power Dissipation (Note 1)		300 mW
Differential Input Voltage		±1V
Operating Temperature Range	LM565H	−55°C to +125°C
	LM565CH, LM565CN	0°C to 70°C
Storage Temperature Range		−65°C to +150°C
Lead Temperature (Soldering, 10 sec)		300°C

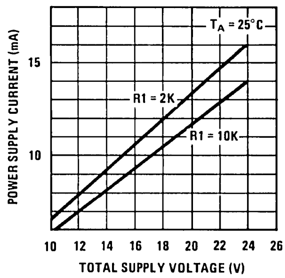
electrical characteristics (AC Test Circuit, T_A = 25°C, V_C = ±6V)

PARAMETER	CONDITIONS	LM565			LM565C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Power Supply Current			8.0	12.5		8.0	12.5	mA
Input Impedance (Pins 2, 3)	$-4V < V_2, V_3 < 0V$	7	10			5		kΩ
VCO Maximum Operating Frequency	C_o = 2.7 pF	300	500			500		kHz
Operating Frequency Temperature Coefficient			100			200		ppm/°C
Frequency Drift with Supply Voltage			100			200		ppm/%
Triangle Wave Output Voltage		2	2.4	3	2	2.4	3	V_{p-p}
Triangle Wave Output Linearity			0.2			0.5		%
Square Wave Output Level		4.7	5.4		4.7	5.4		V_{p-p}
Output Impedance (Pin 4)			5			5		kΩ
Square Wave Duty Cycle		45	50	55	40	50	60	%
Square Wave Rise Time			20	100		20		ns
Square Wave Fall Time			50	200		50		ns
Output Current Sink (Pin 4)		0.6	1		0.6	1		mA
VCO Sensitivity	f_o = 10 kHz		6600			6600		Hz/V
Demodulated Output Voltage (Pin 7)	±10% Frequency Deviation	250	300		200	300		mV_{pp}
Total Harmonic Distortion	±10% Frequency Deviation		0.2	0.75		0.2	1.5	%
Output Impedance (Pin 7)			3.5			3.5		kΩ
DC Level (Pin 7)		4.25	4.5	4.75	4.0	4.5	5.0	V
Output Offset Voltage $\|V_7 - V_6\|$			30	100		50	200	mV
Temperature Drift of $\|V_7 - V_6\|$			500			500		μV/°C
AM Rejection		30	40			40		dB
Phase Detector Sensitivity K_D			.68			.68		V/radian

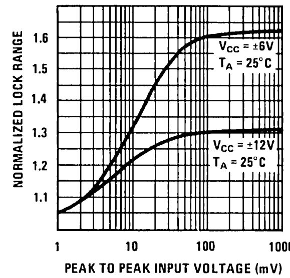
Note 1: The maximum junction temperature of the LM565 is 150°C, while that of the LM565C and LM565CN is 100°C. For operation at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case. Thermal resistance of the dual-in-line package is 100°C/W.

typical performance characteristics

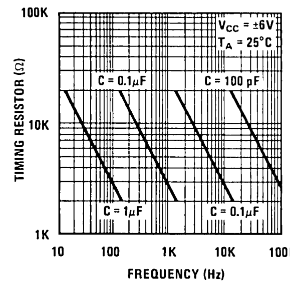
Power Supply Current as a Function of Supply Voltage



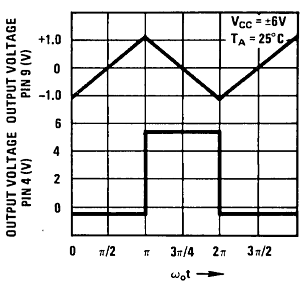
Lock Range as a Function of Input Voltage



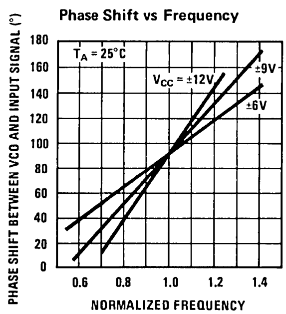
VCO Frequency



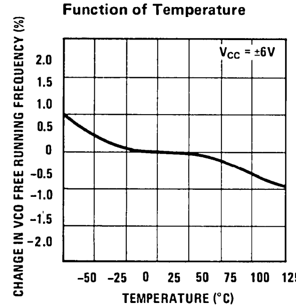
Oscillator Output Waveforms



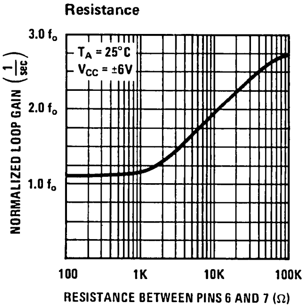
Phase Shift vs Frequency



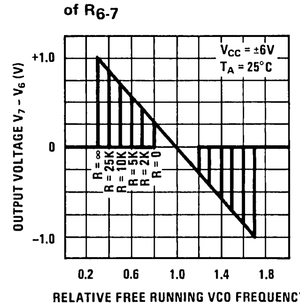
VCO Frequency as a Function of Temperature



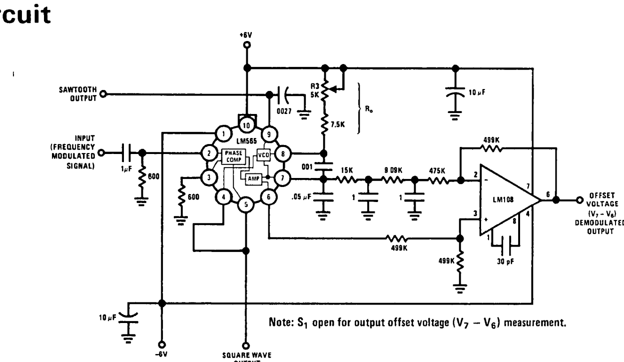
Loop Gain vs Load Resistance



Hold in Range as a Function of R_{6-7}



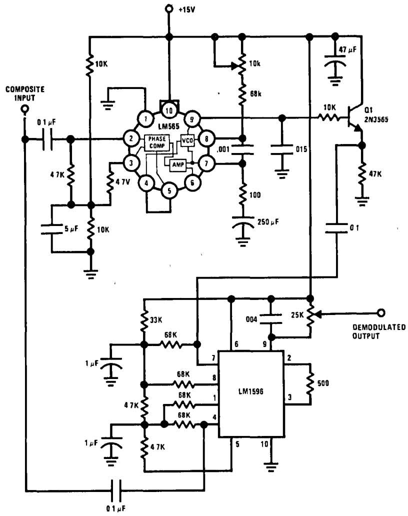
ac test circuit



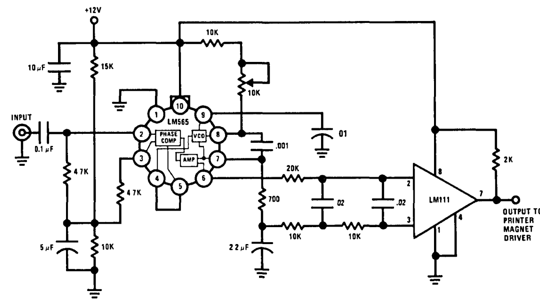
Note: S_1 open for output offset voltage ($V_7 - V_6$) measurement.

5

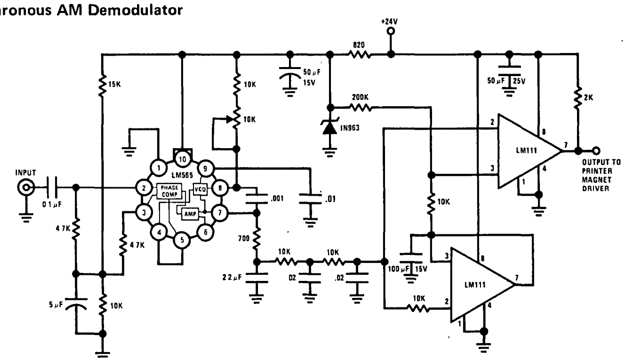
typical applications



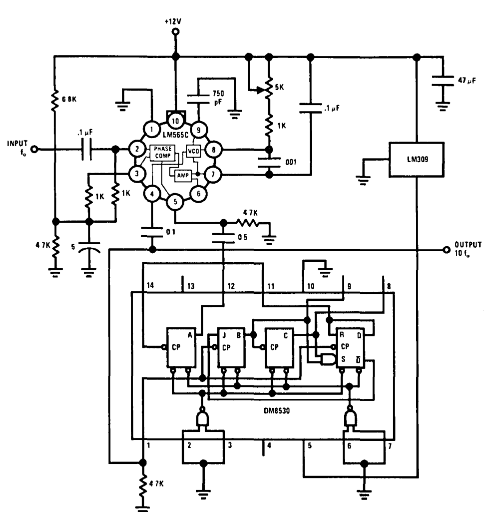
2400 Hz Synchronous AM Demodulator



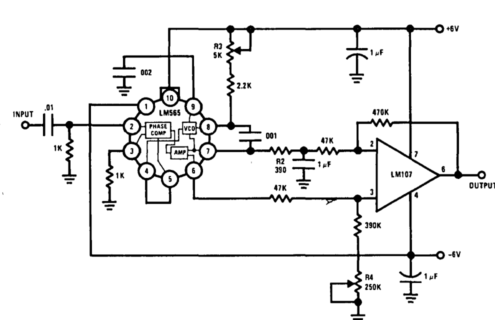
FSK Demodulator (2025-2225 cps)



FSK Demodulator with DC Restoration.



Frequency Multiplier (x10)



IRIG Channel 13 Demodulator

applications information

In designing with phase locked loops such as the LM565, the important parameters of interest are:

FREE RUNNING FREQUENCY

$$f_o \cong \frac{1}{3.7\, R_0 C_0}$$

LOOP GAIN: relates the amount of phase change between the input signal and the VCO signal for a shift in input signal frequency (assuming the loop remains in lock). In servo theory, this is called the "velocity error coefficient".

$$\text{Loop gain} = K_o K_D \left(\frac{1}{\text{sec}}\right)$$

$$K_o = \text{oscillator sensitivity} \left(\frac{\text{radians/sec}}{\text{volt}}\right)$$

$$K_D = \text{phase detector sensitivity} \left(\frac{\text{volts}}{\text{radian}}\right)$$

The loop gain of the LM565 is dependent on supply voltage, and may be found from:

$$K_o K_D = \frac{33.6\, f_o}{V_c}$$

f_o = VCO frequency in Hz

V_c = total supply voltage to circuit.

Loop gain may be reduced by connecting a resistor between pins 6 and 7; this reduces the load impedance on the output amplifier and hence the loop gain.

HOLD IN RANGE: the range of frequencies that the loop will remain in lock after initially being locked.

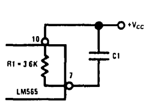
$$f_H = \pm \frac{8\, f_o}{V_c}$$

f_o = free running frequency of VCO

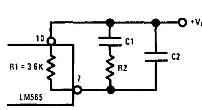
V_c = total supply voltage to the circuit.

THE LOOP FILTER

In almost all applications, it will be desirable to filter the signal at the output of the phase detector (pin 7) this filter may take one of two forms:



Simple Lag Filter



Lag-Lead Filter

A simple lag filter may be used for wide closed loop bandwidth applications such as modulation following where the frequency deviation of the carrier is fairly high (greater than 10%), or where wideband modulating signals must be followed.

The natural bandwidth of the closed loop response may be found from:

$$f_n = \frac{1}{2\pi}\sqrt{\frac{K_o K_D}{R_1 C_1}}$$

Associated with this is a damping factor:

$$\delta = \frac{1}{2}\sqrt{\frac{1}{R_1 C_1 K_o K_D}}$$

For narrow band applications where a narrow noise bandwidth is desired, such as applications involving tracking a slowly varying carrier, a lead lag filter should be used. In general, if $1/R_1C_1 < K_oK_d$, the damping factor for the loop becomes quite small resulting in large overshoot and possible instability in the transient response of the loop. In this case, the natural frequency of the loop may be found from

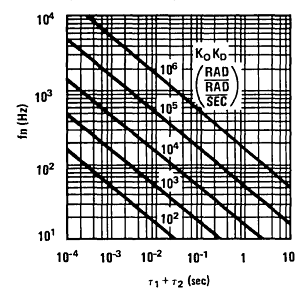
$$f_n = \frac{1}{2\pi}\sqrt{\frac{K_o K_D}{\tau_1 + \tau_2}}$$

$$\tau_1 + \tau_2 = (R_1 + R_2)\, C_1$$

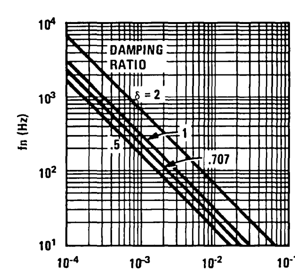
R_2 is selected to produce a desired damping factor δ, usually between 0.5 and 1.0. The damping factor is found from the approximation:

$$\delta \simeq \pi \tau_2 f_n$$

These two equations are plotted for convenience.



Filter Time Constant vs Natural Frequency



Damping Time Constant vs Natural Frequency

Capacitor C_2 should be much smaller than C_1 since its function is to provide filtering of carrier. In general $C_2 \leq 0.1\, C_1$.

Consumer Circuits

LM566/LM566C voltage controlled oscillator

general description

The LM566/LM566C are general purpose voltage controlled oscillators which may be used to generate square and triangular waves, the frequency of which is a very linear function of a control voltage. The frequency is also a function of an external resistor and capacitor.

The LM566 is specified for operation over the −55°C to +125°C military temperature range. The LM566C is specified for operation over the 0°C to +70°C temperature range.

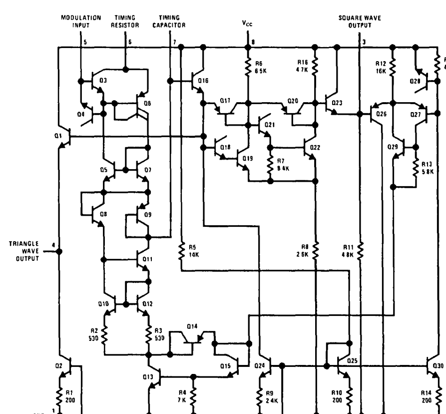
features

- Wide supply voltage range: 10 to 24 volts
- Very linear modulation characteristics
- High temperature stability
- Excellent supply voltage rejection
- 10 to 1 frequency range with fixed capacitor
- Frequency programmable by means of current, voltage, resistor or capacitor.

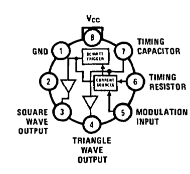
applications

- FM modulation
- Signal generation
- Function generation
- Frequency shift keying
- Tone generation

schematic and connection diagrams



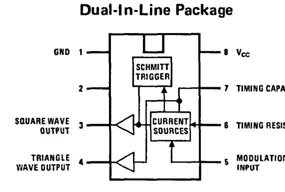
Metal Can



TOP VIEW

Order Number LM566H or LM566CH
See Package 11

Dual-In-Line Package

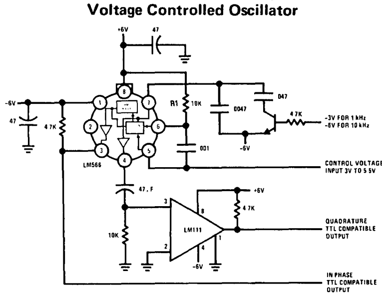


TOP VIEW

Order Number LM566CN
See Package 20

typical application

1 kHz and 10 kHz TTL Compatible Voltage Controlled Oscillator



applications information

The LM566 may be operated from either a single supply as shown in this test circuit, or from a split (±) power supply. When operating from a split supply, the square wave output (pin 4) is TTL compatible (2 mA current sink) with the addition of a 4.7 kΩ resistor from pin 3 to ground.

A .001 μF capacitor is connected between pins 5 and 6 to prevent parasitic oscillations that may occur during VCO switching.

$$f_O = \frac{2(V^+ - V_5)}{R_1 C_1 V^+}$$

where

$2K < R_1 < 20K$

and V_5 is voltage between pin 5 and pin 1

absolute maximum ratings

Power Supply Voltage		26V
Power Dissipation (Note 1)		300 mW
Operating Temperature Range	LM566	−55°C to +125°C
	LM566C	0°C to 70°C
Lead Temperature (Soldering, 10 sec)		300°C

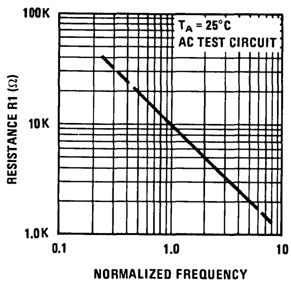
electrical characteristics V_{CC} = 12V, T_A = 25°C, AC Test Circuit

PARAMETER	CONDITIONS	LM566			LM566C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Maximum Operating Frequency	R_0 = 2k, C_0 = 2.7 pF		1			1		MHz
Input Voltage Range Pin 5		3/4 V_{CC}		V_{CC}	3/4 V_{CC}		V_{CC}	
Average Temperature Coefficient of Operating Frequency			100			200		ppm/°C
Supply Voltage Rejection			1			2		%/V
Input Impedance Pin 5			1			1		MΩ
VCO Sensitivity	f_0 = 10 kHz		6600			6600		Hz/V
FM Distortion	±10% Deviation		.2	.75		.2	1.5	%
Maximum Sweep Rate			1			1		MHz
Sweep Range			10:1			10:1		
Output Impedance Pin 3			50			50		Ω
Pin 4			50			50		Ω
Square Wave Output Level	R_{L1} = 10k	5.0	5.4		5.0	5.4		V p-p
Triangle Wave Output Level	R_{L2} = 10k	2.0	2.4		2.0	2.4		V p-p
Square Wave Duty Cycle		45	50	55	40	50	60	%
Square Wave Rise Time			20			20		ns
Square Wave Fall Time			50			50		ns
Triangle Wave Linearity			.2			.5		%

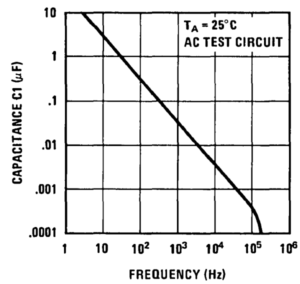
Note 1: The maximum junction temperature of the LM566 is 150°C, while that of the LM566C is 100°C. For operating at elevated junction temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W. The thermal resistance of the dual-in-line package is 100°C/W.

typical performance characteristics

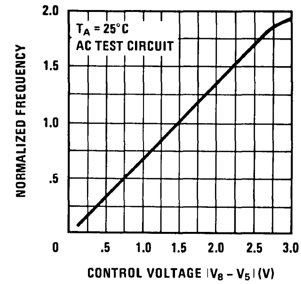
Operating Frequency as a Function of Timing Resistor



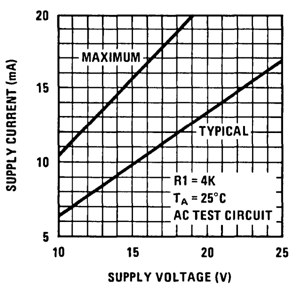
Operating Frequency as a Function of Timing Capacitor



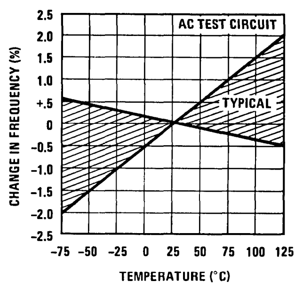
Normalized Frequency as a Function of Control Voltage



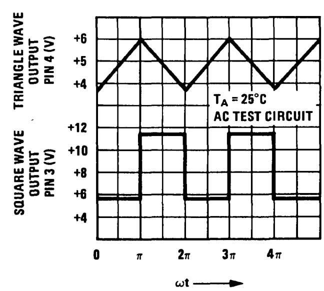
Power Supply Current



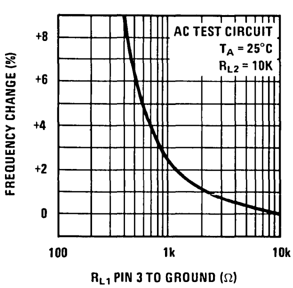
Temperature Stability



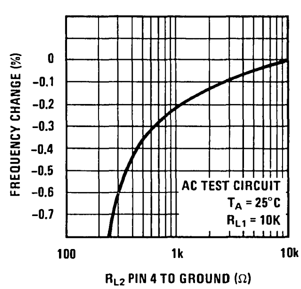
VCO Waveforms



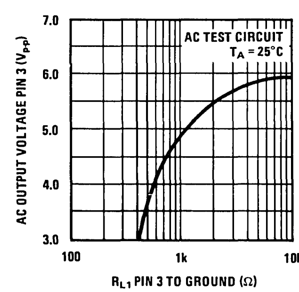
Frequency Stability vs Load Resistance (Square Wave Output)



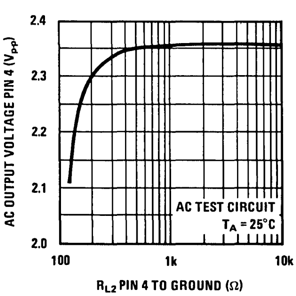
Frequency Stability vs Load Impedance (Triangle Output)



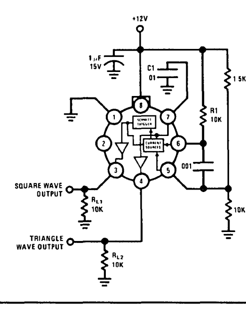
Square Wave Output Characteristics



Triangle Wave Output Characteristics



ac test circuit



Consumer Circuits

LM567/LM567C tone decoder

general description

The LM567 and LM567C are general purpose tone decoders designed to provide a saturated transistor switch to ground when an input signal is present within the passband. The circuit consists of an I and Q detector driven by a voltage controlled oscillator which determines the center frequency of the decoder. External components are used to independently set center frequency, bandwidth and output delay.

features

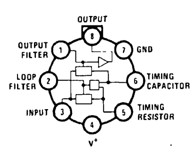
- 20 to 1 frequency range with an external resistor
- Logic compatible output with 100 mA current sinking capability
- Bandwidth adjustable from 0 to 14%
- High rejection of out of band signals and noise
- Immunity to false signals
- Highly stable center frequency
- Center frequency adjustable from 0.01 Hz to 500 kHz

applications

- Touch tone decoding
- Precision oscillator
- Frequency monitoring and control
- Wide band FSK demodulation
- Ultrasonic controls
- Carrier current remote controls
- Communications paging decoders

schematic and connection diagrams

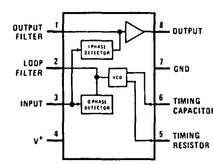
Metal Can Package



TOP VIEW

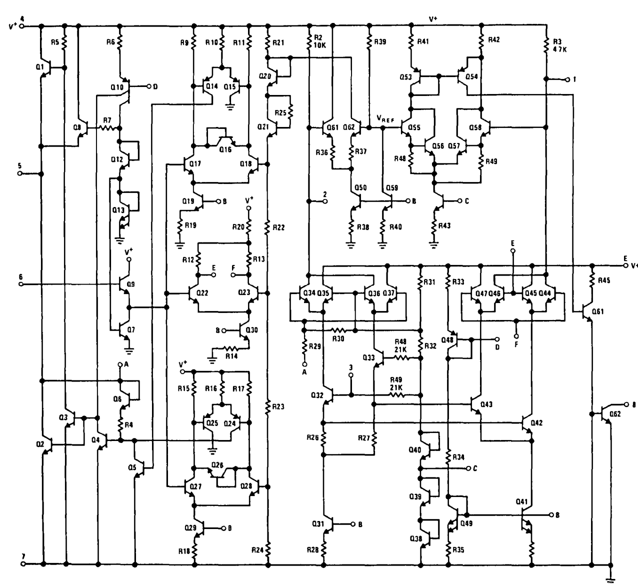
Order Number LM567H or LM567CH
See Package 11

Dual-In-Line Package



TOP VIEW

Order Number LM567CN
See Package 20



5

absolute maximum ratings

Supply Voltage Pin	10V
Power Dissipation (Note 1)	300 mW
V_8	15V
V_3	−10V
V_3	V_8 + 0.5V
Storage Temperature Range	−65°C to +150°C

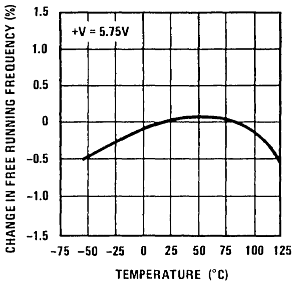
electrical characteristics (AC Test Circuit, T_A = 25°C, V_C = 5V)

PARAMETERS	CONDITIONS	LM567			LM567C/LM567CN			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Power Supply Voltage Range		4.75	5.0	9.0	4.75	5.0	9.0	V
Power Supply Current	R_L = 20k							
Quiescent			6	8		7	10	mA
Power Supply Current	R_L = 20k							
Activated			11	13		12	15	mA
Input Resistance			20			20		kΩ
Smallest Detectable Input Voltage	I_L = 100 mA, $f_i = f_o$		20	25		20	25	mVrms
Largest No Output Input Voltage	I_C = 100 mA, $f_i = f_o$	10	15		10	15		mVrms
Largest Simultaneous Outband Signal to Inband Signal Ratio			6			6		dB
Minimum Input Signal to Wideband Noise Ratio	B_n = 140 kHz		−6			−6		dB
Largest Detection Bandwidth		12	14	16	10	14	18	% of f_o
Largest Detection Bandwidth Skew			1	2		2	3	% of f_o
Largest Detection Bandwidth Variation with Temperature			±0.1			±0.1		%/°C
Largest Detection Bandwidth Variation with Supply Voltage			±2			±2		%V
Highest Center Frequency		100	500		100	500		kHz
Center Frequency Stability	$0 < T_A < 70$		35 ± 60			35 ± 60		ppm/°C
	$-55 < T_A < +125$		35 ± 140			35 ± 140		ppm/°C
Center Frequency Shift with Supply Voltage			0.5	1.0		0.4	2.0	%/V
Fastest ON-OFF Cycling Rate			f_o/20			f_o/20		
Output Leakage Current	V_8 = 15V		0.01	25		0.01	25	µA
Output Saturation Voltage	e_i = 25 mV, I_8 = 30 mA		0.2	0.4		0.2	0.4	V
	e_i = 25 mV, I_8 = 100 mA		0.6	1.0		0.6	1.0	
Output Fall Time			30			30		ns
Output Rise Time			150			150		ns

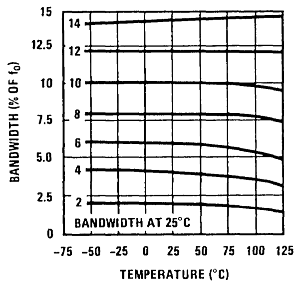
Note 1: The maximum junction temperature of the LM567 is 150°C, while that of the LM567C and LM567CN is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient or 45°C/W, junction to case. For the DIP the device must be derated based on a thermal resistance of 187°C/W, junction to ambient.

typical performance characteristics

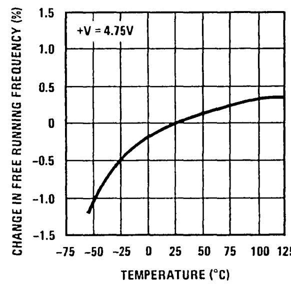
Typical Frequency Drift with Temperature (Mean and S.D.)



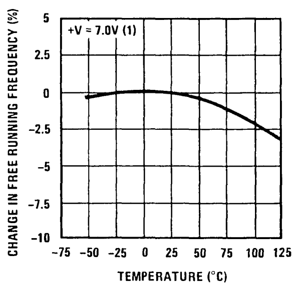
Typical Bandwidth Variation with Temperature



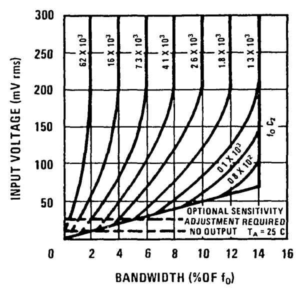
Typical Frequency Drift with (Mean and S.D.) Temperature



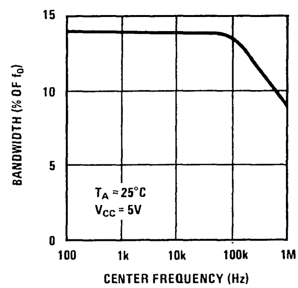
Typical Frequency Drift with Temperature (Mean and S.D.)



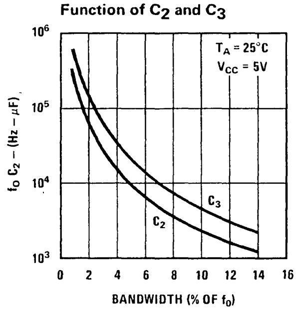
Bandwith vs Input Signal Amplitude



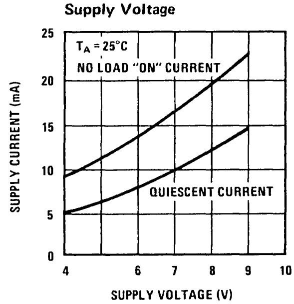
Largest Detection Bandwidth



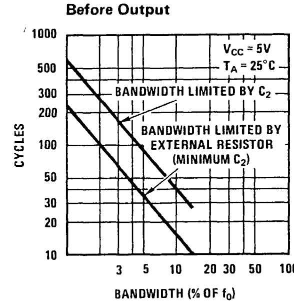
Detection Bandwidth as a Function of C_2 and C_3



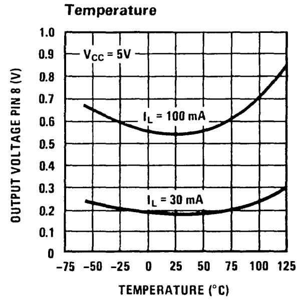
Typical Supply Current vs Supply Voltage



Greatest Number of Cycles Before Output

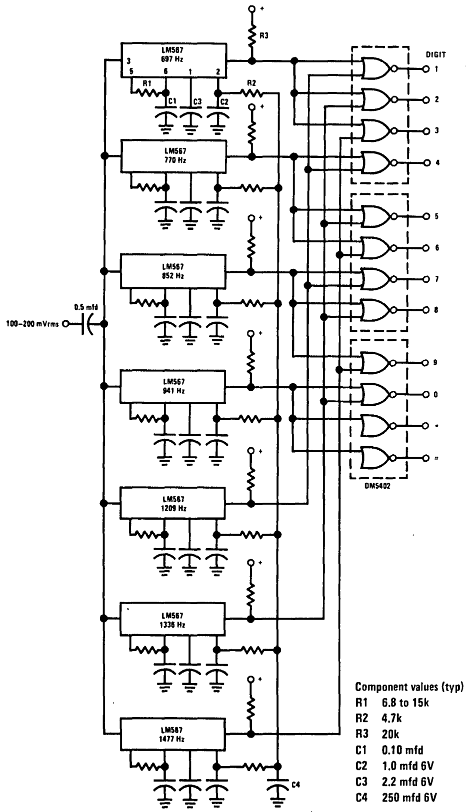


Typical Output Voltage vs Temperature

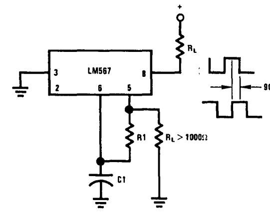


typical applications

Touch-Tone Decoder

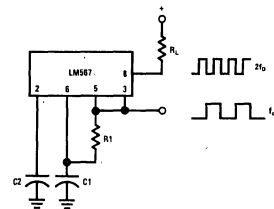


Oscillator with Quadrature Output

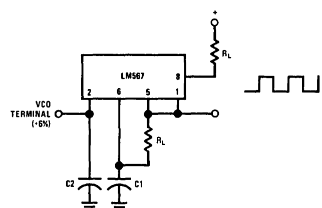


Connect pin 3 to 2.8V to invert output.

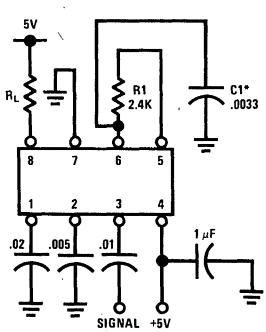
Oscillator with Double Frequency Output



Precision Oscillator Drive 100 mA Loads



ac test circuit



f_i = 100 kHz +5V

*Note: Adjust for f_O = 100 kHz.

applications information

The center frequency of the tone decoder is equal to the free running frequency of the VCO. This is given by

$$f_o \cong \frac{1}{R_1 C_1}$$

The bandwidth of the filter may be found from the approximation

$$BW = 1070 \sqrt{\frac{V_i}{f_o C_2}} \quad \text{in \% of } f_o$$

Where:

V_i = Input voltage (volts rms), $V_i \leq 200$ mV

C_2 = Capacitance at Pin 2 (µF)

Consumer Circuits

LM703L low power drain rf/if amplifier

general description

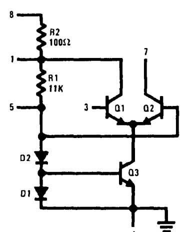
The LM703L is a monolithic RF-IF amplifier, having an efficient DC biasing system, reducing demands upon power supply and decoupling elements. Its low internal feedback guarantees a high stability-limited gain.

Applications include limiting and nonlimiting amplifiers, mixers, and RF oscillators. The LM703L is specifically characterized for operation in consumer applications such as TV sound IF, FM-IF limiter amplifier, and Chroma reference oscillator for color TV.

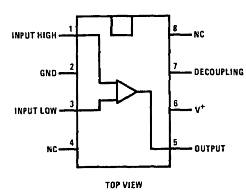
features

- Power Consumption 96 mW (max.)
- Forward Transadmittance 33 mmhos
- Input Conductance 0.35 mmhos
- Output Conductance 0.03 mmhos
- Peak-to-Peak Output Current 5.0 mA

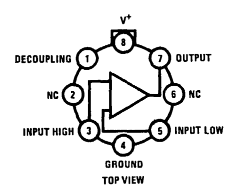
schematic and connection diagrams



Pin connections are for H package.



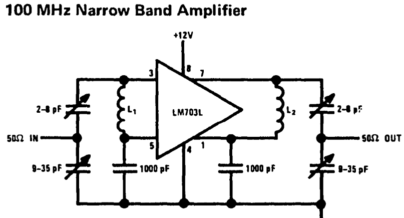
Order Number LM703LN
See Package 20.



Note: Pin 4 connected to case.
Order Number LM703LH
See Package 11

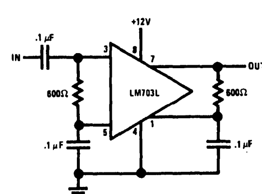
typical applications

100 MHz Narrow Band Amplifier

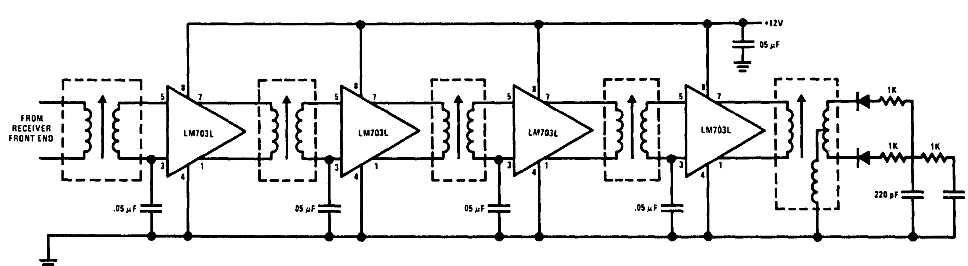


$L_1 = L_2$ = 7t #16, 1/4" i.d., spaced 1 turn.

RC Coupled Video Amplifier



Four Stage 10.7 MHz FM-IF Amplifier



absolute maximum ratings

Supply Voltage	20V
Output Collector Voltage	24V
Voltage Between Input Terminals	±5.0V
Internal Power Dissipation	200 mW
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

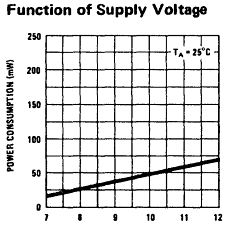
electrical characteristics (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
Power Consumption	$e_{in} = 0$		71	96	mW
Quiescent Output Current	$e_{in} = 0$	1.5	2.5	3.3	mA
Peak-to-Peak Output Current	e_{in} = 400 mV rms, f = 10.7 MHz	3.0	5.0		mA
Output Saturation Voltage				1.7	V
Forward Transadmittance	e_{in} = 10 mV rms, $f \leq$ 10.7 MHz	24.0	33.0		mmho
Reverse Transadmittance	e_{in} = 10 mV rms, $f \leq$ 10.7 MHz		0.002		mmho
Input Conductance	$e_{in} =<$ 10 mV rms, $f \leq$ 10.7 MHz		0.35	1.0	mmho
Input Capacitance	$e_{in} <$ 10 mV rms, $f \leq$ 10.7 MHz		9.0	12.5	pF
Output Capacitance	$f \leq$ 10.7 MHz		2.6	4.0	pF
Output Conductance	$f \leq$ 10.7 MHz		0.03	0.05	mmho
Noise Figure	$R_S = 500\Omega$, f = 10.7 MHz $R_S = 500\Omega$, f = 100 MHz		6.0 8.0		dB dB
Maximum Stable Gain	f = 100 MHz		28.0		dB

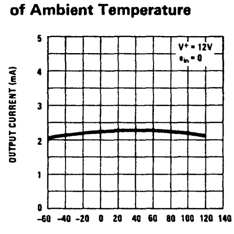
Note 1: These specifications apply for $T_A = 25°C$, $V^+ = 12V$ unless otherwise specified.

typical performance characteristics

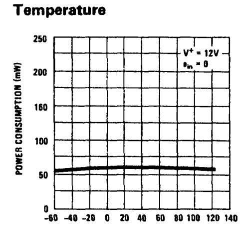
Power Consumption as a Function of Supply Voltage



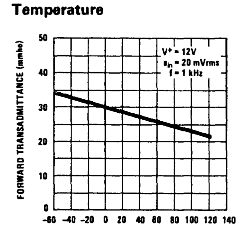
Output Current as a Function of Ambient Temperature



Power Consumption as a Function of Ambient Temperature



Forward Transadmittance as a Function of Ambient Temperature



Consumer Circuits

LM733/LM733C differential video amp

general description

The LM733/LM733C is a two-stage, differential input, differential output, wide-band video amplifier. The use of internal series-shunt feedback gives wide bandwidth with low phase distortion and high gain stability. Emitter-follower outputs provide a high current drive, low impedance capability. It's 120 MHz bandwidth and selectable gains of 10, 100, and 400, without need for frequency compensation, make it a very useful circuit for memory element drivers, pulse amplifiers, and wide band linear gain stages.

The LM733 is specified for operation over the −55°C to +125°C military temperature range. The LM733C is specified for operation over the 0°C to +70°C temperature range.

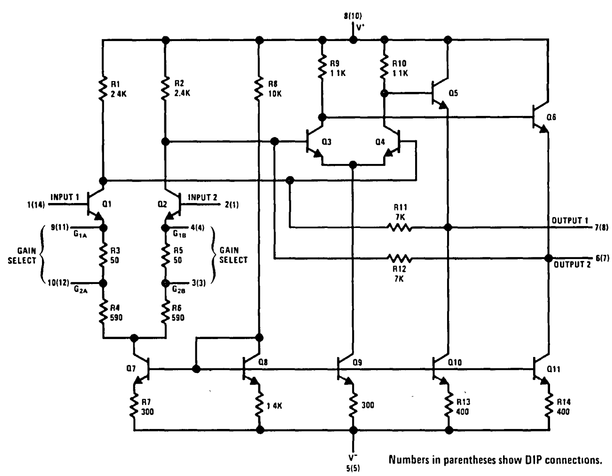
features

- 120 MHz bandwidth
- 250 kΩ input resistance
- Selectable gains of 10, 100, 400
- No frequency compensation
- High common mode rejection ratio at high frequencies.

applications

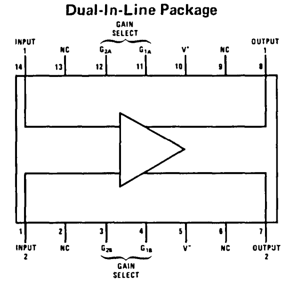
- Magnetic tape systems
- Disk file memories
- Thin and thick film memories
- Woven and plated wire memories
- Wide band video amplifiers.

schematic and connection diagrams



Numbers in parentheses show DIP connections.

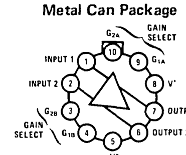
Dual-In-Line Package



Order Number LM733D or LM733CD
See Package 1

Order Number LM733CN
See Package 22

Metal Can Package

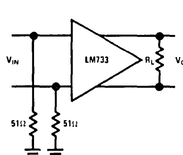


Note: Pin 5 connected to case.
TOP VIEW

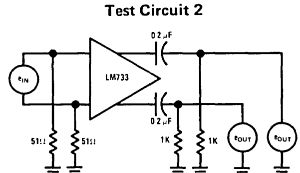
Order Number LM733H or LM733CH
See Package 14

test circuits

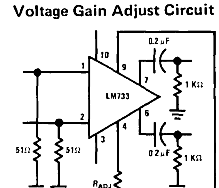
Test Circuit 1



Test Circuit 2



Voltage Gain Adjust Circuit



V_S = 6V, T_A = 25°C
(Pin numbers apply to TO-5 package)

absolute maximum ratings

Differential Input Voltage	±5V
Common Mode Input Voltage	±6V
V_{CC}	±8V
Output Current	10 mA
Power Dissipation (Note 1)	500 mW
Junction Temperature	+150°C
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range LM733	−55°C to +125°C
LM733C	0°C to +70°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (T_A = 25°C,unless otherwise specified,see test circuits, V_S = ±6.0V)

CHARACTERISTICS	TEST CIRCUIT	TEST CONDITIONS	LM733 MIN	LM733 TYP	LM733 MAX	LM733C MIN	LM733C TYP	LM733C MAX	UNITS
Differential Voltage Gain									
Gain 1 (Note 2)			300	400	500	250	400	600	
Gain 2 (Note 3)	1	R_L = 2 kΩ V_{OUT} = 3 $V_{p\text{-}p}$	90	100	110	80	100	120	
Gain 3 (Note 4)			9.0	10	11	8.0	10	12	
Bandwidth									
Gain 1				40			40		MHz
Gain 2	2			90			90		MHz
Gain 3				120			120		MHz
Rise Time									
Gain 1		V_{OUT} = 1 $V_{p\text{-}p}$		10.5			10.5		ns
Gain 2	2			4.5	10		4.5	12	ns
Gain 3				2.5			2.5		ns
Propagation Delay		V_{OUT} = 1 $V_{p\text{-}p}$							
Gain 1				7.5			7.5		ns
Gain 2	2			6.0	10		6.0	10	ns
Gain 3				3.6			3.6		ns
Input Resistance									
Gain 1				4.0			4.0		kΩ
Gain 2			20	30		10	30		kΩ
Gain 3				250			250		kΩ
Input Capacitance		Gain 2		2.0			2.0		pF
Input Offset Current				0.4	3.0		0.4	5.0	µA
Input Bias Current				9.0	20		9.0	30	µA
Input Noise Voltage		BW = 1 kHz to 10 MHz		12			12		µVrms
Input Voltage Range	1		±1.0			±1.0			V
Common Mode Rejection Ratio									
Gain 2	1	V_{CM} = ±1V f ≤ 100 kHz	60	86		60	86		dB
Gain 2		V_{CM} = ±1V f = 5 MHz		60			60		dB
Supply Voltage Rejection Ratio									
Gain 2	1	ΔV_S = ±0.5V	50	70		50	70		dB
Output Offset Voltage									
Gain 1	1	$R_L = \infty$		0.6	1.5		0.6	1.5	V
Gain 2 and 3				0.35	1.0		0.35	1.5	V
Output Common Mode Voltage	1	$R_L = \infty$	2.4	2.9	3.4	2.4	2.9	3.4	V
Output Voltage Swing	1	R_L = 2k	3.0	4.0		3.0	4.0		
Output Sink Current			2.5	3.6		2.5	3.6		mA
Output Resistance				20			20		Ω
Power Supply Current	1	$R_L = \infty$		18	24		18	24	mA

electrical characteristics

(The following specifications apply for $-55°C < T_A < 125°C$ for the LM733 and $0°C < T_A < 70°C$ for the LM733C, $V_S = \pm 6.0V$)

CHARACTERISTICS	TEST CIRCUIT	TEST CONDITIONS	LM733 MIN	LM733 TYP	LM733 MAX	LM733C MIN	LM733C TYP	LM733C MAX	UNITS
Differential Voltage Gain									
Gain 1			200		600	250		600	
Gain 2	1	$R_L = 2\ k\Omega$, $V_{OUT} = 3\ V_{p\text{-}p}$	80		120	80		120	
Gain 3			8.0		12.0	8.0		12.0	
Input Resistance Gain 2			8			8			kΩ
Input Offset Current					5			6	μA
Input Bias Current					40			40	μA
Input Voltage Range	1		±1			±1			V
Common Mode Rejection Ratio									
Gain 2	1	$V_{CM} = \pm 1V$, $f \leq 100\ kHz$	50			50			dB
Supply Voltage Rejection Ratio									
Gain 2	1	$\Delta V_S = \pm 0.5V$	50			50			dB
Output Offset Voltage									
Gain 1	1	$R_L = \infty$			1.5			1.5	V
Gain 2 and 3					1.2			1.5	V
Output Voltage Swing	1	$R_L = 2k$	2.5			2.8			V_{PP}
Output Sink Current			2.2			2.5			mA
Power Supply Current	1	$R_L = \infty$			27			27	mA

Note 1: The maximum junction temperature of the LM733 is 150°C, while that of the LM733C is 100°C. For operation at elevated temperatures devices in the TO-100 package must be derated based on a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case. Thermal resistance of the dual-in-line package is 100°C/W.

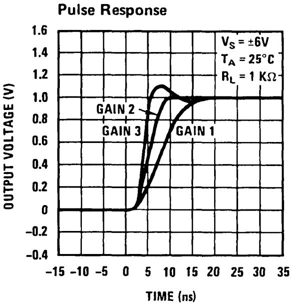
Note 2: Pins G1A and G1B connected together.

Note 3: Pins G2A and G2B connected together.

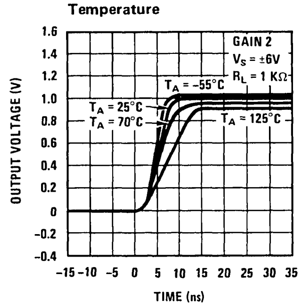
Note 4: Gain select pins open.

typical performance characteristics

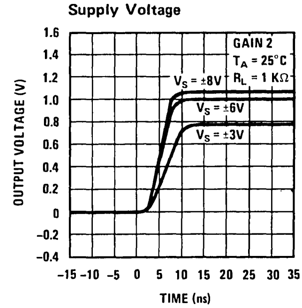
Pulse Response



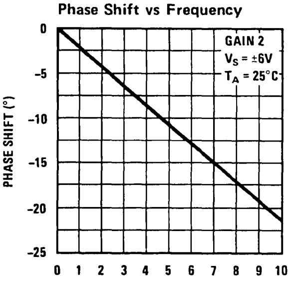
Pulse Response vs Temperature



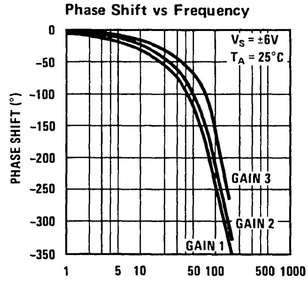
Pulse Response vs Supply Voltage



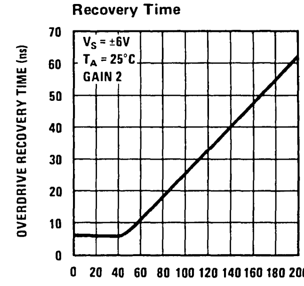
Phase Shift vs Frequency



Phase Shift vs Frequency



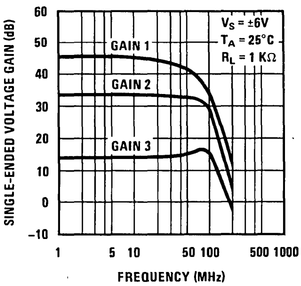
Differential Overdrive Recovery Time



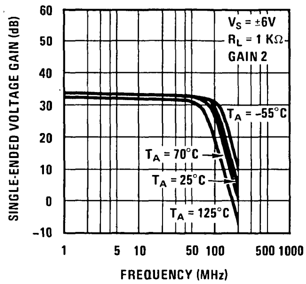
5

typical performance characteristics (con't)

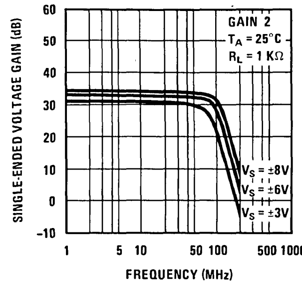
Voltage Gain vs Frequency



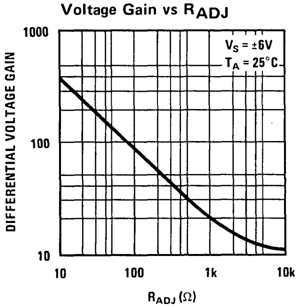
Gain vs Frequency Temperature



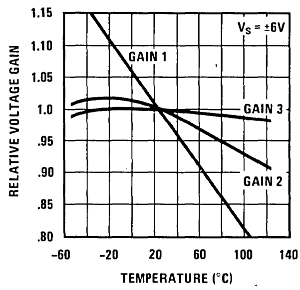
Gain vs Frequency vs Supply Voltage



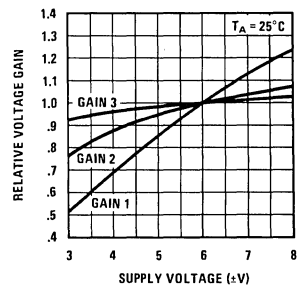
Voltage Gain vs R_{ADJ}



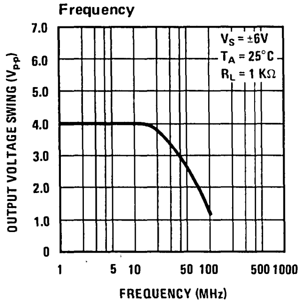
Voltage Gain vs Temperature



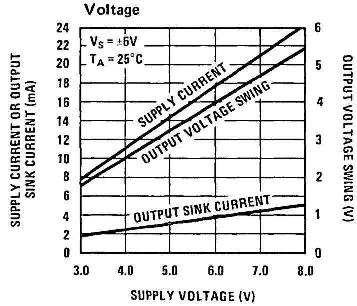
Voltage Gain vs Supply Voltage



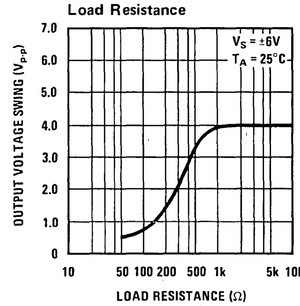
Output Voltage Swing vs Frequency



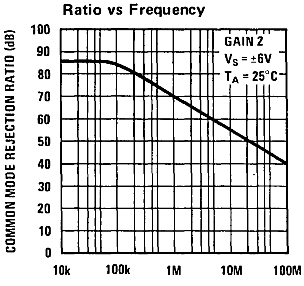
Supply Current, Output Voltage and Current Swing vs Supply Voltage



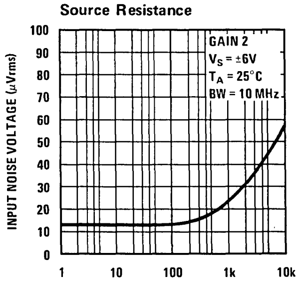
Output Voltage Swing vs Load Resistance



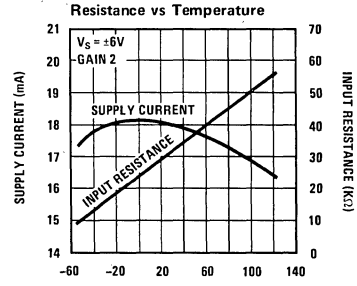
Common Mode Rejection Ratio vs Frequency



Input Noise Voltage vs Source Resistance



Supply Current and Input Resistance vs Temperature



Consumer Circuits

LM746 color television chroma demodulator

general description

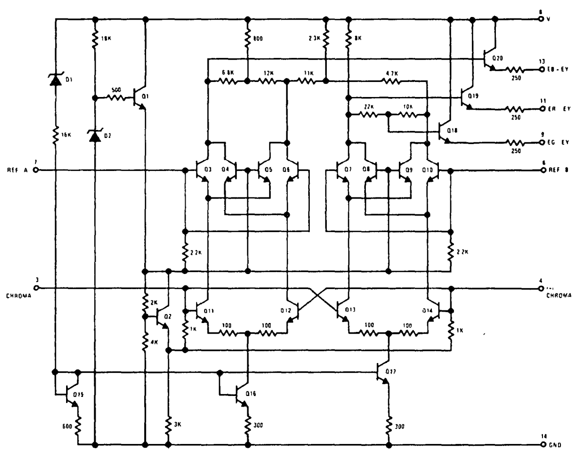
The LM746 is a monolithic silicon integrated circuit which demodulates the chroma subcarrier information contained in a color television video signal and provides color-difference signals at the outputs

The low DC voltage drift of the outputs insures excellent performance in direct-coupled chrominance output circuitry.

features

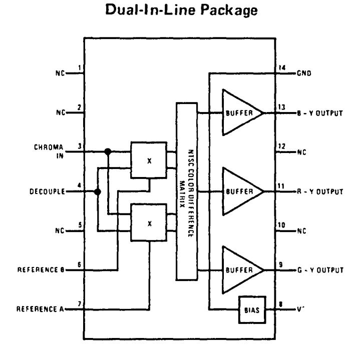
- Low output voltage drift with temperature
- Doubly balanced demodulation
- Internal color-difference matrix for NTSC color television
- 10V peak-to-peak $E_B - E_Y$ output

schematic and block diagrams



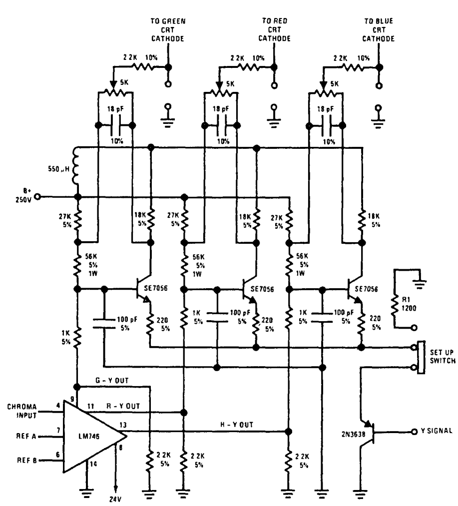
Pin numbers shown for Dual-In-Line Package.

Dual-In-Line Package



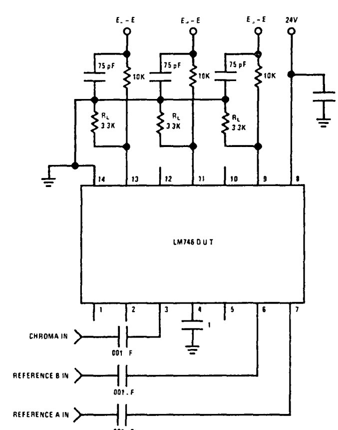
Order Number LM746N or LM746N-01
See Packages 22 and 24

typical application



Pin numbers shown for Dual-In-Line Package.

test circuit 1



103°C from reference A.

absolute maximum ratings

Power Dissipation		Storage Temperature	−65°C to +150°C
T_A = 70°C or less	450 mW	Supply Voltage	+30V
T_A = 70°C or more	Derate Linearly 8.2 mW/°C	Reference Input Volt (p-p)	5V
Operating Temperature	0°C to +70°C	Chroma Input Voltage (p-p)	5V

electrical characteristics (T_A = 25°C) (V_{CC} = 24V) (R_L = 3.3K

PARAMETER	SYMBOL	TEST CKT	CONDITIONS	MIN	TYP	MAX	UNITS
STATIC							
Supply Current	I_S	1	$e_C = 0$ R_L = 1M	5.5	9.0	12.5	mA
Supply Current	I_S	1	$e_C = 0$ R_L = 1M T_A = 70°C		9.0	13.0	mA
Supply Current	I_S	1	$e_C = 0$ R_L = 3.3k	16.5	22	25.5	mA
Supply Current	I_S	1	$e_C = 0$ R_L = 3.3k T_A = 70°C		22		mA
Power Dissipation	P_D	1	$e_C = 0$		340	430	mW
Power Dissipation	P_D	1	$e_C = 0$ T_A = 70°C		340	445	mW
DC Output Volts	V9, V11, V13	1	$e_C = 0$ R_L = 3.3k	13.2	14.5	15.8	V
DC Output Volts	V9, V11, V13	1	$e_C = 0$ T_A = 70°C R_L = 3.3k	13.0	14.5	16.0	V
Absolute Value of DC Difference Voltage Between any 2 Output Terminals	$\lvert \Delta V_O \rvert$		$e_C = 0$ R_L = 3.3k		.15	.6	V
Temperature Coefficient			$e_C = 0$	-5.0	-.3	+5 0	mV/°C
DYNAMIC							
Chroma Input Voltage Sensitivity	e_C	1	$E_B - E_Y = 5\ V_{p\text{-}p}$		.4	.7	$V_{p\text{-}p}$
$E_R - E_Y$ Output Voltage	V11	1	$E_B - E_Y = 5\ V_{p\text{-}p}$	3.5	3.8	4.2	$V_{p\text{-}p}$
$E_G - E_Y$ Output Voltage	V9	1	$E_B - E_Y = 5\ V_{p\text{-}p}$	.75	1.0	1.25	$V_{p\text{-}p}$
Maximum $E_B - E_Y$ Output Voltage	V13	1	$e_C = 1.5\ V_{p\text{-}p}$	8.0	10.0		$V_{p\text{-}p}$
$E_B - E_Y$ Demod Angle Relative to $E_R - E_Y$	$E_R\phi$	1	$E_B - E_Y = 5\ V_{p\text{-}p}$	101	106	111	degrees
$E_B - E_Y$ Demod Angle Relative to $E_G - E_Y$	$E_G\phi$	1	$E_B - E_Y = 5\ V_{p\text{-}p}$	−96	−104	−112	degrees
AC Unbalance @ Any Output Terminal		1	$e_C = 0$		.1	.8	$V_{p\text{-}p}$

Consumer Circuits

LM1303 stereo preamplifier

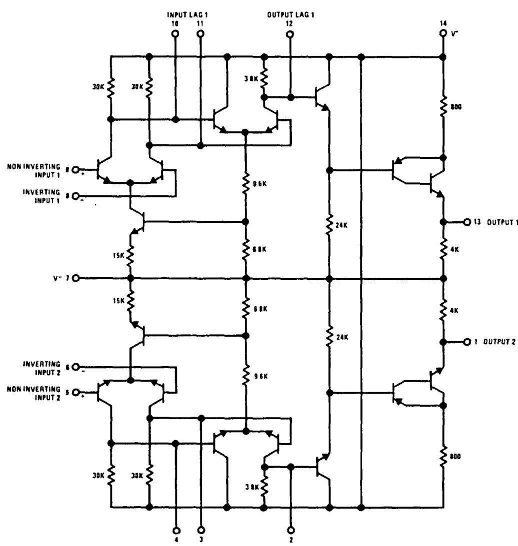
general description

The LM1303 consists of two identical operational amplifiers constructed on a single silicon chip. Intended for amplification of low-level stereo signals, the LM1303 features low input noise voltage, high open-loop voltage gain, large output voltage swing and short circuit protection.

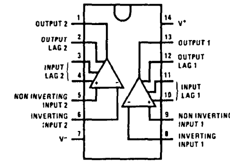
features

- Large Output Voltage Swing 4.0V rms min
- High Open-Loop Voltage Gain 6,000 min
- Channel Separation 60 dB min at 10 kHz

schematic and connection diagrams



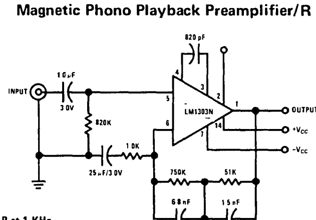
Dual-In-Line Package

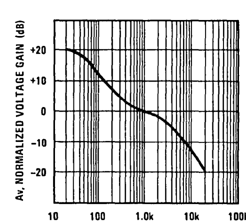


Order Number LM1303N
See Package 22

typical application and characteristic

Magnetic Phono Playback Preamplifier/R IAA Equalized





Voltage gain	34 dB at 1 KHz
Input overload point	100 mVrms at 1 KHz
Output voltage swing	5.0 Vrms at 1 KHz and 0.1% THD
Output noise level	Better than 70 dB below 10 mV phono input (input shorted)

FIGURE 1

5

absolute maximum ratings

Supply Voltage	±15V
Power Dissipation (Note 1)	415 mW
Operating Temperature Range	0 to 75°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 2)

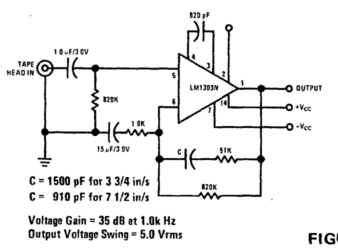
PARAMETER	MIN	TYP	MAX	UNITS
Input Offset Voltage		1.5	10	mV
Input Offset Current		0.2	0.4	μA
Input Bias Current		1.0	10	μA
Supply Current Both Amplifiers V_{OUT} = 0V			15	mA
Large Signal Voltage Gain	6,000	10,000		V/V
Channel Separation f = 10 kHz	60	70		dB
Output Voltage Swing R_L = 10 kΩ	4.0	5.5		Vrms

Note 1: The maximum junction temperature of the LM1303 is 100°C. For operating at elevated temperatures, devices must be derated based on a thermal resistance of 150°C/W, junction to ambient.

Note 2: These specifications apply for V_S = ±13V and T_A = 25°C, unless otherwise specified.

typical application and characteristic

Tape Head Playback Preamplifier/NAB Equalization



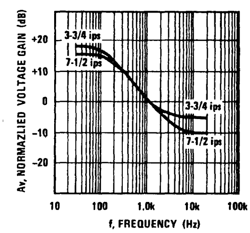
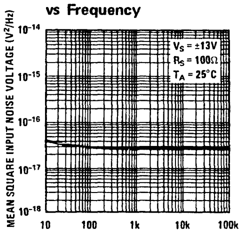


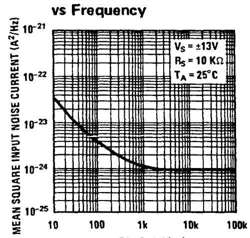
FIGURE 2

typical performance characteristics

Input Noise Voltage vs Frequency



Input Noise Current vs Frequency



Consumer Circuits

LM1304/LM1305/LM1307/LM1307E FM multiplex stereo demodulator

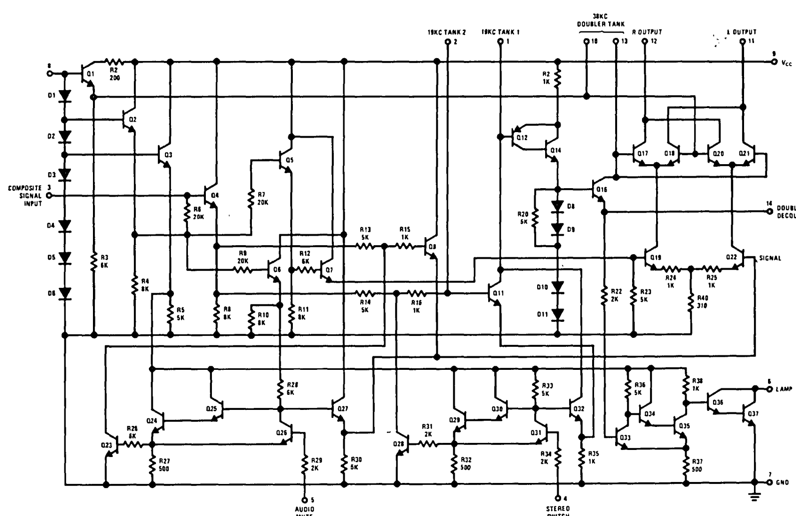
general description

The LM1304, LM1305, LM1307 and LM1307E are designed to derive the left and right channel audio information from the detected composite stereo signal. The LM1304 eliminates the need for an external stereo-channel separation control. The LM1305 is similar to the LM1304 but permits the use of an external stereo-channel separation control for maximum separation. The LM1307 is also similar to the LM1304 but does not have the audio mute control, or the stereo/mono switch. The LM1307E is similar to the LM1307 but has the option of emitter-follower output drivers for buffers or high current applications.

features

- Operation over a wide power supply range
- Built in stereo-indicator lamp driver — 100 mA typical
- Automatic switching between stereo and monaural
- Audio mute control

circuit schematics



LM1304

Order Number LM1304N or LM1305N or LM1307N or LM1307EN See Package 22

Order Number LM1304N-01 or LM1305N-01 or LM1307N-01 or LM1307EN-01 See Package 24

absolute maximum ratings

Power Supply Voltage	+22V
Lamp Driver Current	120 mA
Power Dissipation	625 mW
Derate Above T_A = +25°C	5.0 mW/°C
Operating Temperature Range (Ambient)	0°C to +75°C
Storage Temperature Range	-65°C to +150°C
Output Current (LM1307E)	25 mA
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (V_{CC} = 12V, T_A = 25°C, 75 μs de-emphasis unless otherwise noted)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Impedance	f = 1 kHz	12	20		kΩ
Stereo Channel Separation (Note 1)	f = 100 Hz		35		dB
(Note 3)	f = 1 kHz	30	45		dB
	f = 10 kHz		30		dB
Channel Balance	Monaural Input = 200 mV		0.2	1.0	dB
Total Harmonic Distortion (Note 1)	f_{MOD} = 1 k_c		0.5	1.0	%
Ultrasonic Frequency Rejection	19 kHz		30		dB
(Note 2)	38 kHz	20	25		dB
Inherent SCA Rejection (Without De-Emphasis)	60 kHz, 67 kHz, 74 kHz		50		dB
Lamp Indicator	R_A = 180Ω				
	Min 19 kHz Input Level for Lamp On		16	25	mVrms
	Max 19 kHz Input Level for Lamp Off	5.0	14		mVrms
Power Dissipation	Without Lamp		150	300	mW
Audio Muting (LM1304/5 Only)					
	Mute On (Pin 5 Voltage)	0.6	.8	1.0	V
	Mute Off (Pin 5 Voltage)	1.3	1.6	2.0	V
	Attenuation in Mute Mode		55		dB
Stereo-Monaural Switching	Stereo (Pin 4 Voltage)	1.3	1.6	2.0	V
(LM1304/5 Only)	Monaural (Pin 5 Voltage)	0.6	.8	1.0	V

Note 1: Measurement made with standard multiplex composite signal. L = 1, R = 0 or L = 0, R = 1; composite signal defined as 564 mV peak to peak (100 mVrms as read on Ballantine 310-A voltmeter) with a 20 mVrms 19 kHz pilot carrier.

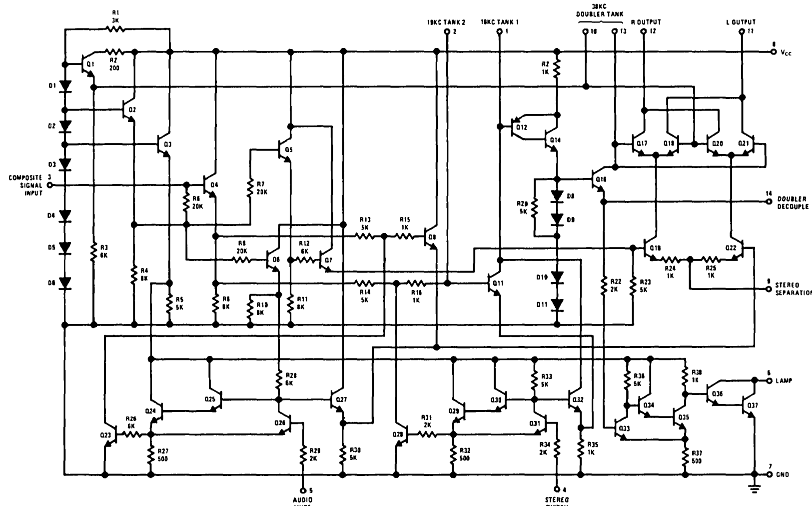
Note 2: Referenced to 1 kHz output signal with signal per Note 1.

Note 3: Stereo channel separation is adjusted for maximum separation in the LM1305 with a resistor from Pin 9 to GND.

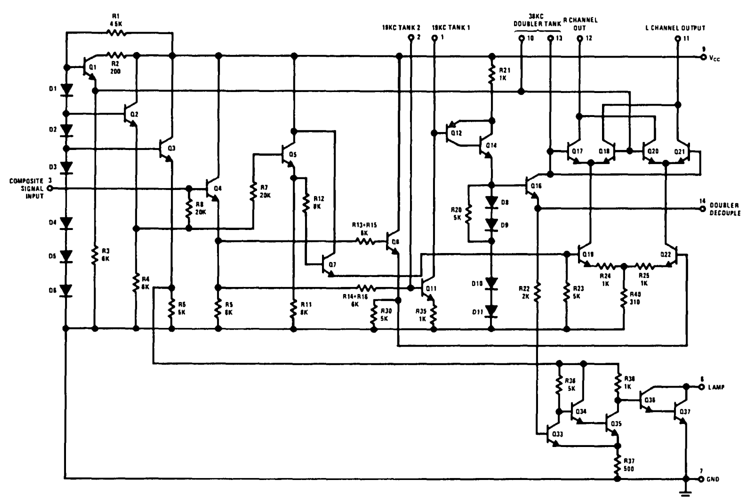
(R_A = 180Ω, All voltages measured with respect to GND)
(V_{CC} = 12V, 2.7 kΩ in series w/Pin 8)

Pins	1	2	3	4	5	6	7	8	9	10	11	12	13	14
LM1304	12	2.3	3.0	1.9	1.9	0.8	0	4.6	12	3.9	9.7	9.7	3.9	1.9
LM1305	12	2.3	3.0	1.9	1.9	0.8	0	12	0.36	3.9	9.7	9.7	3.9	1.9
LM1307	12	2.3	3.0	–	–	0.8	0	–	12	3.9	9.7	9.7	3.9	1.9
LM1307E	12	2.3	3.0	–	.8	12	0	9.7	9.0	9.0	9.7	3.9	3.9	1.9

circuit schematics (con't)

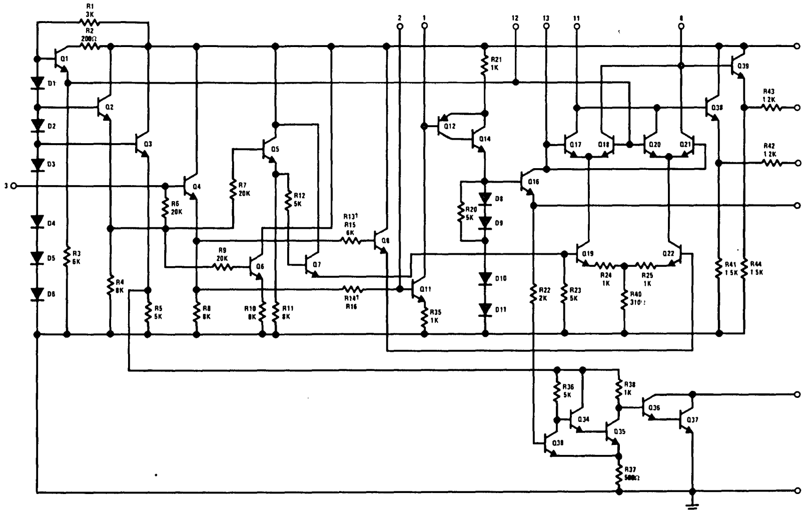


LM1305



LM1307

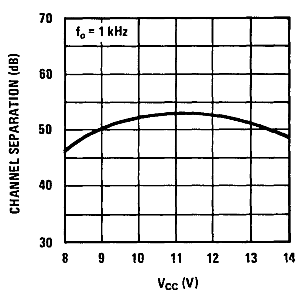
circuit schematics (con't)



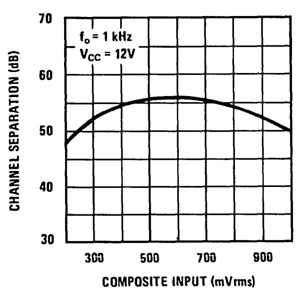
LM1307E

typical performance characteristics

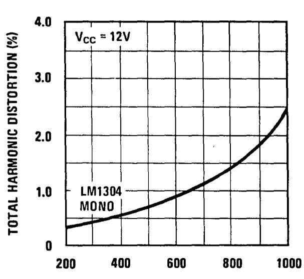
Channel Separation vs V_{CC}



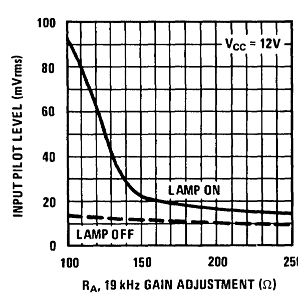
Channel Separation vs Composite Input Level



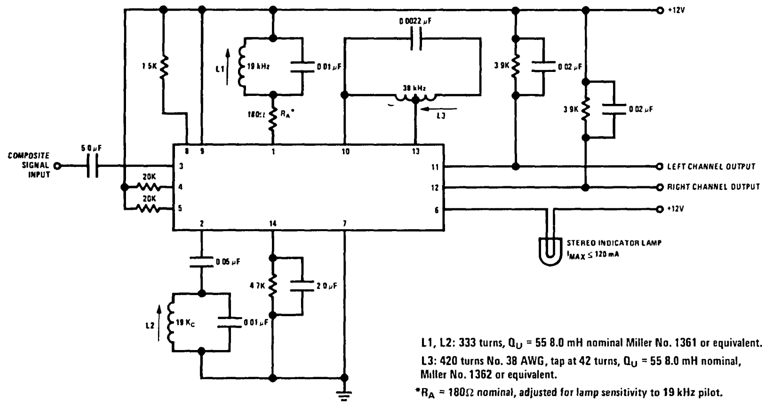
Total Harmonic Distortion vs Composite Input Level



Multiplex Sensitivity vs 19 kHz Gain Adjustment

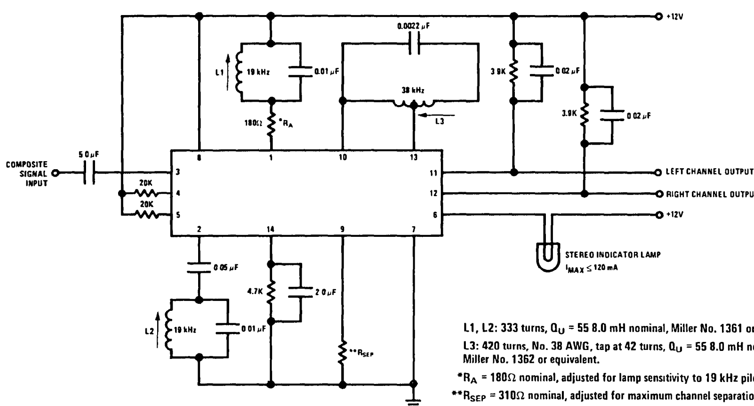


circuit configurations



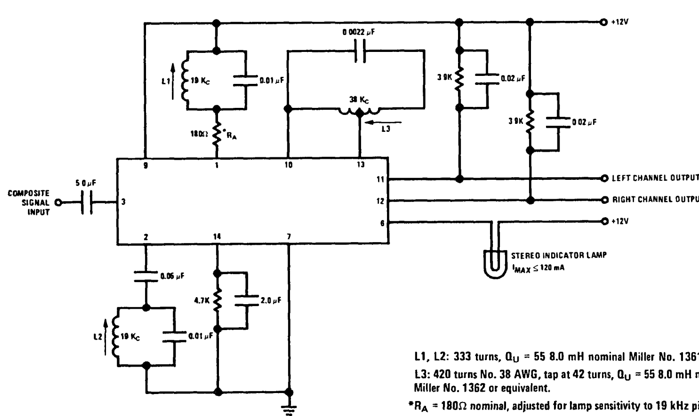
L1, L2: 333 turns, Q_U = 55 8.0 mH nominal Miller No. 1361 or equivalent.
L3: 420 turns No. 38 AWG, tap at 42 turns, Q_U = 55 8.0 mH nominal, Miller No. 1362 or equivalent.
*R_A = 180Ω nominal, adjusted for lamp sensitivity to 19 kHz pilot.

LM1304 Typical Circuit Configuration



L1, L2: 333 turns, Q_U = 55 8.0 mH nominal, Miller No. 1361 or equivalent.
L3: 420 turns, No. 38 AWG, tap at 42 turns, Q_U = 55 8.0 mH nominal, Miller No. 1362 or equivalent.
*R_A = 180Ω nominal, adjusted for lamp sensitivity to 19 kHz pilot.
**R_{SEP} = 310Ω nominal, adjusted for maximum channel separation.

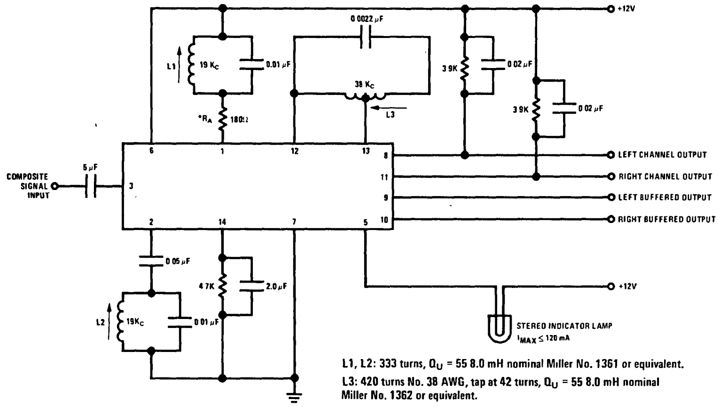
LM1305 Typical Circuit Configuration



L1, L2: 333 turns, Q_U = 55 8.0 mH nominal Miller No. 1361 or equivalent.
L3: 420 turns No. 38 AWG, tap at 42 turns, Q_U = 55 8.0 mH nominal, Miller No. 1362 or equivalent.
*R_A = 180Ω nominal, adjusted for lamp sensitivity to 19 kHz pilot.

LM1307 Typical Circuit Configuration

circuit configurations (con't)



L1, L2: 333 turns, Q_U = 55 8.0 mH nominal Miller No. 1361 or equivalent.
L3: 420 turns No. 38 AWG, tap at 42 turns, Q_U = 55 8.0 mH nominal Miller No. 1362 or equivalent.
*R_A = 180Ω nominal, adjusted for lamp sensitivity to 19 kHz pilot.

LM1307E Typical Circuit Configuration

Consumer Circuits

LM1310 phase locked loop FM stereo demodulator

general description

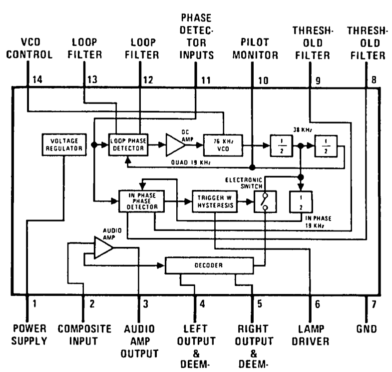
The LM1310 is an integrated FM stereo demodulator using phase locked loop techniques to regenerate the 38 kHz subcarrier. A second version also available is the LM1800 (see separate data sheet) which adds superb power supply rejection and buffered (emitter follower) outputs to the basic phase locked decoder circuit. The features available in these integrated circuits make possible a system delivering high fidelity sound within the cost restraints of inexpensive stereo receivers.

features

- Automatic stereo/monaural switching
- No coils, all tuning performed with single potentiometer
- Wide supply operating voltage range
- Excellent channel separation

connection diagram

Dual-In-Line Package

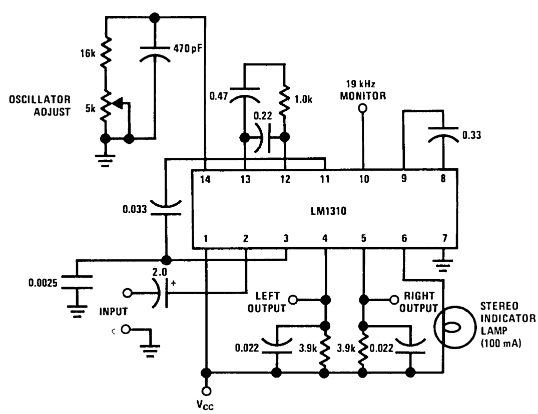


TOP VIEW

Order Number LM1310N

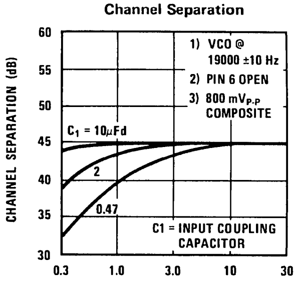
See Package 22

typical application

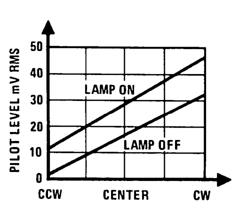


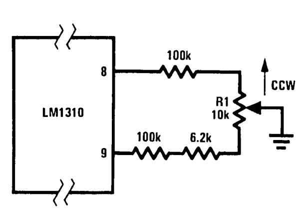
typical performance characteristics

Channel Separation



Stereo/Monaural Switch Point Adjustment





absolute maximum ratings

Supply Voltage	18V	Operating Supply Voltage Range	+10V to +18V
Power Dissipation (Note 3)	575 mW	Storage Temperature Range	−55°C to +150°C
Operating Temperature Range	0°C to +70°C	Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Current	Lamp "off"		18	30	mA
Lamp Driver Saturation	100 mA Lamp Current		1.3	1.8	V
Lamp Driver Leakage			1.0		nA
Pilot Level for Lamp "on"	Pin 11 Adjusted to 19.00 kHz		16	23	mVrms
Pilot Level for Lamp "off"	Pin 11 Adjusted to 19.00 kHz	3.0	8.0		mVrms
Stereo Lamp Hysteresis		3.0	6.0		dB
Stereo Channel Separation	100 Hz (Note 2)		40		dB
	1000 Hz (Note 2)	30	45		dB
	10000 Hz (Note 2)		45		dB
Monaural Channel Unbalance	200 mVrms, 1000 Hz Input		0.3	1.5	dB
Monaural Voltage Gain	200 mVrms, 1000 Hz Input	90	130	190	mVrms
Total Harmonic Distortion (Mono)	500 mVrms, 1000 Hz Input		0.2	1.0	%
Total Harmonic Distortion (Stereo)	1000 Hz (Note 2)		0.2		%
Capture Range	25 mVrms of Pilot		±3.0		% of f_o
Ultrasonic Freq. Rejection	Combined 19 and 38 kHz, Ref. to Outputs		33		dB
Dynamic Input Resistance		20	45		kΩ
SCA Rejection	200 mVrms Composite at 67 kHz		50		dB

Note 1: T_A = 25°C and V^+ = 12V unless otherwise specified.

Note 2: The stereo input signal is made by summing 123 mVrms LEFT or RIGHT modulated signal with 25 mVrms of 19 kHz pilot tone, measuring all voltages with an average responding meter calibrated in rms. The resulting waveform is about 800 mVp-p.

Note 3: The maximum junction temperature is +125°C and the package should be derated at +175°C/W junction to ambient.

Consumer Circuits

LM1351 FM detector, limiter and audio amplifier

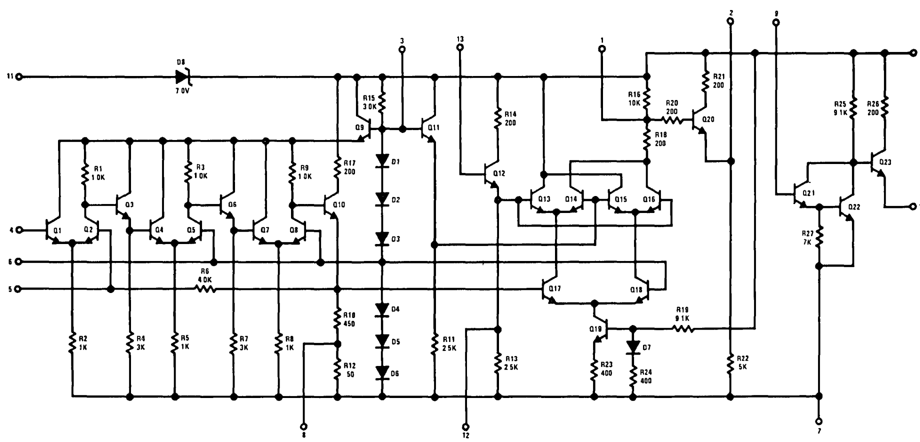
general description

The LM1351 is a monolithic integrated circuit FM detector, limiter and audio amplifier that requires a minimum of external components for operation. It includes three stages of IF limiting and a balanced product detector. The audio amplifier is capable of driving a single external transistor class A-audio output stage.

features

- A direct replacement for MC1351
- Simple detector alignment: one coil or ceramic filter.
- Sensitivity: 3 dB limiting voltage 80 μV typ.
- Low harmonic distortion
- High IF voltage gain
- High audio preamplifier open loop gain

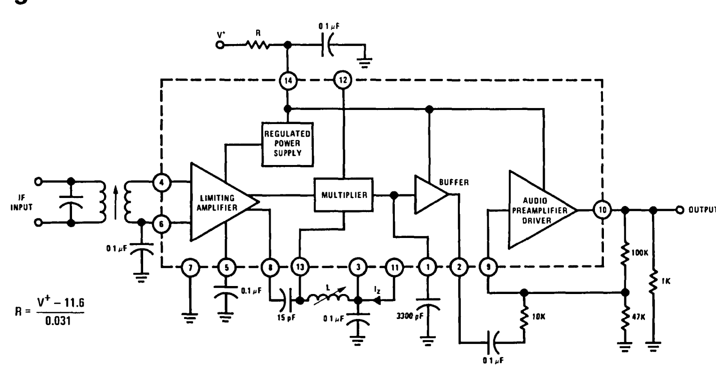
schematic diagram



Order Number LM1351N
See Package 22

Order Number LM1351N-01
See Package 24

block diagram



$$R = \frac{V^+ - 11.6}{0.031}$$

5

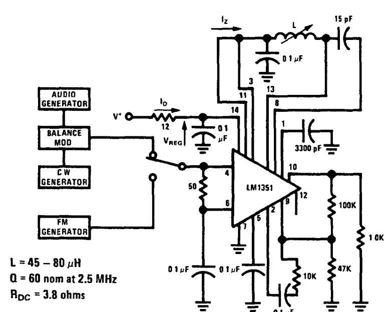
absolute maximum ratings

Supply Voltage	16V
Input Signal Voltage (Pin 4)	0.7 Vrms
Power Dissipation	
T_A = 25°C or less	850 mW
T_A = 25°C or more	Derate Linearly 6.67 mW/°C
Operating Temperature Range	0°C to 75°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (T_A = 25°C, V_{CC} = 12V, unless otherwise noted)

PARAMETER	SYMBOL	CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
STATIC CHARACTERISTICS						
Supply Current	I_{14}	I_Z = 5 mA		31		mA
Power Dissipation	P_D	I_Z = 5 mA		300	375	mW
Nominal Zener Voltage	V_{14}	I_Z = 5 mA		11.6		V
DYNAMIC CHARACTERISTICS f_0 = 4.5 MHz, ΔF = ±25 kHz, unless otherwise noted						
Amplifier Voltage Gain	$A_{V(IF)}$	$V_{IN} \leq$ 0.3 mVrms		65		dB
Audio Preamplifier Open Loop Gain	$A_{V(AF)}$	V_{IN} = 500 mV @ 400 Hz		40		dB
Input Limiting Threshold	$V_{IN(LIM)}$	FM = 400 Hz		80	160	µVrms
Recovered Audio Output	$V_{O(AF)}$		0.35	0.50		Vrms
Recovered Audio Output	$V_{O(AF)}$	f_0 = 5.5 MHz, AF = ±50 kHz		0.8		Vrms
Total Harmonic Distortion	T_{HD}	Q_L = 24, Δf = 7.5 kHz		1.0		%
Maximum Undistorted Audio Output Voltage	V_{OMAX}	Q_L = 24 Audio Gain = 10		3.5		Vrms
AM Suppression	AMR	AM: 1 kHz @ 30%, V_{IN} = 20 mV	38	45		dB

test circuit



Consumer Circuits

LM1596/LM1496 balanced modulator-demodulator

general description

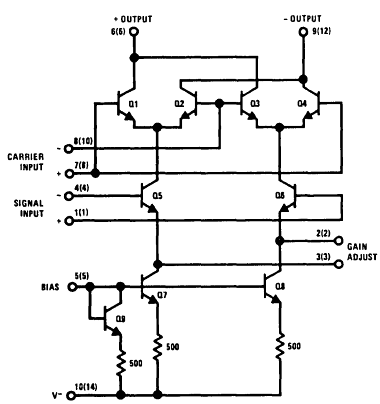
The LM1596/LM1496 are double balanced modulator-demodulators which produce an output voltage proportional to the product of an input (signal) voltage and a switching (carrier) signal. Typical applications include suppressed carrier modulation, amplitude modulation, synchronous detection, FM or PM detection, broadband frequency doubling and chopping.

The LM1596 is specified for operation over the −55°C to +125°C military temperature range. The LM1496 is specified for operation over the 0°C to +70°C temperature range.

features

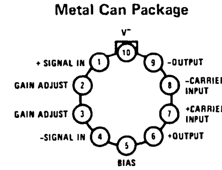
- Excellent carrier suppression
  - 65 dB typical at 0.5 MHz
  - 50 dB typical at 10 MHz
- Adjustable gain and signal handling
- Fully balanced inputs and outputs
- Low offset and drift
- Wide frequency response up to 100 MHz

schematic and connection diagrams



Numbers in parentheses show DIP connections.

Metal Can Package

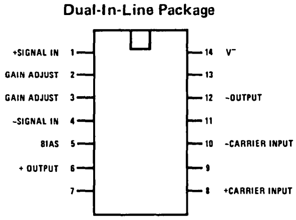


TOP VIEW

Note: Pin 10 is connected electrically to the case through the device substrate.

Order Number LM1496H or LM1596H
See Package 11

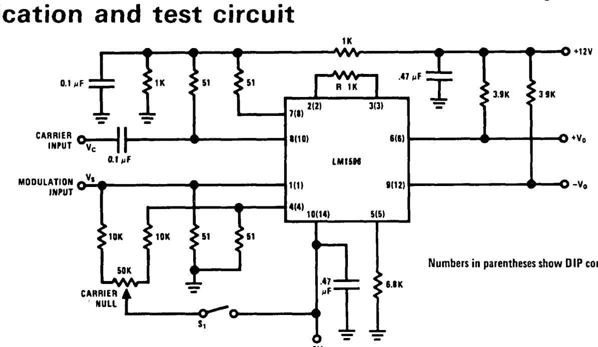
Dual-In-Line Package



TOP VIEW

Order Number LM1496N
See Package 22

typical application and test circuit



Numbers in parentheses show DIP connections.

Note: S_1 is closed for "adjusted" measurements.

Suppressed Carrier Modulator

5

absolute maximum ratings

Internal Power Dissipation (Note 1)		500 mW
Applied Voltage (Note 2)		30V
Differential Input Signal ($V_7 - V_8$)		±5.0V
Differential Input Signal ($V_4 - V_1$)		$\pm(5+I_5R_e)$ V
Input Signal ($V_2 - V_1$, $V_3 - V_4$)		5.0V
Bias Current (I_5)		12 mA
Operating Temperature Range	LM1596	−55°C to +125°C
	LM1496	0°C to +70°C
Storage Temperature Range		−65°C to +150°C
Lead Temperature (Soldering, 10 sec)		300°C

electrical characteristics (T_A = 25°C, unless otherwise specified, see test circuit)

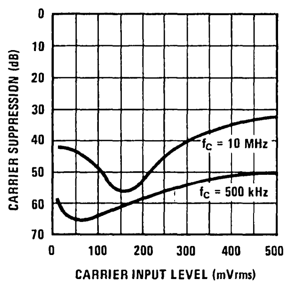
PARAMETER	CONDITIONS	LM1596 MIN	LM1596 TYP	LM1596 MAX	LM1496 MIN	LM1496 TYP	LM1496 MAX	UNITS
Carrier Feedthrough	V_C = 60 mVrms sine wave f_C = 1.0 kHz, offset adjusted		40			40		μVrms
	V_C = 60 mVrms sine wave f_C = 10 MHz, offset adjusted		140			140		μVrms
	V_C = 300 mV_{pp} square wave f_C = 1.0 kHz, offset adjusted		0.04	0.2		0.04	0.2	mVrms
	V_C = 300 mV_{pp} square wave f_C = 1.0 kHz, offset not adjusted		20	100		20	150	mVrms
Carrier Suppression	f_S = 10 kHz, 300 mVrms f_C = 500 kHz, 60 mVrms sine wave offset adjusted	50	65		50	65		dB
	f_S = 10 kHz, 300 mVrms f_C = 10 MHz, 60 mVrms sine wave offset adjusted		50			50		dB
Transadmittance Bandwidth	R_L = 50Ω Carrier Input Port, V_C = 60 mVrms sine wave f_S = 1.0 kHz, 300 mVrms sine wave		300			300		MHz
	Signal Input Port, V_S = 300 mVrms sine wave $V_7 - V_8$ = 0.5Vdc		80			80		MHz
Voltage Gain, Signal Channel	V_S = 100 mVrms, f = 1.0 kHz $V_7 - V_8$ = 0.5Vdc	2.5	3.5		2.5	3.5		V/V
Input Resistance, Signal Port	f = 5.0 MHz $V_7 - V_8$ = 0.5 Vdc		200			200		kΩ
Input Capacitance, Signal Port	f = 5.0 MHz $V_7 - V_8$ = 0.5 Vdc		2.0			2.0		pF
Single Ended Output Resistance	f = 10 MHz		40			40		kΩ
Single Ended Output Capacitance	f = 10 MHz		5.0			5.0		pF
Input Bias Current	$(I_1 + I_4)/2$		12	25		12	30	μA
Input Bias Current	$(I_7 + I_8)/2$		12	25		12	30	μA
Input Offset Current	$(I_1 - I_4)$		0.7	5.0		0.7	5.0	μA
Input Offset Current	$(I_7 - I_8)$		0.7	5.0		5.0	5.0	μA
Average Temperature Coefficient of Input Offset Current	(−55°C < T_A < +125°C)		2.0					nA/°C
	(0°C < T_A < +70°C					2.0		nA/°C
Output Offset Current	$(I_6 - I_9)$		14	50		14	60	μA
Average Temperature Coefficient of Output Offset Current	(−55°C < T_A < +125°C)		90					nA/°C
	(0°C < T_A < +70°C)					90		nA/°C
Signal Port Common Mode Input Voltage Range	f_S = 1.0 kHz		5.0			5.0		V_{p-p}
Signal Port Common Mode Rejection Ratio	$V_7 - V_8$ = 0.5 Vdc		−85			−85		dB
Common Mode Quiescent Output Voltage			8.0			8.0		Vdc
Differential Output Swing Capability			8.0			8.0		V_{p-p}
Positive Supply Current	$(I_6 + I_9)$		2.0	3.0		2.0	3.0	mA
Negative Supply Current	(I_{10})		3.0	4.0		3.0	4.0	mA
Power Dissipation			33			33		mW

Note 1: LM1596 rating applies to case temperatures to +125°C; derate linearly at 6.5 mW/°C for ambient temperature above 75°C. LM1496 rating applies to case temperatures to +70°C.

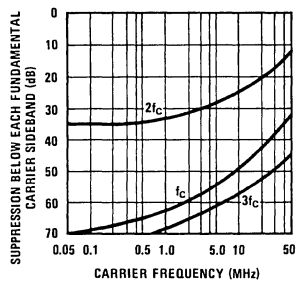
Note 2: Voltage applied between pins 6-7, 8-1, 9-7, 9-8, 7-4, 7-1, 8-4, 6-8, 2-5, 3-5.

typical performance characteristics

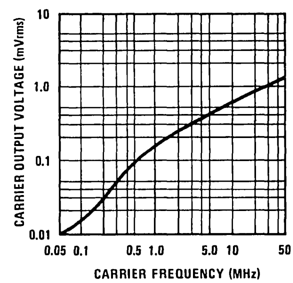
Carrier Suppression vs Carrier Input Level



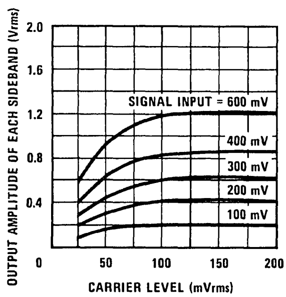
Carrier Suppression vs Frequency



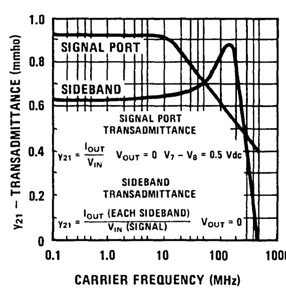
Carrier Feedthrough vs Frequency



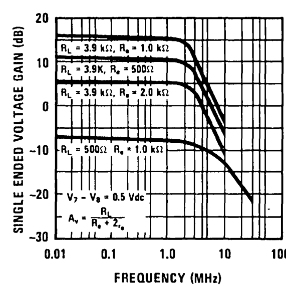
Sideband Output vs Carrier Levels



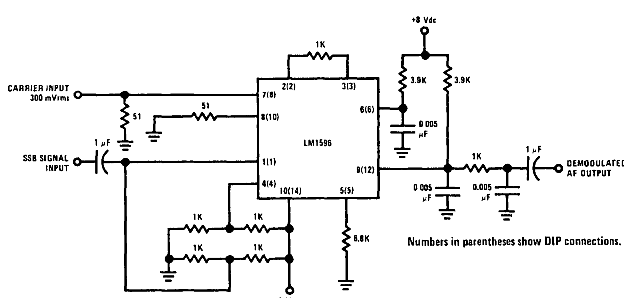
Sideband and Signal Port Transadmittances vs Frequency



Signal-Port Frequency Response



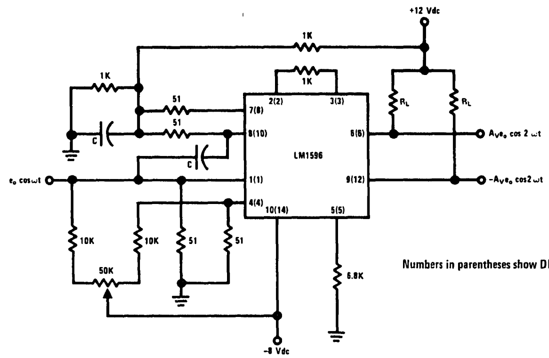
typical applications (con't)



SSB Product Detector

This figure shows the LM1596 used as a single sideband (SSB) suppressed carrier demodulator (product detector). The carrier signal is applied to the carrier input port with sufficient amplitude for switching operation. A carrier input level of 300 mVrms is optimum. The composite SSB signal is applied to the signal input port with an amplitude of 5.0 to 500 mVrms. All output signal components except the desired demodulated audio are filtered out, so that an offset adjustment is not required. This circuit may also be used as an AM detector by applying composite and carrier signals in the same manner as described for product detector operation.

typical applications (con't)



Numbers in parentheses show DIP connections.

Broadband Frequency Doubler

The frequency doubler circuit shown will double low-level signals with low distortion. The value of C should be chosen for low reactance at the operating frequency.

Signal level at the carrier input must be less than 25 mV peak to maintain operation in the linear region of the switching differential amplifier. Levels to 50 mV peak may be used with some distortion of the output waveform. If a larger input signal is available a resistive divider may be used at the carrier input, with full signal applied to the signal input.

Consumer Circuits

LM1800 phase locked loop FM stereo demodulator

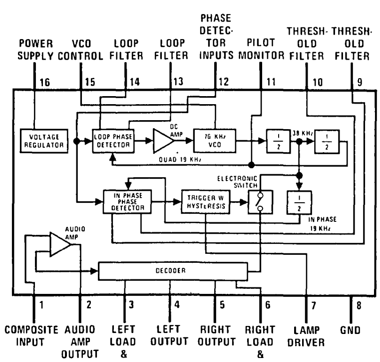
general description

The LM1800 is a second generation integrated FM stereo demodulator using phase locked loop techniques to regenerate the 38 kHz subcarrier. The numerous features integrated on the die make possible a system delivering high fidelity sound while still meeting the cost requirements of inexpensive stereo receivers. More information available in AN-81.

features

- Automatic stereo/monaural switching
- 45 dB power supply rejection
- No coils, all tuning performed with single potentiometer
- Wide operating supply voltage range
- Excellent channel separation
- Emitter follower output buffers

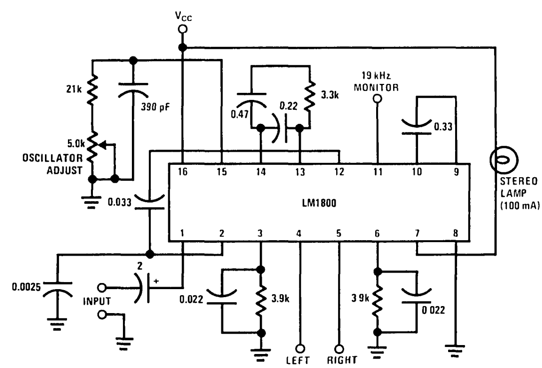
connection diagram



TOP VIEW

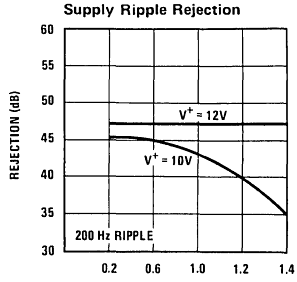
Order Number LM1800N
See Package 23

typical application

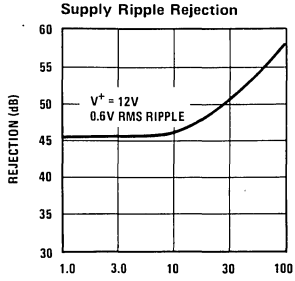


typical performance characteristics

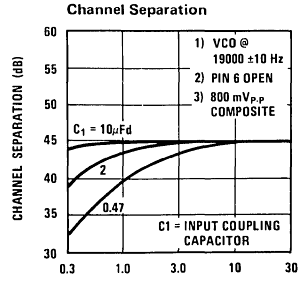
Supply Ripple Rejection



Supply Ripple Rejection



Channel Separation



absolute maximum ratings

Supply Voltage	18V
Power Dissipation (Note 3)	575 mW
Operating Temperature Range	0°C to +70°C
Operating Supply Voltage Range	+10V to +18V
Storage Temperature Range	−55°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Current	Lamp "off"		21	30	mA
Lamp Driver Saturation	100 mA Lamp Current		1.3	1.8	V
Lamp Driver Leakage			1.0		nA
Pilot Level for Lamp "on"	Pin 11 Adjusted to 19.00 kHz		16	23	mVrms
Pilot Level for Lamp "off"	Pin 11 Adjusted to 19.00 kHz	3.0	8.0		mVrms
Stereo Lamp Hysteresis		3.0	6.0		dB
Stereo Channel Separation	100 Hz (Note 2)		40		dB
	1000 Hz (Note 2)	30	45		dB
	10000 Hz (Note 2)		45		dB
Monaural Channel Unbalance	200 mVrms, 1000 Hz Input		0.3	1.5	dB
Monaural Voltage Gain	200 mVrms, 400 Hz Input	140	200	260	mVrms
Total Harmonic Distortion	500 mVrms, 1000 Hz Input		0.5	1.0	%
Capture Range	25 mVrms of Pilot	±2.0		±6.0	% of f_O
Supply Ripple Rejection	600 mVrms of 200 Hz Ripple	35	45		dB
Dynamic Input Resistance		20	45		kΩ
Dynamic Output Resistance		900	1300	2000	Ω
SCA Rejection	200 mVrms composite at 67 kHz		50		dB
Ultrasonic Freq. Rejection	Combined 19 and 38 kHz, Ref. to Output		33		dB

Note 1: T_A = 25°C and V^+ = 12V unless otherwise specified.

Note 2: The stereo input signal is made by summing 123 mVrms LEFT or RIGHT modulated signal with 25 mVrms of 19 kHz pilot tone, measuring all voltages with an average responding meter calibrated in rms. The resulting waveform is about 800 mVp-p.

Note 3: The maximum junction temperature is +125°C and the package should be derated at +175°C/W junction to ambient.

Consumer Circuits

LM1808 monolithic TV sound system

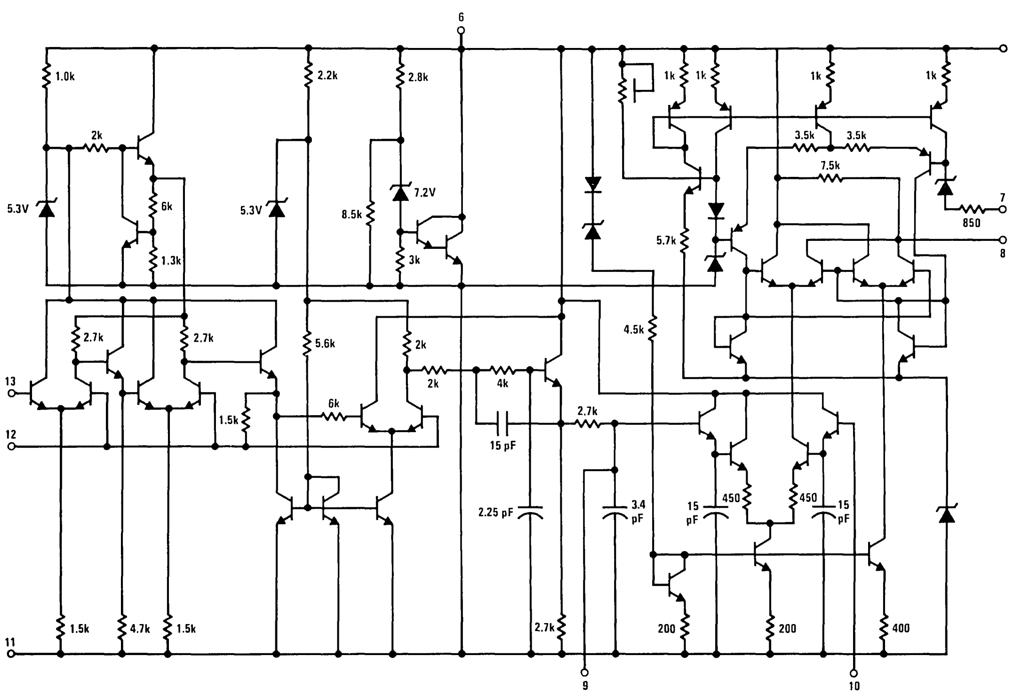
general description

The LM1808 2 watt sound IF circuit is designed for television and related applications. The circuit is comprised of two independent functions: a sound IF and an audio power amplifier. The sound IF portion of the circuit utilizes circuitry similar to the LM3065. An improved volume control circuit is included, however, so that recovered audio is a linear function of the resistance of the control potentiometer. Audio power amplification is accomplished with circuitry similar to the popular LM380 audio power amplifier, featuring both short circuit and thermal protection.

features

- Two watt minimum undistorted output
- Linear volume control — 75 dB range
- Fixed voltage gain in audio amplifier
- Short circuit and thermal protection
- Standard dual-in-line package

schematic diagram (For power amplifier section of schematic see page 3)



IF and Detector

absolute maximum ratings

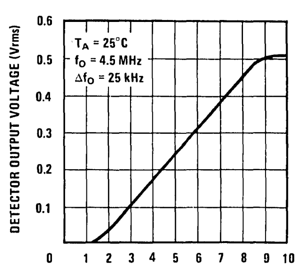
Supply Voltage V_{CC} (Pin 2)	26V
Input Current I_{MAX} (Pin 6)	50 mA
Input Signal Voltage (Between Pins 12 and 13)	3 Vp-p
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	0°C to +70°C
Maximum Junction Temperature	150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics +24V Supply (See Test Circuit)

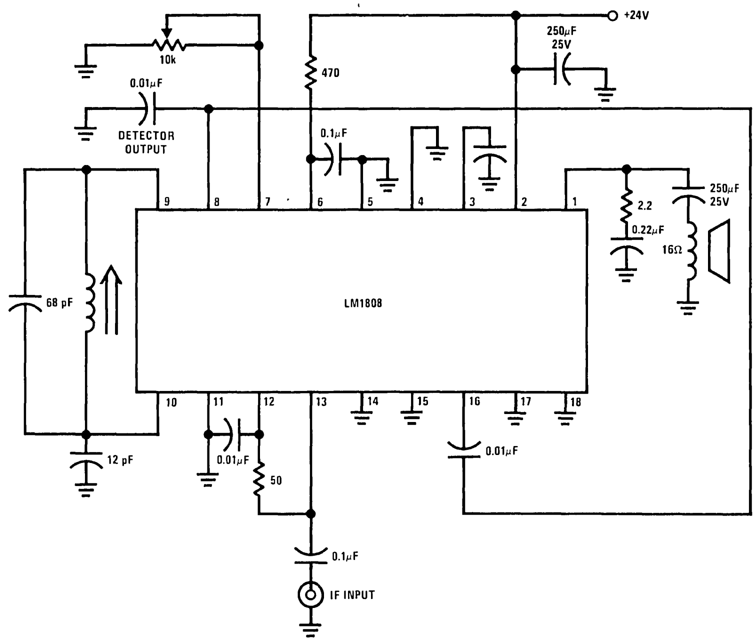
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Zener Regulating Voltage (Pin 6)		10.5	11.5	12.5	V
Thermal Resistance (Junction to Case)			17		°C/W
Output Swing (Pin 1)			19		Vp-p
Feedthrough Signal (Pin 1)	R Pin 7 = 0Ω			15	mVrms
Current into Pin 6	V Pin 6 = 10V	7	10.8	15	mA
AM Rejection	V_{IN} = 1.0 to 100 mVrms, Δf = 25 kHz, AM = 30%	40			dB
Recovered Audio (Pin 8)		350	500		mVrms
Input Limiting Voltage at 4.5 MHz			200	400	μV
Audio Power Amp Voltage Gain (Pin 16 to Pin 1)		40		60	V/V
Output Noise, Input Signal Removed (Pin 1)	R Pin 7 = 10 kΩ		70	150	mVrms
Distortion (Pin 8)	ΔF = 25 kHz, f_O = 4.5 MHz		1.2	2	%
Distortion	P_O = 2W		1.2	2	%
Input Impedance (Pin 16)		50	200		kΩ
Current into Pin 2 (Zero Audio Output at Pin 1)	V_2 = 24V	2	5	20	mA

typical performance characteristics

Volume Control Characteristic

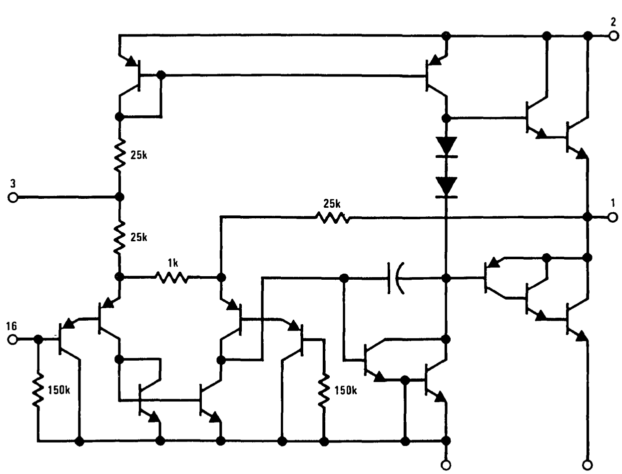


typical application and test circuit



Television Sound System

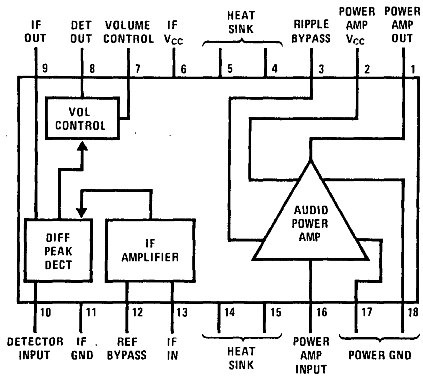
schematic diagram (con't)



Power Amplifier

connection diagram

Dual-In-Line Package



TOP VIEW

Order Number LM1808N
See Package 29

Consumer Circuits

LM1820 AM radio system

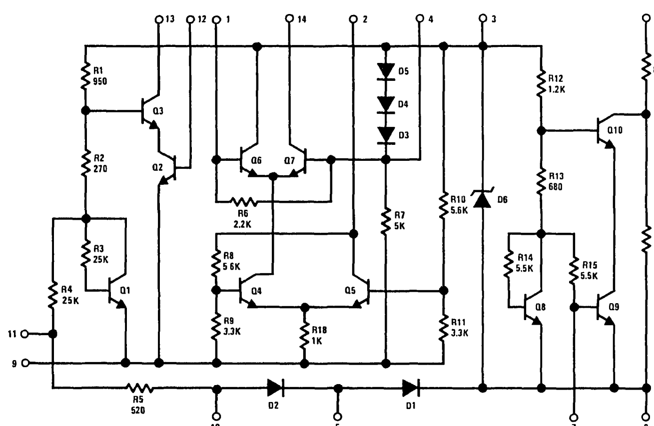
general description

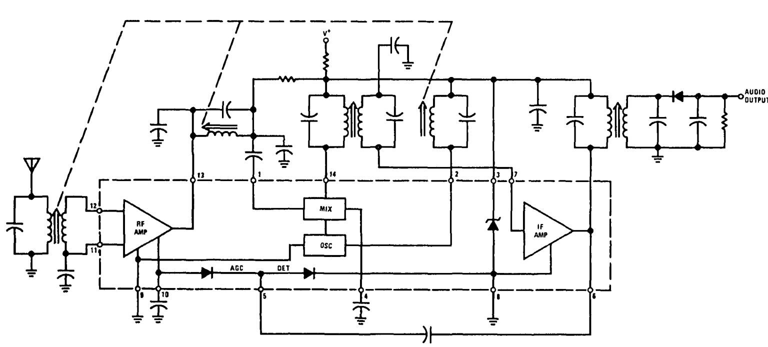
The LM1820 is a monolithic integrated circuit AM radio system. It includes two amplifiers a mixer-oscillator; an AGC detector and a zener regulator.

features

- Overvoltage protection
- Separately accessible amplifiers
- Regulated supply
- AGC for RF stage

schematic and block diagrams





Order Number LM1820N
See Package 22

absolute maximum ratings

Supply Voltage	16V
Current into Supply Terminal (Pin 3)	35 mA
Power Dissipation	
T_A = 25°C or Less	850 mW
T_A = 25°C or More	Derate Linearly 6.67 mW/°C
Operating Temperature Range	−25°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (T_A = 25°C, V^+ = 12V, Figure 1)

PARAMETER	CONDITIONS	LIMITS			UNITS
		MIN	TYP	MAX	
STATIC CHARACTERISTICS					
Supply Current (I)			18		mA
Zener Regulator (V_3)	$I_2 + I_3$ = 15 mA		7.1		V
Local Oscillator Current (I_2)	$I_2 + I_3$ = 15 mA		1.2		mA
IF Current (I_6)	$I_2 + I_3$ = 15 mA		4.5		mA
RF Current (I_{13})	$I_2 + I_3$ = 15 mA		5.6		mA
Mixer Current (I_{14})			300		μA
DYNAMIC CHARACTERISTICS					
RF Transconductance (i_{13}/e_{12})	f_{12} = 1 MHz, e_{12} = 100μV, e_5 = 0 S1 in Pos 1		120		mmhos
RF Input Resistance (R_{12})	f_{12} = 1 MHz, S1 in Pos 2		1		kΩ
IF Transconductance (i_6/e_7)	f_7 = 260 kHz, e_7 = 1 mVrms		90		mmhos
IF Input Resistance (R_7)	f_7 = 260 kHz		1		kΩ
Mixer Transconductance (i_{14}/e_1)	f_1 = 1 MHz, e_1 = 1 mVrms		2.5		mmhos
Mixer Input Resistance (R_1)	f_1 = 1 MHz		1.4		kΩ
Oscillator Voltage (e_2)			1.7		Vrms

test circuit

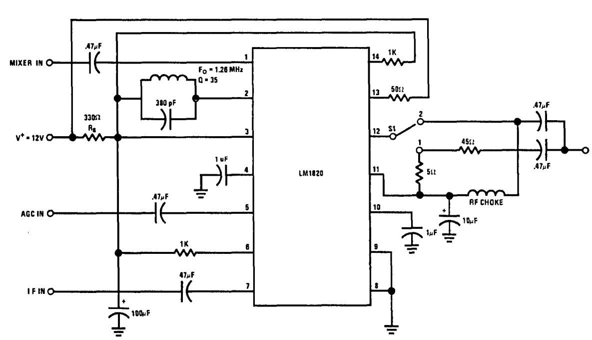


Figure 1.

Consumer Circuits

LM1829 TV chroma processor

general description

The LM1829 is a monolithic integrated circuit which provides complete color TV chroma signal processing except for tint control and chroma demodulation. Subcarrier regeneration is performed by a phase locked loop utilizing sample-and-hold techniques. A crystal controlled voltage controlled oscillator (VCO) provides stable output with only an initial trimmer capacitor adjustment.

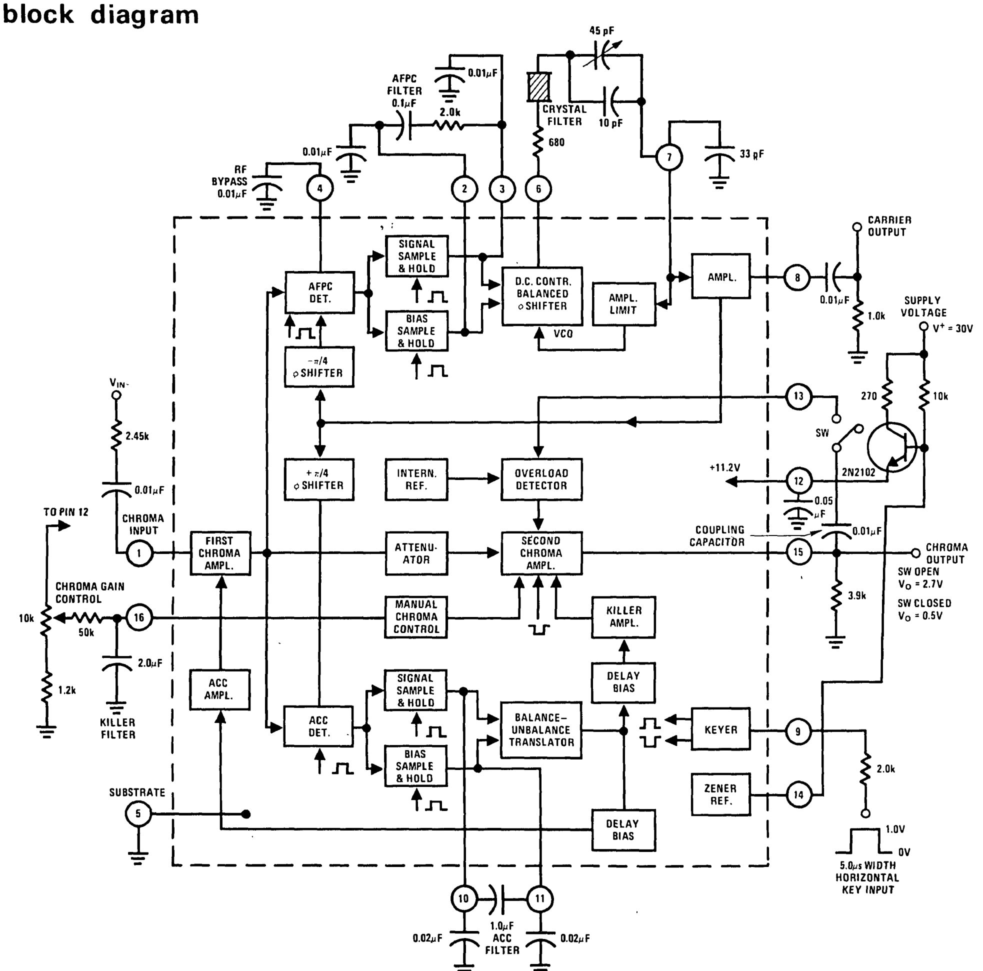
The chroma section uses a synchronous chroma burst level detector in an automatic chrominance control (ACC) loop with color killer. The burst signal is gated out of the chroma signal and the chroma output is then determined by a manual dc saturation control. In addition, an overload detector corrects for variations in burst-to-chrominance ratio.

The LM1829 may be used with the LM3067 chroma demodulator for a complete color processing system.

features

- Phase-locked loop subcarrier regenerator
- Automatic chrominance control (ACC) with color killer
- Supplementary ACC with overload detector
- Burst-cancelled chroma output
- Linear dc saturation control
- Internal zener-regulated reference potentials

block diagram



absolute maximum ratings (T_A = 25°)

DC Supply Voltage between Terminals 5 and 12*	12V
Device Dissipation:	
Up to T_A = 70°C	600 mW
Above T_A = 70°C derate linearly at	7.5 mW/°C
Operating Ambient Temperature Range	−40°C to +80°C
Storage Ambient Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	+265°C
At distance not less than 1/32" (0.79 mm) from case	

*This rating does not apply when using the internal zener reference in conjunction with an external pass transistor.

dc electrical characteristics

(T_A = 25°C) Test Circuit No. 1, S_1, S_2 normally OFF.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Current (I_{12})		15	25	35	mA
Zener Reference (V_{14})		11.0	11.7	12.7	V
Chroma Input (V_1)		1.3	2.0	2.7	V
AFPC Filter (V_2)	S_1 ON	7.0	7.8	8.6	V
AFPC Filter (V_3)	S_1 OFF	6.9	7.8	8.7	V
Pin 2–3 Offset (V_2–V_3)	V_2, V_3 measured as above	−100		+100	mV
RF Bypass (V_4)		6.0	7.5	9.0	V
VCO Loop (V_6)	S_2 ON	7.0	8.1	9.2	V
VCO Loop (V_7)		1.3	2.0	2.7	V
Subcarrier Output (V_8)		6.0	7.5	9.0	V
ACC Filter (V_{10})	S_1 OFF	7.0	7.8	8.6	V
ACC Filter (V_{11})	S_1 ON	6.8	7.8	8.8	V
Pin 10–11 Offset (V_{10}–V_{11})	V_{10}, V_{11} measured as above	−200		+200	mV
Overload Detector (V_{13})		0.3	0.5	0.6	V
Chroma Output (V_{15})	S_3 ON	4.5	6.0	8.5	V

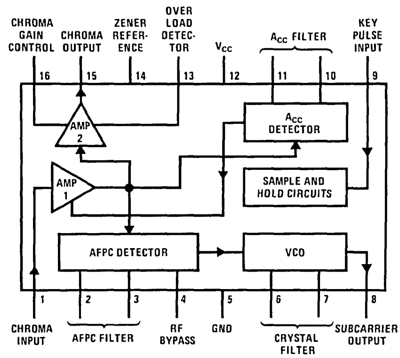
ac electrical characteristics

Test Circuit No. 2, S_1 normally OFF.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Subcarrier Output (V_8)	f = 3.579545 MHz	0.5	1.0	1.6	Vp-p
Pull-In Range		±250			Hz
100% Chroma Output (V_{15})	V_1 = 0.5 Vp-p	1.6	2.7	3.9	Vp-p
Overload Detector (V_{15})	S_1 ON	375	475	575	mVp-p
Killer Threshold (V_1)	$V_{15} \leq 20$ mVp-p	10		60	mVp-p

connection diagram

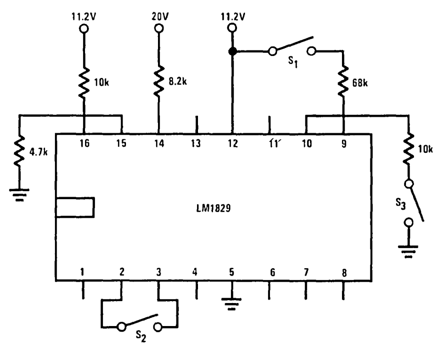
Dual-In-Line Package



TOP VIEW

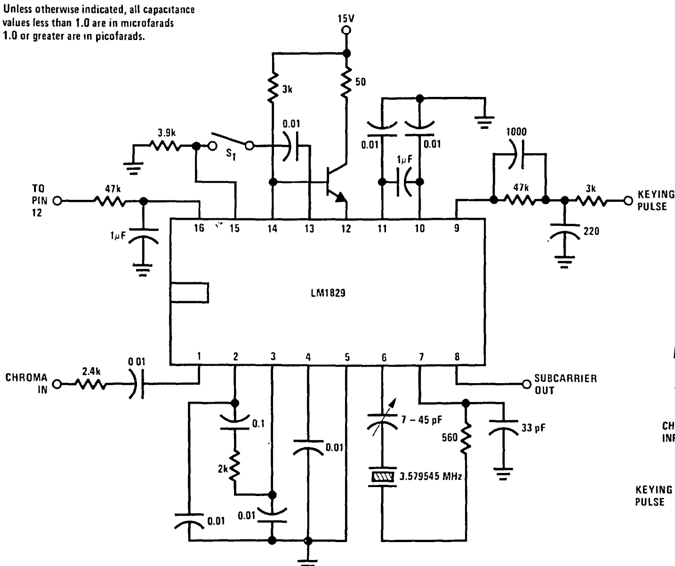
Order Number LM1829N
See Package 23

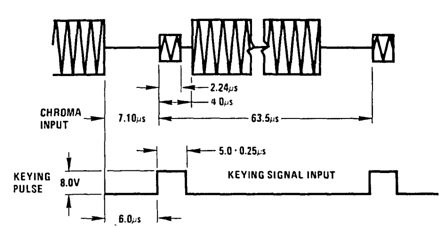
ac test circuits



Test Circuit No. 1

All resistance values are in ohms.
Unless otherwise indicated, all capacitance values less than 1.0 are in microfarads 1.0 or greater are in picofarads.





Test Circuit No. 2

5

Consumer Circuits

LM1845 signal processing system

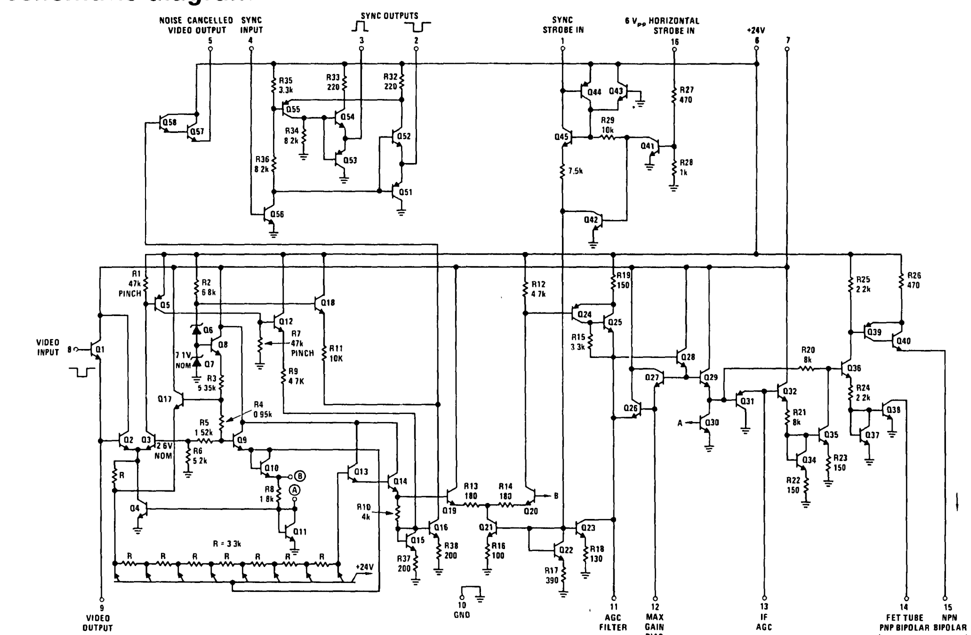
general description

The LM1845 is a signal processing system for television receivers which performs the functions of AGC and sync separation. It provides both positive and negative going sync signals and includes an internal AGC amplifier with noise cancelling. AGC outputs are available for both IF and tuner.

features

- Video internally delayed for total noise inversion
- Low impedance noise cancelled positive and negative going sync outputs
- No noise threshold or AGC detector level adjustment
- Low impedance video output for driving luminance channel or a video output stage
- Two delayed tuner AGC outputs; one for an NPN bipolar tuner and one for a FET, tube, or PNP

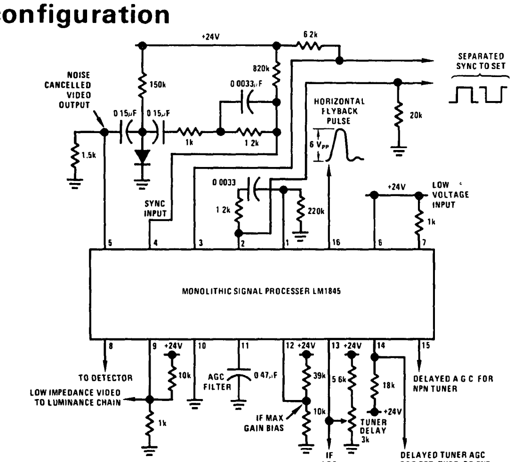
schematic diagram



Order Number LM1845N
See Package 23

Order Number LM1845N-01
See Package 25

typical circuit configuration



absolute maximum ratings

Supply Voltage	30V
Power Dissipation (Note 2)	625 mW
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	−55°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 1)

PARAMETERS	CONDITIONS	MIN	TYP	MAX	UNITS
AGC Threshold		4.65		5.3	V
Threshold Separation			1.7		V
Negative Sync Output (Low)	I_{P4} = 100 μA			2.5	V
Negative Sync Output (High)	V_{P4} = 0V	23.9			V
Positive Sync Output (Low)	V_{P4} = 0V			0.1	V
Positive Sync Output (High)	I_{P4} = 100 μA	20.5			V
AGC Filter Discharge Current			1.70		mA
AGC Filter Charge Current			20		mA
Reverse Tuner AGC Maximum Current			3.2		mA
Forward Tuner AGC Maximum Current			9.8		mA
Supply Current	1 Kohm between P6 and P7		10		mA

Note 1: T = 25°C and V_{CC} = 24V.

Note 2: The maximum junction temperature of the LM1845 is 125°C. For operating at elevated temperatures the derating factor is 175°C/W junction to ambient.

5

Consumer Circuits

LM2111 FM detector and limiter

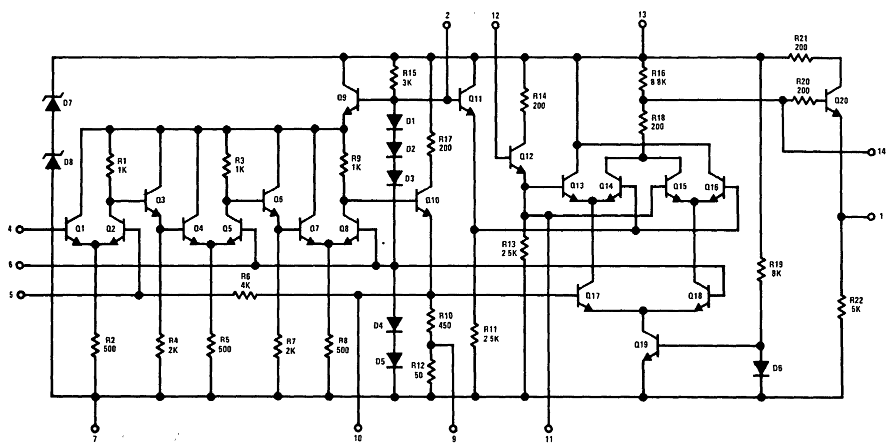
general description

The LM2111 is a monolithic integrated circuit FM detector and limiter that requires a minimum of external components for operation. It includes three stages of IF limiting and a balanced product detector.

features

- A direct replacement for ULN2111A and MC1357
- Simple detector alignment: one coil or ceramic filter
- Sensitivity: 3 dB limiting voltage 300 μV typ.
- Low harmonic distortion
- High IF voltage gain

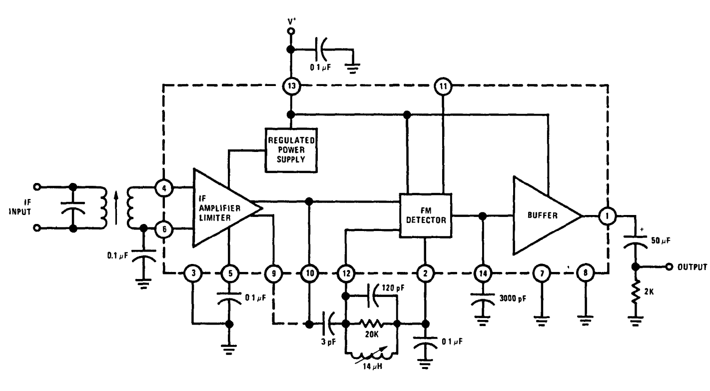
schematic diagram



Order Number LM2111N
See Package 22

Order Number LM2111N-01
See Package 24

block diagram



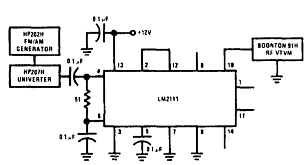
absolute maximum ratings

Supply Voltage	15V	Operating Temperature Range	0°C to +85°C
Input Signal Voltage (Pin 4)	3.5V	Storage Temperature Range	−65°C to +150°C
Power Dissipation		Lead Temperature (Soldering, 10 sec)	300°C
T_A = 25°C or less	850 mW		
T_A = 25°C or more	Derate Linearly 6.67 mW/°C		

electrical characteristics (T_A = 25°C, V_{CC} = 12V)

PARAMETER	SYMBOL	TEST CIRCUIT	CONDITIONS	LIMITS			UNITS
				MIN	TYP	MAX	
STATIC CHARACTERISTICS							
Supply Current	I_{13}			12	17	22	mA
Amplifier Input Reference	V_6				1.45		V
Detector Input Reference	V_2				3.65		V
Amplifier High Output Level	V_{10}			1.25	1.45	1.65	V
Amplifier Low Output Level	V_9			0.125	0.145	0.20	V
Detector Output Level	V_1			4.3	5.0	5.7	V
De-emphasis Resistance	R_d			7.2	8.8	10.8	kΩ
DYNAMIC CHARACTERISTICS	f_0 = 4.5 MH ΔF = ±25 kHz, Peak Separation = 15.0 kHz, Source Resistance = 50Ω						
Amplifier Voltage Gain	A_{IF}	1	$V_{IN} \leq 0.3$ mVrms	55	58		dB
Amplifier Output Voltage	$V_{10(IF)}$	1	V_{IN} = 10 mV	1.25	1.45		$V_{p\text{-}p}$
Input Limiting Threshold	$V_{IN(LIM)}$	2	FM = 400 Hz		400	800	µVrms
Recovered Audio Output	$V_{O(af)}$	2	V_{IN} = 60 mV, FM = 400 Hz	0.5	0.6		Vrms
Output Distortion	T_{HD}	2	100% FM Modulation		1.5		%
AM Suppression	AMR	2	AM: 1 kHz @ 30%, V_{IN} = 10 mV	40	46		dB
DYNAMIC CHARACTERISTICS	f_0 = 10.7 MHz, ΔF = ±75 kHz, Peak Separation = 1 MHz, Source Resistance = 50Ω						
Amplifier Voltage Gain	A_{IF}	1	$V_{IN} \leq 0.3$ mVrms		53		dB
Amplifier Output Voltage	$V_{10(IF)}$	1	V_{IN} = 10 mV		1.45		$V_{p\text{-}p}$
Input Limiting Threshold	$V_{IN(LIM)}$	2	FM = 400 Hz		300		µVrms
Recovered Audio Output	$V_{O(af)}$	2	V_{IN} = 60 mV, FM = 400 Hz		0.3		Vrms
Output Distortion	T_{HD}	2	100% FM Modulation		0.3		%
AM Suppression	AMR	2	AM: 1 kHz @ 30%, V_{IN} = 10 mV		40		dB

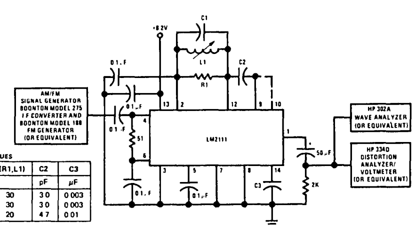
test circuit



TEST CIRCUIT 1

COMPONENT VALUES

f	L1	C1	R1	Q(R1,L1)	C2	C3
MHz	µH	pF	kΩ		pF	µF
4 5	14	120	20	30	3 0	0 003
5 5	8 0	100	20	30	3 0	0 003
10 7	2 0	120	3 9	20	4 7	0 01



TEST CIRCUIT 2

Consumer Circuits

LM2113 FM detector and limiter

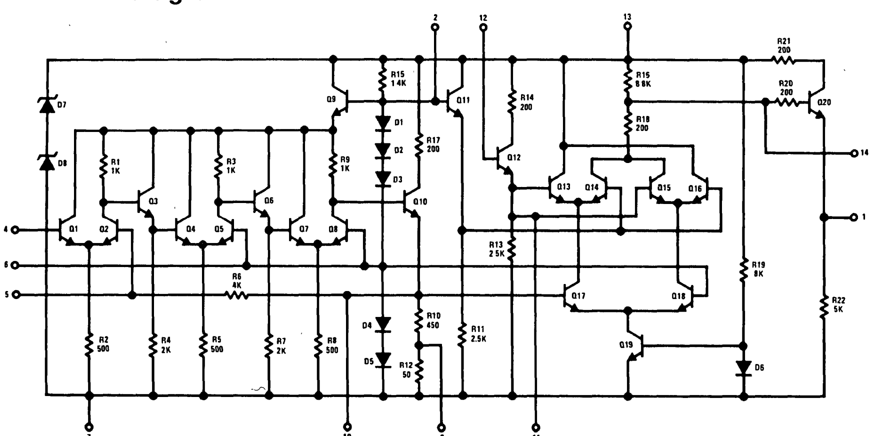
general description

The LM2113 is a monolithic integrated circuit FM detector and limiter that requires a minimum of external components for operation. It includes three stages of IF limiting and a balanced product detector.

features

- A direct replacement for ULN 2113A
- Simple detector alignment: one coil or ceramic filter
- Sensitivity: 3 dB limiting voltage 300 μV typ.
- Low harmonic distortion
- High IF voltage gain
- Nominal 8V supply

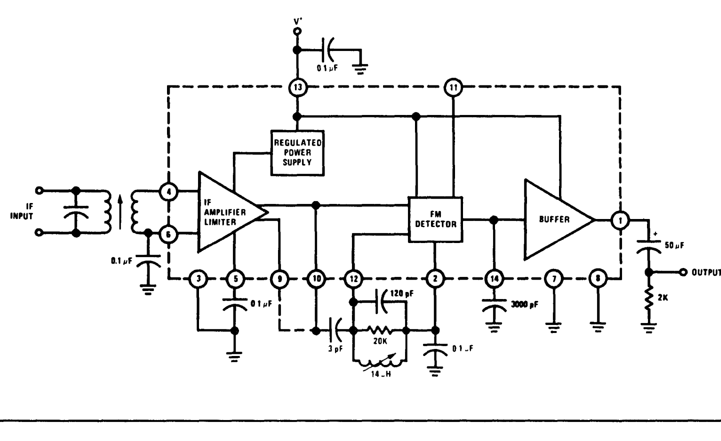
schematic diagram



Order Number LM2113N
See Package 22

Order Number LM2113N-01
See Package 24

block diagram



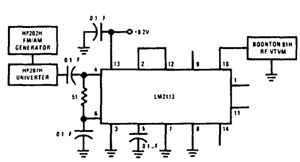
absolute maximum ratings

Supply Voltage	14V	Operating Temperature Range	0°C to +85°C
Input Signal Voltage (Pin 4)	3.5V	Storage Temperature Range	-65°C to +150°C
Power Dissipation		Lead Temperature (Soldering, 10 sec)	300°C
T_A = 25°C or less	850 mW		
T_A = 25°C or more	Derate Linearly 6.67 mW/°C		

electrical characteristics (T_A = 25°C, V_{CC} = 8.2V)

PARAMETER	SYMBOL	TEST CIRCUIT	CONDITIONS	LIMITS MIN	TYP	MAX	UNITS
STATIC CHARACTERISTICS							
Supply Current	I_{13}			11	16	22	mA
Amplifier Input Reference	V_6				1.45		V
Detector Input Reference	V_2				3.65		V
Amplifier High Output Level	V_{10}			1.25	1.45	1.65	V
Amplifier Low Output Level	V_9			0.125	0.145	0.20	V
Detector Output Level	V_1			3.0	3.8	4.5	V
De-emphasis Resistance	R_d			7.2	8.8	10.8	kΩ
DYNAMIC CHARACTERISTICS f_0 = 4.5 MH, Δf = ±25 kHz, Peak Separation = 150 kHz, Source Resistance = 50Ω							
Amplifier Voltage Gain	A_{IF}	1	$V_{IN} \leq 0.3$ mVrms		58		dB
Amplifier Output Voltage	$V_{10(IF)}$	1	V_{IN} = 10 mV		1.45		V_{p-p}
Input Limiting Threshold	$V_{IN(LIM)}$	2	FM = 400 Hz		300		μVrms
Recovered Audio Output	$V_{O(af)}$	2	V_{IN} = 60 mV, FM = 400 Hz		0.5		Vrms
Output Distortion	T_{HD}	2	100% FM Modulation		1.5		%
AM Suppression	AMR	2	AM: 1 kHz @ 30%, V_{IN} = 10 mV		46		dB
DYNAMIC CHARACTERISTICS f_0 = 10.7 MHz, Δf = ±75 kHz, Peak Separation = 550 kHz, Source Resistance = 50Ω							
Amplifier Voltage Gain	A_{IF}	1	$V_{IN} \leq 0.3$ mVrms		53		dB
Amplifier Output Voltage	$V_{10(IF)}$	1	V_{IN} = 10 mV		1.45		V_{p-p}
Input Limiting Threshold	$V_{IN(LIM)}$	2	FM = 400 Hz	230	300	500	μV
Recovered Audio Output	$V_{O(af)}$	2	V_{IN} = 60 mV, FM = 400 Hz	0.3	0.4	0.5	Vrms
Output Distortion	T_{HD}	2	100% FM Modulation		1.0		%
AM Suppression	AMR	2	AM: 1 kHz @ 30%, V_{IN} = 10 mV		40		dB

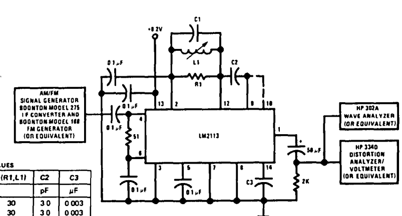
test circuits



TEST CIRCUIT 1

COMPONENT VALUES

f	L1	C1	R1	Q(R1,L1)	C2	C3
MHz	μH	pF	kΩ		pF	μF
4.5	14	120	20	30	3.0	0.003
5.5	8.0	100	20	30	3.0	0.003
10.7	2.0	120	3.9	20	4.7	0.01



TEST CIRCUIT 2

5

Consumer Circuits

LM3011 wide band amplifier

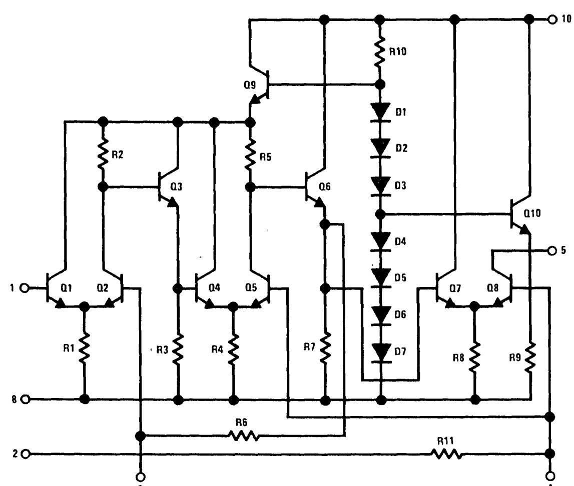
general description

The LM3011 is a monolithic wide band amplifier circuit that requires a minimum of external components for operation. It includes three stages of limiting.

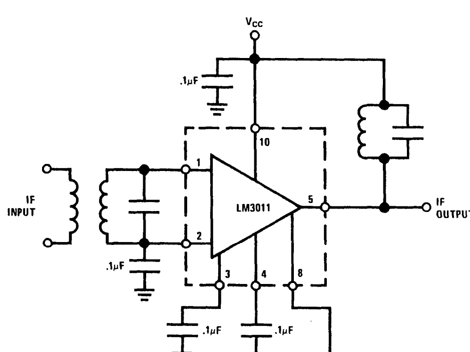
features

- A direct replacement for CA3011
- High amplifier gain
- Excellent limiting characteristics
- Wide frequency capability

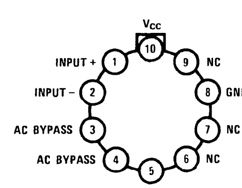
schematic diagram



block diagram



connection diagram



Order Number LM3011H
See Package 12

absolute maximum ratings

Supply Voltage	15V	Operating Temperature Range	−55°C to +125°C
Input Signal (Pin 1)	±3V	Storage Temperature Range	−65°C to +150°C
Power Dissipation	300 mW	Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (T_A = 25°C)

PARAMETER	CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
STATIC CHARACTERISTICS					
Total Device Dissipation (P_T)	V_{CC} = 6V (Figure 1)	60	90	133	mW
Total Device Dissipation (P_T)	V_{CC} = 7.5V (Figure 1)	95	120	187	mW
DYNAMIC CHARACTERISTICS V_{CC} = 7.5V, F = 4.5 MHz, unless otherwise noted					
Voltage Gain (A)	V_{CC} = 6V, f = 1 MHz (Figure 2)	60	66		dB
Voltage Gain (A)	V_{CC} = 7.5V, f = 1 MHz (Figure 2)	65	70		dB
Voltage Gain (A)	V_{CC} = 7.5V, f = 10.7 MHz (Figure 2)	55	61		dB
Parallel Input Resistance (R_{IN})			3		kΩ
Parallel Input Capacitance (C_{IN})			7		pF
Parallel Output Resistance (R_{OUT})			31.5		kΩ
Parallel Output Capacitance (C_{OUT})			4.2		pF
Noise Figure (NF)			8.7		dB
Input Limiting Voltage ($V_{IN(Lim)}$)	(−3 dB) (Figure 2)		300	400	μV

test circuits

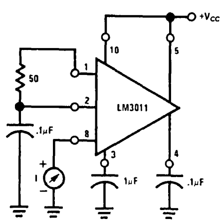


FIGURE 1

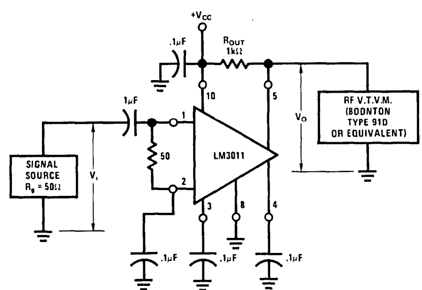


FIGURE 2

Consumer Circuits

LM3028A/LM3028B/LM3053 differential rf/if amplifier

general description

The LM3028A/LM3028B/LM3053 is a monolithic RF/IF amplifier intended for emitter-coupled (differential) or cascode amplifier operation from DC to 120 MHz in industrial and communications equipment. The LM3028A/LM3028B and LM3053 are plug-in replacements for the CA3028A/CA3028B and CA3053 respectively. The LM3028B is similar to the LM3028A but has premium performance with tighter limits in offset voltage and current, bias current and voltage gain. The LM3053 is similar to the LM3028A/LM3028B but is recommended for IF amplifier operation with less critical DC parameters.

features

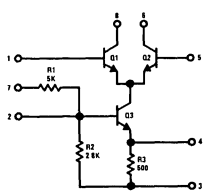
- Controlled for input offset voltage, input offset current, and input bias current*
- Balanced differential amplifier configuration with controlled constant-current source to provide unexcelled versatility
- Single- and dual-ended operation
- Operation from DC to 120 MHz*
- Balanced-AGC capability*
- Wide operating-current range.

*Does not apply to the LM3053.

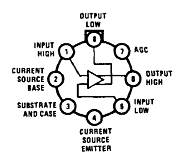
applications

- RF and IF linear amplifiers, both differential and cascode
- Mixers
- Oscillators
- Converters in commercial FM
- DC, audio and sense amplifiers
- Limiting IF amplifiers
- Hybrid building block
- Emitter coupled switches

schematic and connection diagrams

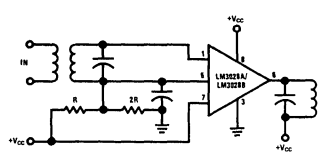


Metal Can Package

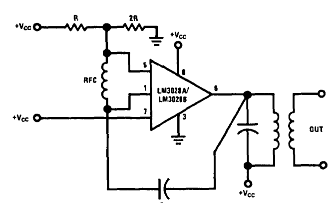


Order Number LM3028AH or LM3028BH or LM3053H
See Package 11

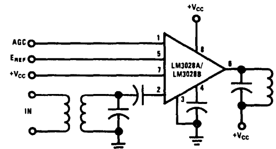
typical applications



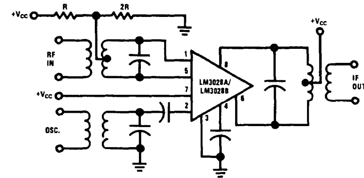
A Balanced Differential Amplifier with a Controlled Constant-Current-Source Drive and AGC Capability



Oscillator



A Cascode Amplifier with a Constant-Impedance AGC Capability



Mixer

absolute maximum ratings

	LM3028A/ LM3028B	LM3053
Supply Operating Voltage	±15V	±12V
Differential Input Voltage	±5V	±5V
Voltage Between 1 & 8	0V to +20V	0V to +15V
Voltage Between 5 & 6	0V to +20V	0V to +15V
Voltage Between 2 & 3	+5V to −11V	+5V to −11V
Voltage Between 2 & 4	+5V to −1V	+5V to −1V

Storage Temperature	−65°C to 200°C
Operating Temperature	−55°C to 125°C
Power Dissipation @ 25°C	450 mW
Derate 5 mW/°C Above 85°C	
Soldering Temperature (10 seconds)	300°C
Lead Temperature (Soldering, 10 sec)	

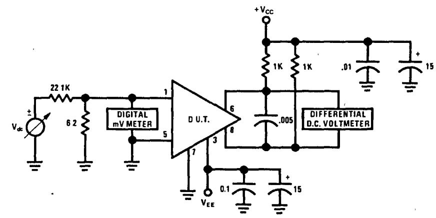
dc electrical characteristics

	SYMBOL	TEST CIRCUIT	V_{CC}	V_{EE}	LM3028A MIN	LM3028A TYP	LM3028A MAX	LM3028B MIN	LM3028B TYP	LM3028B MAX	LM3053 MIN	LM3053 TYP	LM3053 MAX	UNITS
Input Offset Voltage	V_{OS}	A	6	−6			5 0		0 4	2 0				mV
			12	−12			5 0		0 4	2 0				mV
Input Offset Current	I_{OS}	B	6	−6			5 0		0 15	2 0				μA
			12	−12			5 0		0 25	2.0				μA
Input Bias Current	I_{BIAS}	B	6	−6		7 5	50		7.5	40				μA
		B	12	−12		17	106		17	80				μA
		C	9	−								13	85	μA
		C	12	−								18	125	μA
Output Quiescent Operating Current	I_Q	B	6	−6	0.9	1 25	2 0	1.1	1.25	1.5				
		B	12	−12	2.3	3 15	5.0	2.5	3.15	4 0				
		C	9	−							1.2	2 2	3 5	mA
		C	12	−							2.3	3 15	5 0	mA
AGC Bias Current into Terminal 7	I_{AGC}	D	12	V_{AGC}=9V		1 1			1.1					mA
		D	12	V_{AGC}=12V		1.5			1.5					mA
			9									1 05		mA
			12									1.45		mA
Input Current into Terminal 7	I_7	B	6	−6	0.5	0 7	1.1	0 5	0 7	1.1				mA
		B	12	−12	1 0	1.5	2 2	1 0	1 5	2 2				mA
Power Dissipation	P_D	B	6	−6	24	35	54	24	35	42				mW
		B	12	−12	120	170	260	120	170	220				mW
		C	9	−								48	80	mW
		C	12	−								91	150	mW

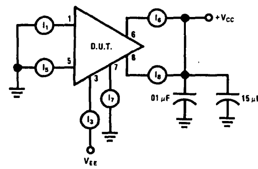
ac electrical characteristics

	SYMBOL	TEST CIRCUIT	V_{CC}	V_{EE}	LM3028A MIN	LM3028A TYP	LM3028A MAX	LM3028B MIN	LM3028B TYP	LM3028B MAX	LM3053 MIN	LM3053 TYP	LM3053 MAX	UNITS
100 MHz Power Gain	A_P	E(Cascode)	9	−	17	22		17	22					dB
		F(Diff.)	9	−	14 5	18.5		14 5	18 5					dB
10 7 MHz Power Gain	A_P	E(Cascode)	9	−	36	42		36	42					dB
		F(Diff.)	9	−	29	33 5		29	33 5					dB
100 MHz Noise Figure	NF	E(Cascode)	9	−		6 7	9 0		6 7	9 0				dB
		F(Diff.)	9	−		5 9	9 0		5 9	9 0				dB
Input Admittance at 10 7 MHz	Y_{11}	Cascode	+9	−		0.5+j1.3			0 5+j1.3			0 5+j1 3		mmho
		Diff.	+9	−		0 4+j0 58			0 4+j0.58			0 4+j0 58		mmho
Reverse Transadmittance at 10.7 MHz	Y_{12}	Cascode	+9	−		0 2+j0			0 2+j0			0 2+j0		μmho
		Diff	+9	−		10+j0 2			10+j0.2			10+j0 2		μmho
Forward Transadmittance at 10 7 MHz	Y_{21}	Cascode	+9	−		95−j27			95−j27			95−j27		mmho
		Diff.	+9	−		−32+j 5			−32+j 5			−32+j.5		mmho
Output Admittance at 10 7 MHz	Y_{22}	Cascode	+9	−		0+j100			0+j100			0+j100		μmho
		Diff.	+9	−		20+j160			20+j160			20+j160		μmho
Output Power (Untuned) at 10.7 MHz	P_O	G	+9	−		5.7			5 7			5.7		μW
AGC Range at 10.7 MHz		F	+9	−		76			76			76		dB
Voltage Gain at 10 7 MHz	A_V	H(Cascode)	+9	−		40			40			40		dB
		I(Diff.)	+9	−		30			30			30		dB
Differential 1 kHz Voltage Gain	A_{VD}	J	6	−6				35	38	42				dB
		J	12	−12				40	42.5	45				dB
Maximum Peak to Peak Output Voltage at 1 kHz	$V_{OUT,pp}^{MAX}$	J R_L=2k	6	−6				8	11					V_{p-p}
		J R_L=1 6k	12	−12				16	22					V_{p-p}
3 dB Bandwidth	BW	J R_L=2k	6	−6					11 2					MHz
		J R_L=1.6k	12	−12					12 7					MHz
Common-Mode Input Voltage Range	V_{CM}	K	6	−6				−2 5	−3.2 to +4.5	4				V
		K	12	−12				−5	−7 to +9	7				V
Common-Mode Rejection Ratio	CMRR	K	6	−6				60	110					dB
		K	12	−12				60	90					dB
Peak to Peak Output Current V_{IN} = 400 mV at 10.7 MHz	I_{p-p}	Diff.	9	−	2	4 7	7	2 5	4.7	6	2	4.7	7	mA
		Diff.	12	−	3.5	6 5	10	4.5	6.5	8	3 5	6 5	10	mA

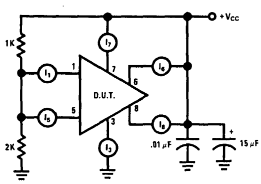
test circuits



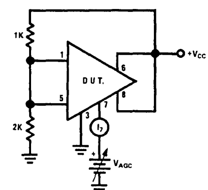
Test Circuit A: VOS LM3028A & LM3028B



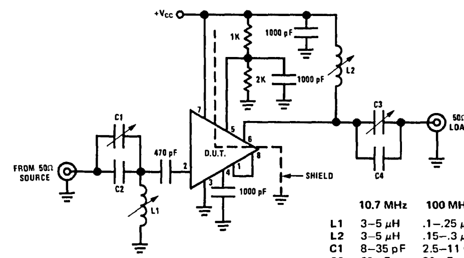
Test Circuit B: I_{OS}, I_{BIAS}, P_D, I_Q & I_7 for LM3028A & LM3028B



Test Circuit C: I_{BIAS}, P_D, I_Q for LM3053

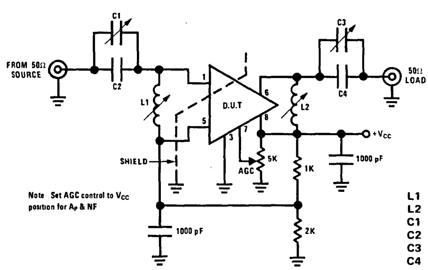


Test Circuit D: I_{AGC} vs V_{AGC} and I_7 for LM3028A & LM3028B



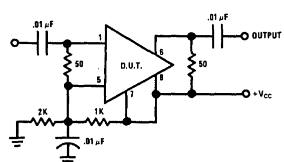
	10.7 MHz	100 MHz
L1	3–5 µH	.1–.25 µH
L2	3–5 µH	.15–.3 µH
C1	8–35 pF	2.5–11 pF
C2	39 pF	20 pF
C3	8–35 pF	2.5–11 pF
C4	36 pF	–

Test Circuit E: Cascode Ap & NF 10.7 MHz & 100 MHz

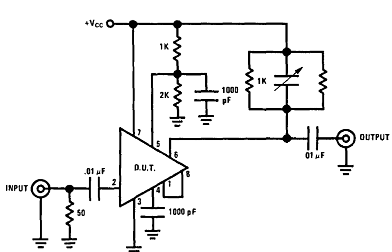


	10.7 MHz	100 MHz
L1	3–6 µH	.2–.5 µH
L2	3–6 µH	.2–.5 µH
C1	8–35 pF	2.5–11 pF
C2	39 pF	–
C3	8–35 pF	2.5–11 pF
C4	36 pF	–

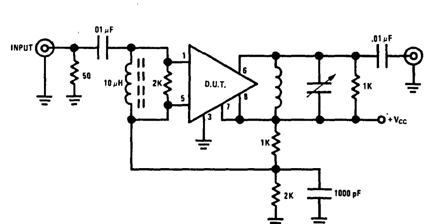
Test Circuit F: Differential Ap, NF and AGC Range, 10.7 MHz & 100 MHz



Test Circuit G: P_O (Untuned) for LM3028A & LM3028B

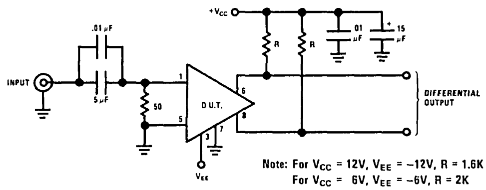


Test Circuit H: Cascode A_V and Transfer Function, 10.7 MHz



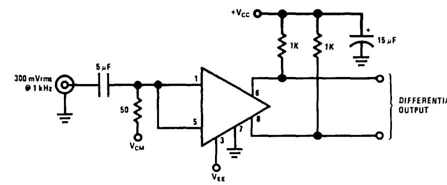
Test Circuit I: Differential Mode A_V and Transfer Function, 10.7 MHz

test circuits (con't)



Note: For V_{CC} = 12V, V_{EE} = −12V, R = 1.6K
For V_{CC} = 6V, V_{EE} = −6V, R = 2K

Test Circuit J: A_V, V_{OUT}, MAX, p/p B.W. for LM3028B



Test Circuit K: CMRR and V_{CM} Range for LM3028B

Consumer Circuits

LM3064 television automatic fine tuning

general description

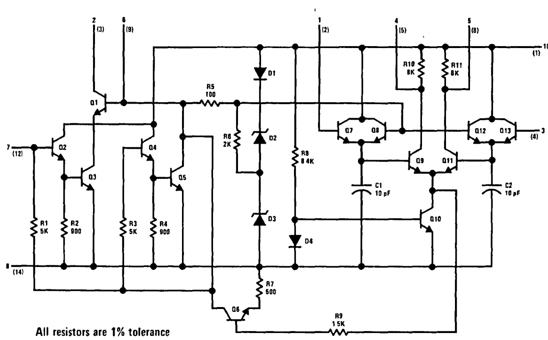
The LM3064 is a monolithic integrated circuit designed primarily for AFT (automatic fine tuning) applications. It includes a zener regulated power supply, IF amp, differential peak detector, and an AGC circuit.

The LM3064 is supplied in both the formed and straight lead TO-5 and 14 lead dual-in-line package.

features

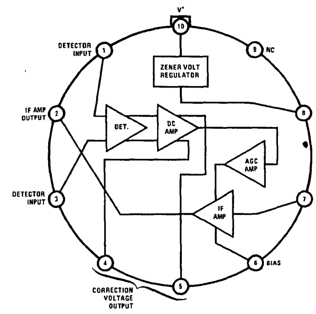
- Primarily intended for AFT applications
- High gain input amp (18 mV for rated output)
- Differential output correction voltage
- Wide operating temperature –40°C to +85°C
- Formed leads available for easy PC board design

schematic and connection diagrams



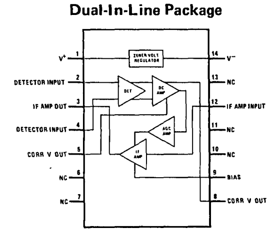
All resistors are 1% tolerance and are in ohms.

Metal Can Package



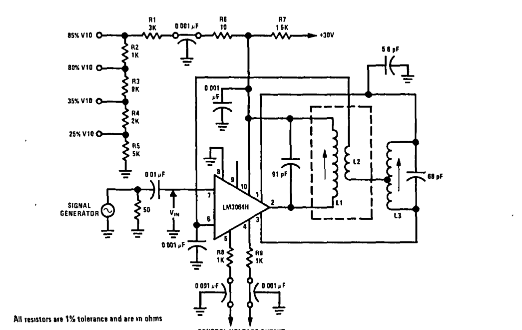
Order Number LM3064H
See Package 14

Dual-In-Line Package

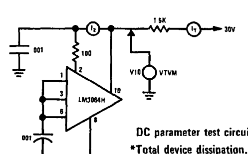


Order Number LM3064N, N-01
See Package 22 & 24

test circuits



Test Circuit 1
Correction Voltage Test Circuit



DC parameter test circuit tests:
*Total device dissipation.
*Zener regulating voltage.
*Quiescent operating current.
*Quiescent current into pin 2.

Test Circuit 2
DC Parameter Test Circuit

absolute maximum ratings

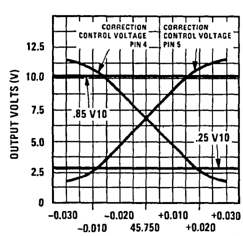
Power Dissipation
T_A = 25°C or Less 700 mW
T_A = 25°C or More Derate Linearly 5.6 mW/°C for TO-5
Derate Linearly 10 mW/°C for DIP

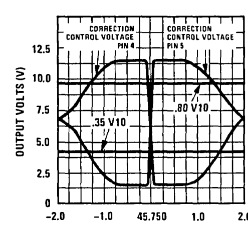
Operating Temperature Range −40°C to +85°C
Storage Temperature Range −65°C to +150°C
Power Supply Current 50 mA

electrical characteristics (T_A = 25°C)

PARAMETER	SYMBOL	TEST CIRCUIT	CONDITIONS	LIMITS MIN	LIMITS MAX	UNITS
STATIC						
Device Dissipation	P_T	2	V_{CC} = 30V; R_S = 1.5k	130	150	mW
Current Drain	I_T	2	V_{10} = 10.5V	4.0	9.5	mA
Zener Regulating Voltage	V_{10}	2	V_{CC} = 30V; R_S = 1.5k	10.9	12.8	V
Quiescent Current into Pin 2	I_2	2	V_{CC} = 30V; R_S = 1.5k	1	4	mA
Quiescent Voltage at Pin 4	V_4	1	V_{CC} = 30V; R_S = 1.5k	5.0	8.0	V
Quiescent Voltage at Pin 5	V_5	1	V_{CC} = 30V; R_S = 1.5k	5.0	8.0	V
Output Offset Voltage between Pins 4 & 5	V_4-V_5	1	V_{CC} = 30V; R_S = 1.5k	−1.0	+1.0	V
DYNAMIC – Output Voltage vs Frequency Deviation AFT						
				Correction Voltage as Shown Below		
Correction Control Voltage at Pin 4			V_{CC} = 30V; R_S = 1.5k V_i = 18 mV	% of V_{10}	% of V_{10}	
	V_4	1	f = 45.75 − .03 MHz	85		V
	V_4	1	f = 45.75 + .03 MHz		25	V
	V_4	1	f = 45.75 − .9 MHz	80		V
	V_4	1	f = 45.75 + .9 MHz		35	V
	V_4	1	f = 45.75 − 1.5 MHz		80	V
	V_4	1	f = 45.75 + 1.5 MHz	35		V
Correction Control Voltage at Pin 5 See Curves	V_5	1	f = 45.75 − .03 MHz		25	V
	V_5	1	f = 45.75 + .03 MHz	85		V
	V_5	1	f = 45.75 − .9 MHz		35	V
	V_5	1	f = 45.75 + .9 MHz	80		V
	V_5	1	f = 45.75 − 1.5 MHz	35		V
	V_5	1	f = 45.75 + 1.5 MHz		80	V

correction control voltage





coil winding data

COIL DATA FOR DISCRIMINATOR WINDINGS

L_1 – Discriminator Primary: 3-1/6 turns; No. 20 Enamel-covered wire–close-wound, at bottom of coil form. Inductance of L_1 = 0.165 μH; Q_o = 120 at f_o = 45.75 MHz.

Start winding at Terminal No. 6; finish at Terminal No. 1. See Notes below.

L_2 – Tertiary Windings: 2-1/6 turns; No. 20 Enamel-covered wire–close- wound over bottom end of L_1. Start winding at Terminal No. 3; finish at Terminal No. 4. See Notes below.

L_3 – Discriminator Secondary: 3-1/2 turns; center-tapped, space wound at bottom of coil form. Inductance of L_3 = 0.180 μH; Q_o = 150 at f_o = 45.75 MHz.

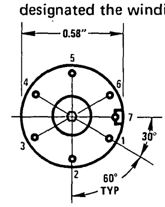
Start winding at Terminal No. 2; finish at Terminal No. 5, connect center tap to Terminal No. 7. See Notes.

Note 1: Coil Forms; Cylindrical; –0.30" dia. max.

Note 2: Tuning Core: 0.250" dia. x 0.37" length. Material: Carbinal J or equivalent.

Note 3: Coil Form Base: See drawing below.

Note 4: End of coil nearest terminal board to be designated the winding start end.



L_1 is aligned for symmetrical bandwidth on either side of 45.750 MHz.

L_2 tertiary winding wound on L_1 coil form.

L_3 is aligned for zero differential output between terminals 4 and 5 at f_o = 45.750 MHz.

5

Consumer Circuits

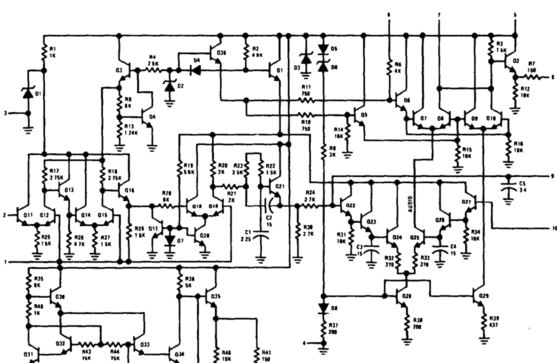
LM3065 television sound system

general description

The LM3065 is a monolithic integrated circuit television sound system that requires a minimum of external components for operation. It includes three stages of IF limiting, an FM detector, an electronic attenuator or volume control, an audio amplifier-driver, and a temperature stable regulated power supply. Volume control is accomplished by varying bias levels of the electronic attenuator with a potentiometer between pin 6 and ground. Because no audio signal is present in this control, hum and noise pickup are easily filtered. Unshielded wire may be used for volume control. Features include:

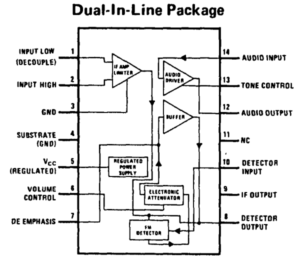
- Electronic attenuator: replaces conventional ac volume control
- Volume reduction range: >60 dB
- Sensitivity: 3 dB limiting voltage—200 μV typically
- High stability
- Low harmonic distortion
- Audio drive capability: 6 mA p-p
- Undistorted audio output voltage: 7V p-p
- Differential peak detector
- Simple detector alignment: one coil
- Internal zener diode regulator
- Excellent AM rejection—50 dB typ. @ 4.5 MHz

schematic and connection diagrams



All resistance values are in ohms, all capacitance values are in picofarads.

Dual-In-Line Package

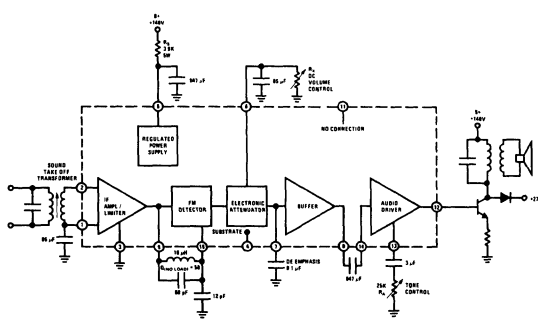


TOP VIEW

Order Number LM3065N
See Package 22

Order Number LM3065N-01
See Package 24

block diagram



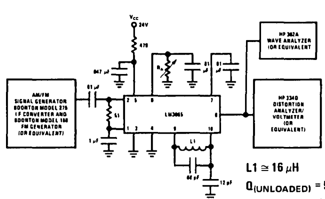
absolute maximum ratings

Input Signal Voltage (Between Pin 1 and 2)	±3V
Power Supply Current (Pin 5)	75 mA
Power Dissipation	
T_A = 25°C or less	850 mW
T_A = 25°C or more	Derate Linearly 6.67 mW/°C
Operating Temperature Range	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

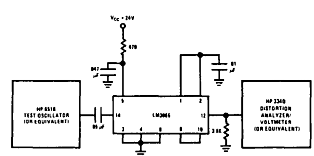
PARAMETER	SYMBOL	TEST CIRCUIT	CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
Static Characteristics							
Zener Regulating Voltage	V_5			10.3	11.5	12.2	V
Quiescent Supply Current	I_5				28		mA
Voltage @ Pin 12	V_{12}			4.0	5.2	5.8	V
Current into Terminal 5	I_5		V_5 = 9V	10.0	12.3	24	mA
Dynamic Characteristics							
IF Amplifier/Detector							
Input Limiting Voltage (−3 dB point)	V_{IN} (lim)	1	fo = 4.5 MHz fm: 400 Hz @ ±25 kHz		200	400	µV
Recovered Audio	V_O (af)	1	fo = 4.5 MHz, V_{IN} = 100 mV fm: 400 Hz @ ±25 kHz	500	750		mV rms
AM Rejection	AMR	1	fo = 4.5 MHz, fm: 400 Hz @ ±25 kHz AM: 1 kHz @ 30%	40	50		dB
Total Harmonic Distortion	THD	1	fo = 4.5 MHz, V_{IN} = 100 mV fm: 400 Hz @ ±25 kHz		.9	2	%
Attenuator							
Volume Reduction Range			fo = 4.5 MHz fm: 400 Hz @ ±25 kHz R_A = 0 for max-volume; R_A = ∞ for minimum volume	60			dB
Audio Driver							
Voltage Gain	Av(af)	2	V_{IN} = 100 mV @ 400 cps	17.5	20		dB
Total Harmonic Distortion	THD	2	V_O = 2V rms @ 400 cps		1.5		%
Undistorted Output Voltage		2	THD = 5% @ 400 cps	2	2.5		V rms

test circuits



L1 ≅ 16 µH
$Q_{(UNLOADED)}$ = 50
Tests: Recovered audio THD
−3 dB limiting voltage
AM rejection
Volume control range
Play though voltage

TEST CIRCUIT 1



Tests: Audio driver voltage gain
Audio driver THD
Undistorted output

TEST CIRCUIT 2

Consumer Circuits

LM3067 chroma demodulator

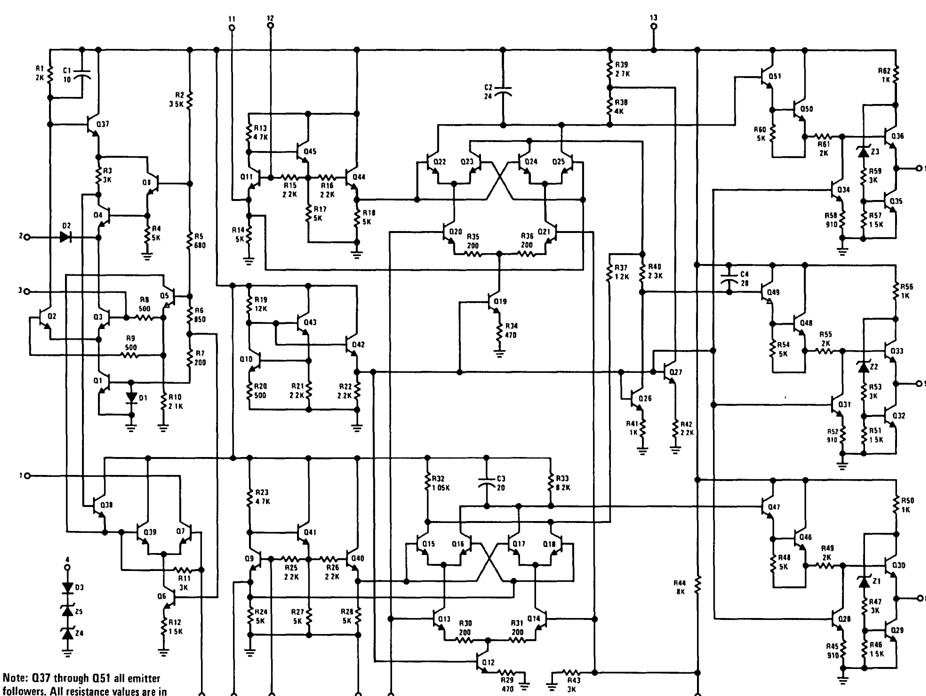
general description

The LM3067 is a monolithic integrated circuit designed primarily for color signal demodulation in color television receivers. A DC tint control is also included. The reference subcarrier and chroma signals are applied and the three demodulated R–Y, G–Y, B–Y color difference signals are delivered with close DC balance and proper amplitude ratios. The tint control achieves a 100°+ phase adjustment by means of a customer-operated DC control. A limiting amplifier and phase shift network provide constant amplitude carriers phase shifted 76° which then feed demodulator drive amplifiers. The demodulators consist of two sets of balanced detectors which receive the reference subcarrier and chroma signal. The chroma signal is then demodulated, matrixed, and DC shifted in voltage. The LM3067 and LM3066 Chroma Signal Processor constitute a complete chroma system for color television receivers.

features

- Balanced chroma demodulators
- DC tint control
- Color difference matrix
- Low output impedance drivers for direct coupling
- Reference subcarrier limiter
- Zener regulated voltage reference
- Internal RF filtering of demodulation components

schematic diagram



Note: Q37 through Q51 all emitter followers. All resistance values are in ohms. All capacitance values are in pF.

Order Number LM3067N
See Package 23

Order Number LM3067N-01
See Package 25

absolute maximum ratings

Power Dissipation	
T_A = 70°C or less	600 mW
Above 70°C	derate linearly 7.7 mW/°C
Ambient Temperature Range	
Operating	-40 to +85°C
Storage	-65 to +150°C
Power Supply Voltage (Pin 13)	+12V
Power Supply Current (Pin 13)	50 mA

electrical characteristics (T_A = 25°C and V^+ = 11.2V)

PARAMETERS	CHARACTERISTICS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
Static Characteristics (Test Circuit 1)					
Voltage Inputs					
Tint Control Input (V_2)	I_2 = 0.25 mA		3.5		
Reference Subcarrier (V_3)			2.1		
Zener Regulator Ref. (V_4)		10.6	11.9	12.6	V
B–Y, R–Y Oscillator Ref. Inputs (V_6,V_{12})			5.7		
Balance (B–Y, R–Y) (V_7,V_{11})			5.0		
B–Y, G–Y, R–Y Outputs ($V_{8,9,10}$)		4.2	5.0	5.8	
Difference Outputs (Note 1), (ΔV_8,ΔV_9,ΔV_{10})		-0.3		0.3	
Chroma Inputs (V_{14},V_{15})			3.0		
Tint Amplifier Balance (V_{16})			4.7		
Input Currents					
Tint Amplifier Output (min.) (I_1(min.))	V_{16} = 8V	0.16	0.37		mA
Total Supply (I_1 + I_{13})		15	24	33	
Dynamic Characteristics (Test Circuit 2)					
Tint Amplifier Output					
Sensitivity (V_1)	V_3 = 7 mVRMS	160	250		mVRMS
Limiting Knee (V_1)	V_3 = 35 mVRMS		300		
Limiting (V_1)	V_3 = 350 mVRMS			380	
Tint Amplifier Phase Ref. (Note 2) (ϕ_6)	V_3 = 70 mVRMS	185	220	235	degrees
Tint Amplifier Phase Ref. (Note 3) ($\Delta\phi_6$)	V_3 = 70 mVRMS	90	105		degrees
Demodulated Chroma Outputs					
R–Y (V_{10})	V_3 = 70 mVRMS V_{14} = 35 mVRMS	0.15	0.25		VRMS
Ratio of G–Y to R–Y (V_9/V_{10})		0.28	0.36	0.44	
Ratio of B–Y to R–Y (V_8/V_{10})		1.0	1.2	1.4	
Color Difference Output					
BW at 3.3 dB ($BW_{Diff.}$)		450	550		kHz
Color Difference Outputs (max. input signals):					
R–Y (V_{10})	V_3 = 70 mVRMS V_{14} 212 mVRMS		3.0		V_{p-p}
G–Y (V_9)			1.1		
B–Y (V_8)			3.6		
Small Signal Input Resistance					
Terminal Number 3 (r_i)			550		Ω
Terminal Numbers 6 and 12 (r_i)			22		
Small Signal Output Resistance					
Terminal Numbers 8, 9, and 10 (r_o)			5		

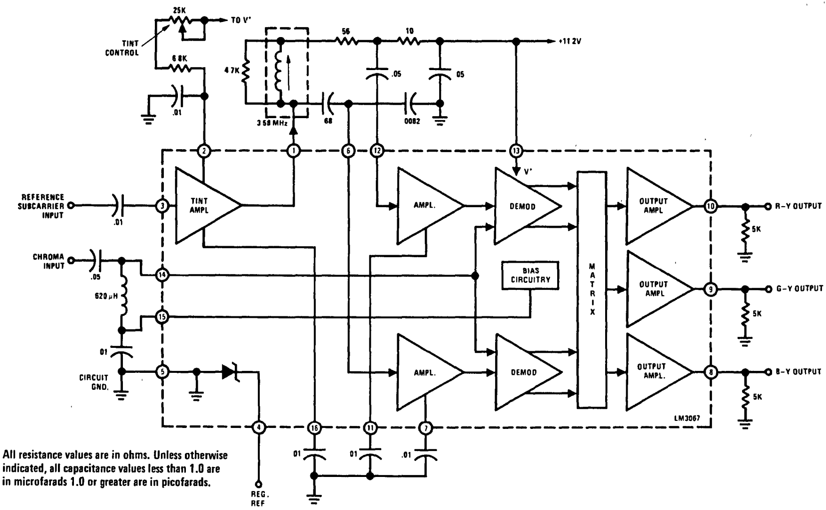
Note 1: $\Delta V_8 = V_8 - \left(\frac{V_8 + V_9 + V_{10}}{3}\right)$, $\Delta V_9 = V_9 - \left(\frac{V_8 + V_9 + V_{10}}{3}\right)$, $\Delta V_{10} = V_{10} - \left(\frac{V_8 + V_9 + V_{10}}{3}\right)$

Note 2: Thermal No. 3 is phase reference.

Note 3: Read phase shift as tint control is varied.

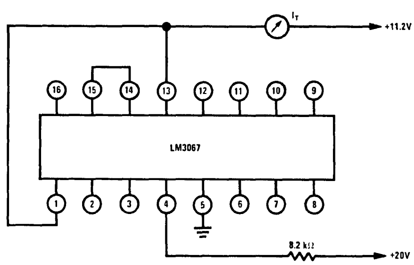
5

block and functional diagram

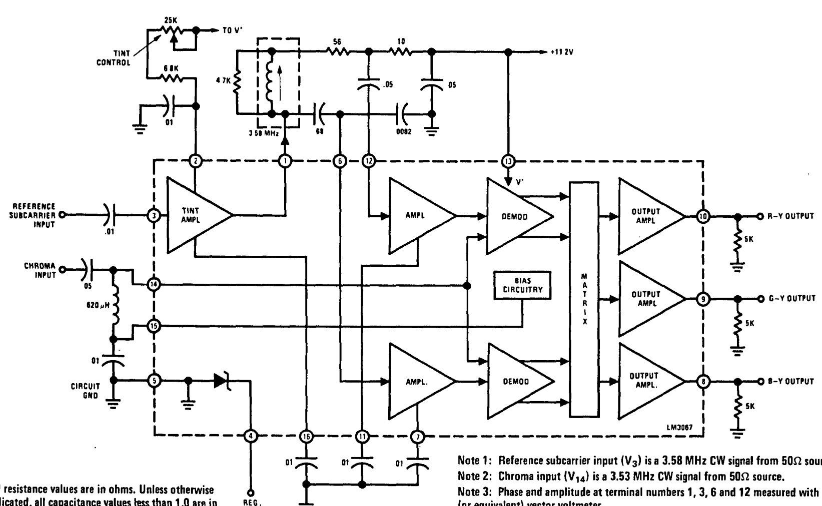


All resistance values are in ohms. Unless otherwise indicated, all capacitance values less than 1.0 are in microfarads 1.0 or greater are in picofarads.

test circuits



TEST CIRCUIT 1



All resistance values are in ohms. Unless otherwise indicated, all capacitance values less than 1.0 are in microfarads 1.0 or greater are in picofarads.

Note 1: Reference subcarrier input (V_3) is a 3.58 MHz CW signal from 50Ω source.
Note 2: Chroma input (V_{14}) is a 3.53 MHz CW signal from 50Ω source.
Note 3: Phase and amplitude at terminal numbers 1, 3, 6 and 12 measured with HP8405A (or equivalent) vector voltmeter.
Note 4: Signals at terminal numbers 8, 9, and 10 measured with HP400E (or equivalent) voltmeter or an oscilloscope.
Note 5: Tint control at maximum unless otherwise noted.

TEST CIRCUIT 2

Consumer Circuits

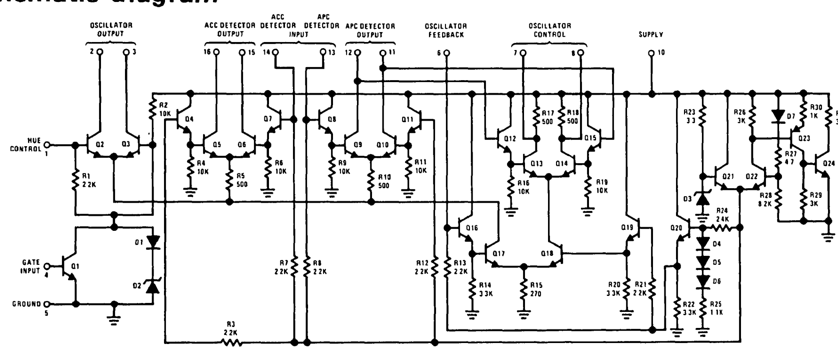
LM3070 chroma subcarrier regenerator

general description

The LM3070 integrated circuit is a phase locked loop oscillator controlled by an Automatic Phase Control (APC) detector, and an Automatic Chroma Control (ACC) detector which generates the correction voltage for the ACC amplifier of the LM3071. Both the APC and the ACC detectors are piloted by the burst signal present in the NTSC color video signal applied at Pins 13 and 14 in quadrature. The APC error output voltage controls the phase shift at Pin 7 in the oscillator feedback loop and locks the frequency of oscillation to the burst signal frequency. The APC and ACC detectors are keyed by the horizontal pulse applied at Pin 4, which also inhibits the oscillator output amplifier during the burst interval. Balance adjustment of DC offsets are provided to establish an initial no-signal offset control in the ACC output, and a no-signal, on-frequency adjustment through the APC detector-amplifier circuit which controls the oscillator frequency. The oscillator output stage is differentially controlled at Pins 2 and 3 by the HUE control to Pin 1.

The circuit also includes a shunt regulator to establish a 12V DC supply.

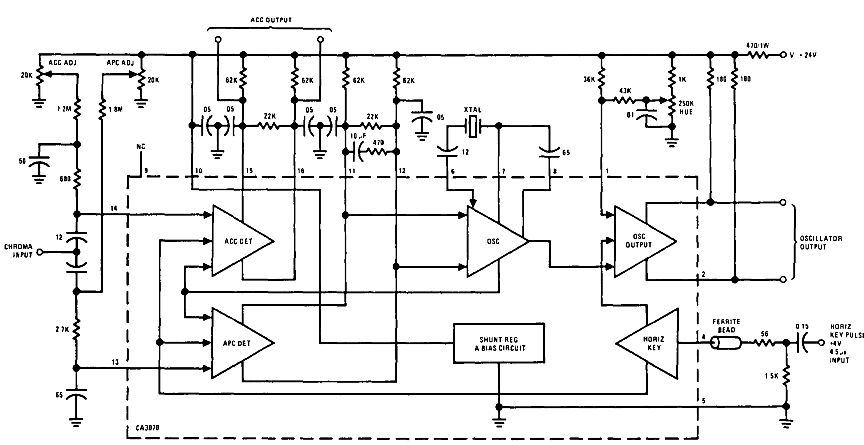
schematic diagram



Order Number LM3070N
See Package 23

Order Number LM3070N-01
See Package 25

block diagram



All resistance values are in ohms. Unless otherwise indicated, all capacitance values less than 10 are in microfarads, 10 or greater are in picofarads.

5

absolute maximum ratings

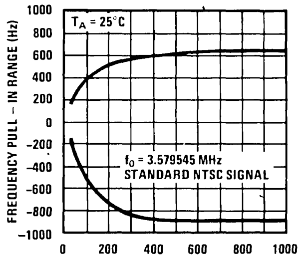
Supply Current	40 mA
Internal Power Dissipation up to 70°C	550 mW
Above 70°C Derate at 7 mW/°C	
Operating Temperature	-40°C to +85°C
Storage Temperature	-65°C to +150°C

electrical characteristics $T_A = 25°C$ $V^+ = 24V$

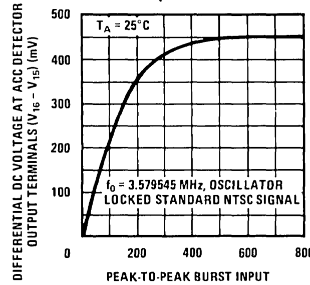
PARAMETER	SYMBOL	CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
STATIC (Refer to Test Circuit 1)						
Supply Current	I_S			25.5		mA
Voltage at Supply Terminal	V_{10}		11.3	12	12.8	V
Supply Regulation	ΔV_{10}	$V^+ = 21V$ to $V^+ = 27V$		30		mV
Total Current into Oscillator Output Terminals	$I_2 + I_3$	S_1 "OFF", S_2 Position 1, Pins 2 and 3 shorted together	4.2	5.8	7.8	mA
APC Output Current	I_{11}, I_{12}	S_1 "ON", S_2 Position 1		1.45		mA
ACC Output Current	I_{15}, I_{16}	S_1 "ON", S_2 Position 1		1.45		mA
APC Output Balance	$V_{11} - V_{12}$	S_1 "ON", S_2 Position 1	-350	0	+350	mV
ACC Output Balance	$V_{15} - V_{16}$	S_1 "ON", S_2 Position 1	-300	0	+300	mV
Oscillator Control Balance	$V_7 - V_8$	S_2 Position 2, $V_{11} = V_{12} = 9.5V$	-300	0	+300	mV
Voltage at Hue Control Terminal	V_1	S_1 "OFF"	7.1	7.7	8.3	V
Voltage at Oscillator Feedback Terminal	V_6	S_2 Position 3		2.8		V
Voltage at APC and ACC Input Terminal	V_{13}, V_{14}		5.8	6.3	6.9	V
DYNAMIC (Refer to Test Circuit 2)						
Oscillator Pullin Range				±650		Hz
Oscillator Control Sensitivity				12		Hz/mV
Oscillator Output at Pin 2	V_2	S_1, Position 1	.75	1.0		V_{p-p}
Oscillator Output at Pin 3	V_3	S_1, Position 2	.75	1.0		V_{p-p}
ACC Detected Output			120	150		mV

typical performance characteristics

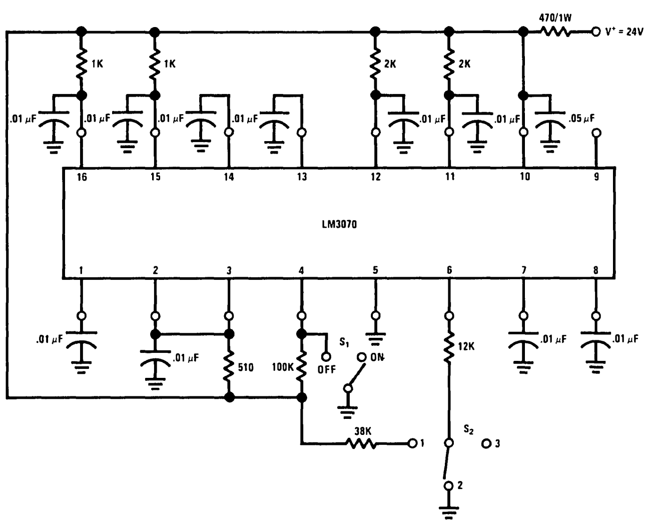
Frequency Pull-In Range as a Function of Burst Input Level



Differential DC Voltage at ACC Detector Output as a Function of Burst Input Level

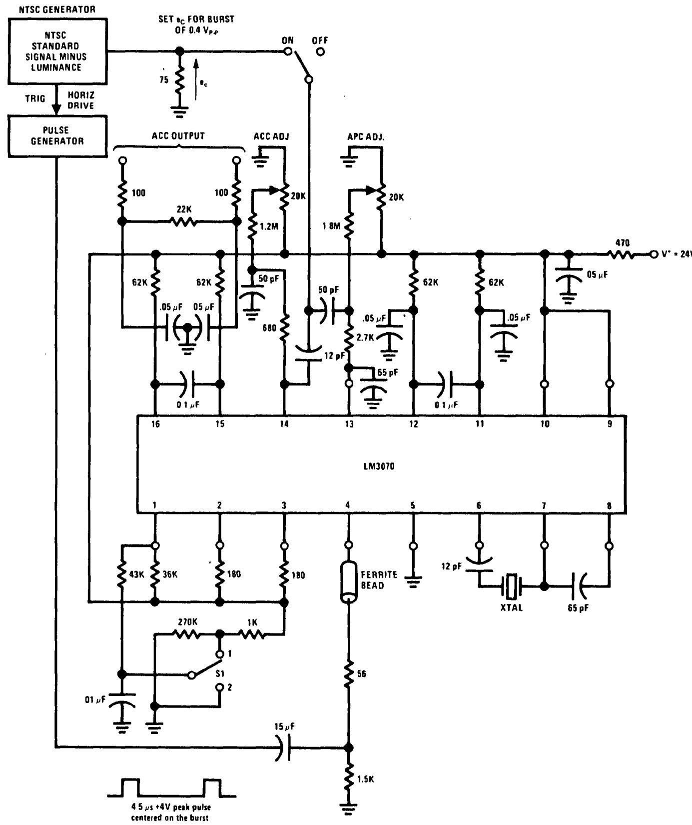


dc test circuit



TEST CIRCUIT 1

ac test circuit



TEST CIRCUIT 2

Consumer Circuits

LM3071 television chroma IF amplifier

general description

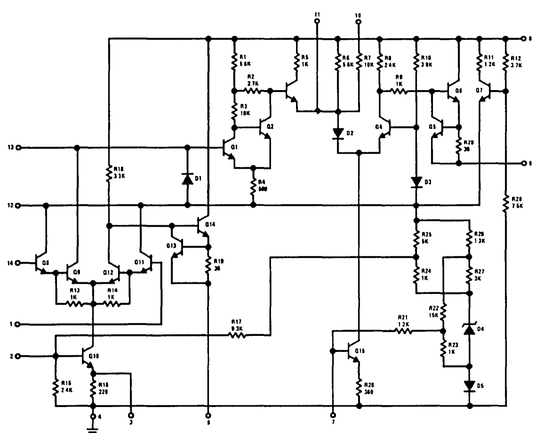
The LM3071 is a two stage chroma IF amplifier on a single silicon chip encapsulated in a 14 lead molded-Dual-In-Line Package. The first stage is an automatic gain controlled amplifier, and its output from Pin 6 is used to drive the ACC detector of the LM3070 or an equivalent circuit. The output from the ACC detector is applied to Pins 1 and 14 to control the gain of the stage. The second amplifier stage is driven from the output of the first at Pin 7, and the gain is controlled by adjusting the DC voltage at Pin 10. The output from Pin 9 supplies the chroma drive signal to the chroma demodulator circuit. In addition, the second stage may be gated "OFF" to provide "color killing" action in the absence of color signal at the output of the first stage. The killer trip point is adjusted externally.

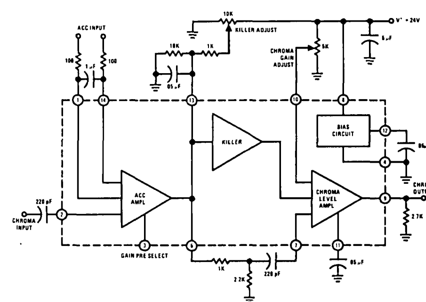
features

- Very effective gain control of both stages
- Good signal handling capability
- Excellent gain stability with temperature and supply voltage variations
- Low distortion

5

schematic and functional diagrams

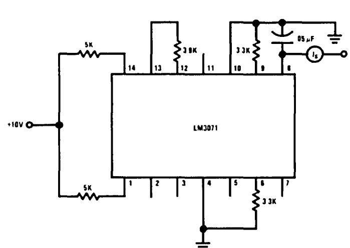




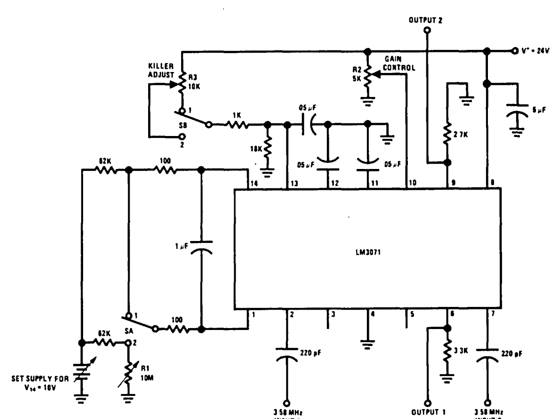
Order Number LM3071N
See Package 22

Order Number LM3071N-01
See Package 24

test circuits



Test Circuit 1



Test Circuit 2

absolute maximum ratings

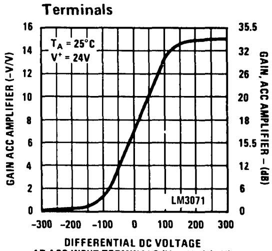
Supply Voltage	$V^+ = 30V$
Internal Power Dissipation at 70°C	550 mW
Above 70°C derate at 7 mW/°C	
Operating Temperature	−40°C to +85°C
Storage Temperature	−65°C to +150°C

electrical characteristics $T_A = 25°C$ $V^+ = 24V$

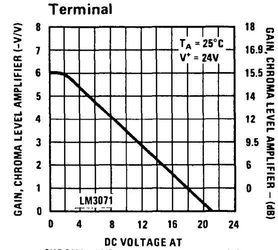
PARAMETER	SYMBOL	CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNIT
STATIC (Refer to Test Circuit 1)						
Supply Current	I_S		17	24	31	mA
Bias Voltage at Pin 12	V_{12}		14	15.3	16.5	V
Voltage at Input 1	V_2			1.7		V
Voltage at Input 2	V_7			1.4		V
Voltage at Output 1	V_6	$V_{ACC} = V_1 - V_{14} = 0V$	15.5	17.5	20	V
Voltage at Output 2	V_9	$V_{10} = 0V$	17.25	18.25	19	V
DYNAMIC (Refer to Test Circuit 2) f = 3.58 MHz						
Gain, ACC Amplifier Stage	A_{V1}	S_A Position 1, $V_1 = V_{14} = 10V$	14	16.5	19	db
Gain Reduction of ACC Amplifier		S_A Position 2, R_1 set for $V_{14} - V_1 = 75$ mV		14		db
Maximum Gain, Chroma Level Amplifier	A_{V2}	S_B Position 1, $V_{10} = 0V$	13	15.5	17	db
90% Chroma Gain Control Reference Voltage	V_{10}	S_B Position 1, R_2 set for 90% of Maximum Gain	2.3	3.5	4.8	V_{DC}
10% Chroma Gain Control Reference Voltage	V_{10}	S_B Position 1, R_2 Set for 10% of Maximum Gain	17	20	21.7	V_{DC}
Maximum Chroma Output Before Distorting	V_9	S_B Position 1, $V_{10} = 0V$		5.5		V_{p-p}
ACC Amplifier Bandwidth	BW_1	S_A Position 1		12		MHz
Level Amplifier Bandwidth	BW_2			30		MHz
Killer on Threshold	V_{13}	S_B Position 2, Adjust R_3 to Kill Output		16.5		V_{DC}
Gain Variation with V^+, Level Amplifier Stage	ΔA_{V2}	R_2 set for 10% of maximum Gain $V^+ = 24 \pm 3V$		0.3		db
Gain Variation with Temperature, Level Amplifier Stage	ΔA_{V2}	R_2 set for 10% of Maximum Gain $T_A = 25°C$ to $T_A = 70°C$		0.5		db
ACC Amplifier Input Resistance	R_I1			2.0		kΩ
ACC Amplifier Input Capacitance	C_I1			5		pF
Level Amplifier Input Resistance	R_I2			2.2		kΩ
Level Amplifier Input Capacitance	C_I2			4.2		pF

typical performance characteristics

ACC Amplifier Gain as a Function of Differential DC Voltage at ACC Input Terminals



Chroma Level Amplifier Gain as a Function of DC Voltage at Chroma Level Control Terminal



Consumer Circuits

LM3075 FM detector/limiter and audio preamplifier

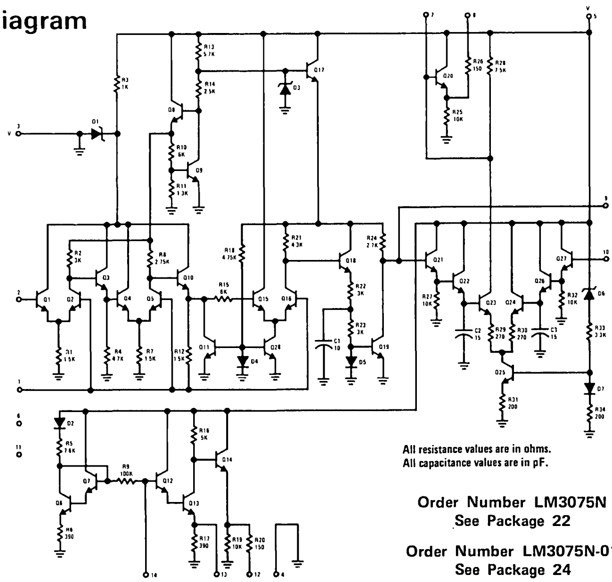
general description

The LM3075 is a monolithic integrated circuit FM detector/limiter and audio preamplifier that requires a minimum of external components for operation. It includes three stages of IF limiting and a differential-peak-detection circuit.

features

- A direct replacement for the CA3075
- Simple detector alignment: one coil
- Sensitivity: 3 dB limiting voltage 250 μV typical at 10.7 MHz
- Low harmonic distortion
- Excellent AM rejection 55 dB typ. at 10.7 MHz
- Internal audio preamplifier

schematic diagram

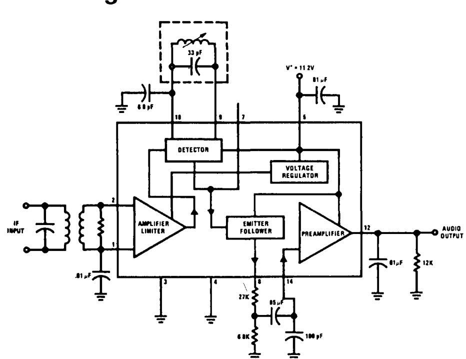


All resistance values are in ohms.
All capacitance values are in pF.

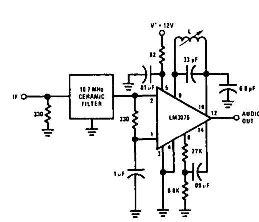
Order Number LM3075N
See Package 22

Order Number LM3075N-01
See Package 24

block diagram



typical application



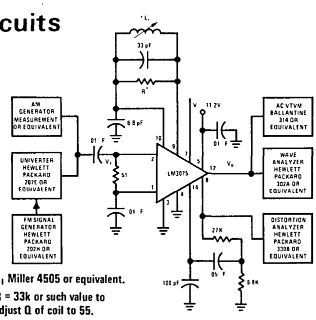
absolute maximum ratings

Power Supply Current (Pin 5)	30 mA
Supply Voltage (Pin 5)	12.5V
Power Dissipation	
T_A = 25°C or Less	850 mW
T_A = 25°C or More	Derate Linearly 6.67 mW/°C
Operating Temperature Range	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics T_A = 25°C

PARAMETER	SYMBOL	TEST CIRCUIT	CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
STATIC CHARACTERISTICS							
Supply Current	I_5		V_{CC} = 8.5V	8.5	15		mA
			V_{CC} = 11.2V		17.5		mA
			V_{CC} = 12.5V		19	29	mA
Detector Output Level (High)	V_7				6.1		V
Detector Output Level (Low)	V_8		V_{CC} = 11.2V		5.4		V
Audio Amplifier Output Level	V_{12}				5.2		V
DYNAMIC CHARACTERISTICS AT V^+ = 11.2V, f_0 = 10.7 MHz, Δf = ±75 kHz, fm = 400 Hz							
Input Limiting Threshold	$V_{IN(LIM)}$	1			250	600	μV
AM Rejection	AMR	1	AM: 1 kHz @ 30%, V_{IN} = 100 mV		55		dB
Recovered AF Voltage (At Terminal 12)	V_0 (AF)	1			1.5		V
Total Harmonic Distortion	T_{HD}	1			1	2	%
Audio Preamplifier							
Voltage Gain	$A_{V(af)}$	2	V_{IN} = 100 mV, f = 400 Hz		21		dB
Total Harmonic Distortion	T_{HD}	2	V_{OUT} = 2V, f = 400 Hz		1.5	5	%

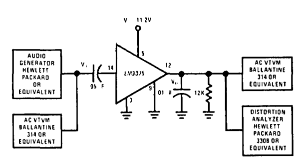
test circuits



*L_1 Miller 4505 or equivalent.

**R = 33k or such value to adjust Q of coil to 55.

TEST CIRCUIT 1



TEST CIRCUIT 2

Transistor/Diode Arrays

LM114/LM114A, LM115/LM115A matched dual monolithic transistors

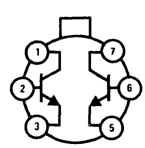
general description

These devices contain a pair of junction-isolated NPN transistors fabricated on a single silicon substrate. This monolithic structure makes possible extremely-tight parameter matching at low cost. Further, advanced processing techniques yield exceptionally high current gains at low collector currents, virtual elimination of "popcorn noise," low leakages and improved long-term stability. Some of the major features of these pairs are indicated by the following specifications:

- Low offset voltage—0.5 mV maximum
- Low drift—2 μV/°C maximum from −55°C to 125°C
- High current gain—500 minimum at 10 μA
- Tight beta match—10% maximum
- High breakdown voltage—to 60V
- Matching guaranteed over a 0V to 45V collector-base voltage range.

Although designed primarily for high breakdown voltage and exceptional dc characteristics, these transistors have surprisingly good high-frequency performance. The gain-bandwidth product is 450 MHz with 1 mA collector current and 5V collector-base voltage and 22 MHz with 10 μA collector current. Collector-base capacitance is only 1.3 pF at 5V.

connection diagram



TOP VIEW

Order Number LM114H or LM114AH
LM115H or LM115AH
See Package 10

absolute maximum ratings

	LM114 LM114A	LM115 LM115A
Collector-Base Voltage (BV_{CBO})	45V	60V
Collector-Emitter Voltage (BV_{CER})	45V	60V
Collector-Collector Voltage	45V	60V
Emitter-Emitter Voltage	45V	60V
Emitter-Base Voltage (BV_{EBO})	6V	
Collector Current	20 mA	
Total Power Dissipation (Note 1)	1.8W	
Operating Junction Temperature	−55°C to 150°C	
Storage Temperature	−65°C to 150°C	
Lead Temperature (soldering, 10 sec)	300°C	

Note 1: The maximum dissipation given is for a 25°C case temperature. For operation under other conditions, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 70°C/W junction to case or 230°C/W junction to ambient.

6

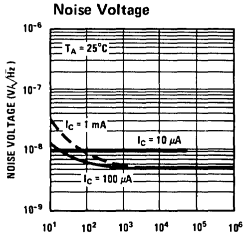
electrical characteristics (Note 2)

PARAMETER	CONDITIONS	MAXIMUM LIMITS				UNITS
		LM114	LM114A	LM115	LM115A	
Offset Voltage	$1\ \mu A \leq I_C \leq 100\ \mu A$	2.0	0.5	2.0	0.5	mV
Offset Current	$I_C = 10\ \mu A$ $I_C = 1\ \mu A$	10	2.0 0.5	10	2.0 0.5	nA nA
Bias Current	$I_C = 10\ \mu A$ $I_C = 1\ \mu A$	40	20 3.0	40	40 6.0	nA nA
Offset Voltage Change	$0V \leq V_{CB} \leq V_{max}$ $I_C = 10\ \mu A$	1.5	0.2	2.0	0.3	mV
Offset Current Change	$0V \leq V_{CB} \leq V_{max}$ $I_C = 10\ \mu A$	4.0	1.0	4.0	1.0	nA
Offset Voltage Drift	$-55^{\circ}C \leq T_A \leq 125^{\circ}C$ $I_C = 10\ \mu A$	10	2.0	10	2.0	$\mu V/^{\circ}C$
Offset Current	$-55^{\circ}C \leq T_A \leq 125^{\circ}C$ $I_C = 10\ \mu A$	50	12	50	20	nA
Bias Current	$-55^{\circ}C \leq T_A \leq 125^{\circ}C$ $I_C = 10\ \mu A$	150	60	150	150	nA
Collector-Base Leakage Current	$V_{CB} = V_{max}$ $T_A = 25^{\circ}C$ $T_A = 125^{\circ}C$	50 50	10 10	50 50	10 10	pA nA
Collector-Emitter Leakage Current	$V_{CE} = V_{max}, V_{EB} = 0$ $T_A = 25^{\circ}C$ $T_A = 125^{\circ}C$	200 200	50 50	200 200	50 50	pA nA
Collector-Collector Leakage Current	$V_{CC} = V_{max}$ $T_A = 25^{\circ}C$ $T_A = 125^{\circ}C$	300 300	100 100	300 300	100 100	pA nA

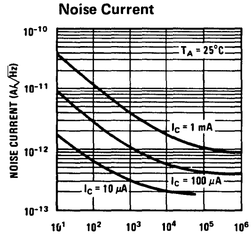
Note 2: These specifications apply for $T_A = 25^{\circ}C$ and $0V \leq V_{CB} \leq V_{max}$, unless otherwise specified. For the LM114 and LM114A, $V_{max} = 30V$. For the LM115 and LM115A, $V_{max} = 45V$.

typical performance characteristics

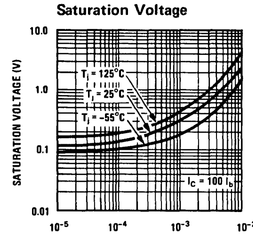
Noise Voltage



Noise Current



Saturation Voltage



Transistor/Diode Arrays

LM194/LM394 supermatch pair

general description

The LM194 and LM394 are junction isolated ultra well-matched monolithic NPN transistor pairs with an order of magnitude improvement in matching over conventional transistor pairs. This was accomplished by advanced linear processing and a unique new device structure.

Electrical characteristics of these devices such as drift versus initial offset voltage, noise, and the exponential relationship of base-emitter voltage to collector current closely approach those of a theoretical transistor. Extrinsic emitter and base resistances are much lower than presently available pairs, either monolithic or discrete, giving extremely low noise and theoretical operation over a wide current range. Most parameters are guaranteed over a current range of 1μA to 1 mA and 0 to 40V collector-base voltage, ensuring superior performance in nearly all applications.

To guarantee long term stability of matching parameters, internal clamp diodes have been added across the emitter-base junction of each transistor. These prevent degradation due to reverse biased emitter current—the most common cause of field failures in matched devices. The parasitic isolation junction formed by the diodes also clamps the substrate region to the most negative emitter to ensure complete isolation between devices.

The LM194 and LM394 will provide a considerable improvement in performance in most applications requiring a closely matched transistor pair. In many cases, trimming can be eliminated entirely, improving reliability and decreasing costs. Additionally, the low noise and high gain make this device attractive even where matching is not critical.

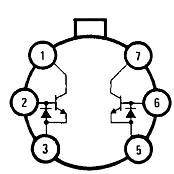
The LM194 and LM394 are available in an isolated header 6-lead TO-5. The LM194 is identical to the LM394 except for tighter electrical specifications and wider temperature range.

features

- Emitter-base voltage matched to 50μV
- Offset voltage drift less than 0.1μV/°C
- Current gain (h_{FE}) matched to 2%
- Common-mode rejection ratio greater than 120 dB
- Parameters guaranteed over 1μA to 1 mA collector current
- Extremely low noise
- Superior logging characteristics compared to conventional pairs
- Plug-in replacement for presently available devices

connection diagram

Metal Can Package



TOP VIEW

Order Number LM194H or LM394H

See Package 11

absolute maximum ratings

Collector Current	20 mA
Collector-Emitter Voltage	40V
Collector-Base Voltage	40V
Collector-Substrate Voltage	40V
Collector-Collector Voltage	40V
Base-Emitter Current	±10 mA
Power Dissipation	500 mW
Junction Temperature	
LM194	−55°C to +135°C
LM394	−25°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (T_J = 25°C)

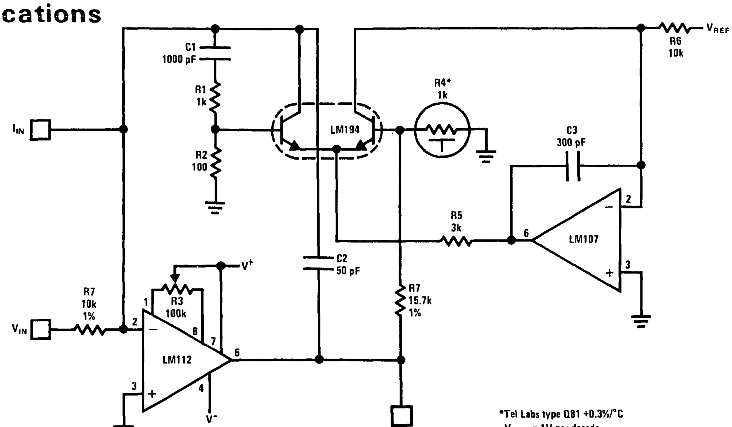
PARAMETER	CONDITIONS	LM194			LM394			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Current Gain (h_{FE}) (Note 1)	V_{CB} = 0V to 40V							
	I_C = 1 mA	500	700		300	700		
	I_C = 100μA	400	550		250	550		
	I_C = 10μA	300	450		200	450		
	I_C = 1μA	200	300		150	300		
Current Gain Match (h_{FE} Match)	V_{CB} = 0V to 40V							
	I_C = 10μA to 1 mA		0.5	2		0.5	4	%
	I_C = 1μA		1.0			1.0		%
Emitter-Base Offset Voltage	V_{CB} = 0 I_C = 1μA to 1 mA		25	50		25	150	μV
Change in Emitter-Base Offset Voltage vs Collector-Base Voltage (CMRR)	(Note 1) I_C = 1μA to 1 mA, V_{CB} = 0V to 40V		10	25		10	50	μV
Change in Emitter-Base Offset Voltage vs Collector Current	V_{CB} = 0V, I_C = 1μA to 0.3 mA		5	25		5	50	μV
Emitter-Base Offset Voltage Temperature Drift (Note 2)	I_C = 10μA to 1 mA							
	$I_{C1} = I_{C2}$		0.08	0.3		0.08	0.8	μV/°C
	V_{OS} Trimmed to 0 at 25°C		0.03	0.1		0.03	0.3	μV/°C
Logging Conformity (Note 3)	I_C = 3 nA to 300μA, V_{CB} = 0		150			150		μV
Collector-Base Leakage	V_{CB} = 40V		50			50		pA
Collector-Collector Leakage	V_{CC} = 40V		70			70		pA
Input Voltage Noise	I_C = 100μA, V_{CB} = 0V, f = 100 Hz to 100 kHz		1.8			1.8		nV/√Hz
Collector to Emitter Saturation Voltage	I_C = 1 mA, I_B = 10μA		0.2			0.2		V
	I_C = 1 mA, I_B = 100μA		0.1			0.1		V

Note 1: Collector base voltage is swept from 0 to 40V at a collector current of 1μA, 10μA, 100μA, and 1 mA.

Note 2: Offset voltage drift with V_{OS} = 0 at T_A = 25°C is valid only when the ratio of I_{C1} to I_{C2} is adjusted to give the initial zero offset. This ratio must be held to within 0.003% over the entire temperature range. Measurements taken at +25°C and temperature extremes.

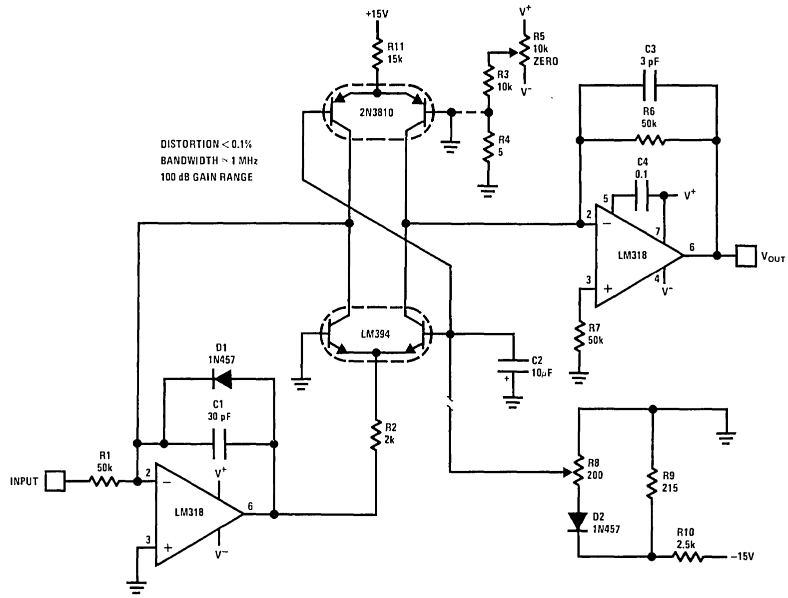
Note 3: Logging conformity is measured by computing the best fit to a true exponential and expressing the error as a base-emitter voltage deviation.

typical applications

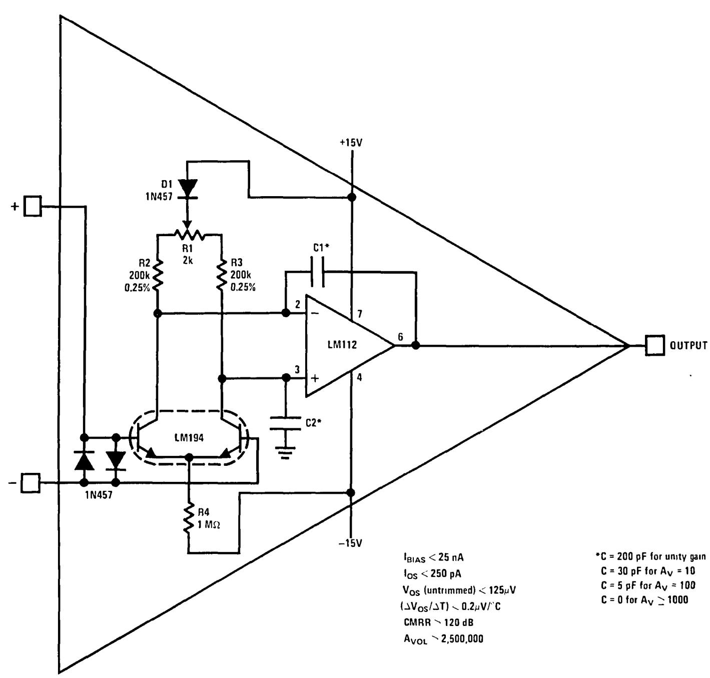


Fast, Accurate Logging Amplifier, V_{IN} = 10V to 0.1 mV or I_{IN} = 1 mA to 10 nA

typical applications (con't)

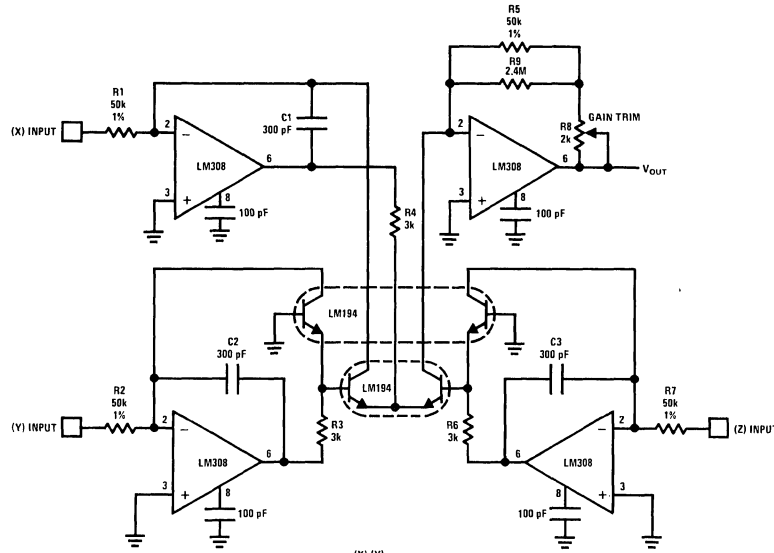


Voltage Controlled Variable Gain Amplifier



Precision Low Drift Operational Amplifier

typical applications (con't)



*Typical linearity 0.1%.

$V_{OUT} = \frac{(X)\,(Y)}{(Z)}$; positive inputs only.

High Accuracy One Quadrant Multiplier/Divider

Transistor/Diode Arrays

LM195/LM295/LM395 power transistors

general description

The LM195/LM295/LM395 are fast, monolithic power transistors with complete overload protection. These devices, which act as high gain power transistors, have included on the chip, current limiting, power limiting, and thermal overload protection making them virtually impossible to destroy from any type of overload. In the standard TO-3 transistor power package, the LM195 will deliver load currents in excess of 1.0A and can switch 40V in 500 ns.

The inclusion of thermal limiting, a feature not easily available in discrete designs, provides virtually absolute protection against overload. Excessive power dissipation or inadequate heat sinking causes the thermal limiting circuitry to turn off the device preventing excessive heating.

The LM195 offers a significant increase in reliability as well as simplifying power circuitry. In some applications, where protection is unusually difficult, such as switching regulators, lamp or solenoid drivers where normal power dissipation is low, the LM195 is especially advantageous.

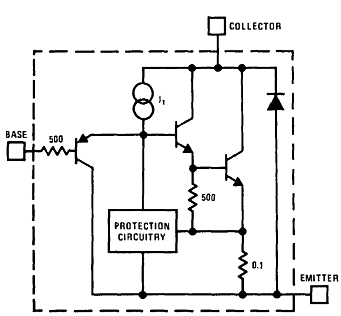
The LM195 is easy to use and only a few precautions need be observed. Excessive collector to emitter voltage can destroy the LM195 as with any power transistor. When the device is used as an emitter follower with low source impedance, it is necessary to insert a 5.0k resistor in series with the base lead to prevent possible emitter follower oscillations. Although the device is usually stable as an emitter follower, the resistor eliminates the possibility of trouble without degrading performance. Finally, since it has good high frequency response, supply by passing is recommended.

The LM195/LM295/LM395 are available in standard TO-3 power packages and solid Kovar TO-5. The LM195 is rated for operation from −55°C to +150°C, the LM295 from −25°C to +150°C and the LM395 from 0°C to +125°C.

features

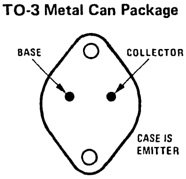
- Internal thermal limiting
- Greater than 1.0A output current
- 3.0μA typical base current
- 500 ns switching time
- 2.0V saturation
- Base can be driven up to 40V without damage
- Directly interfaces with CMOS or TTL

simplified circuit and connection diagrams



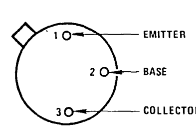
Simplified Circuit of the LM195

TO-3 Metal Can Package



Order Number LM195K, LM295K or LM395K
See Package 18

TO-5 Metal Can Package



Order Number LM195H, LM295H or LM395H
See Package 9

absolute maximum ratings

Collector to Emitter Voltage	
LM195, LM295	42V
LM395	36V
Collector to Base Voltage	
LM195, LM295	42V
LM395	36V
Base to Emitter Voltage (Forward)	
LM195, LM295	42V
LM395	36V
Base to Emitter Voltage (Reverse)	20V
Collector Current	Internally Limited
Power Dissipation	Internally Limited
Operating Temperature Range	
LM195	−55°C to +150°C
LM295	−25°C to +150°C
LM395	0°C to +125°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 1)

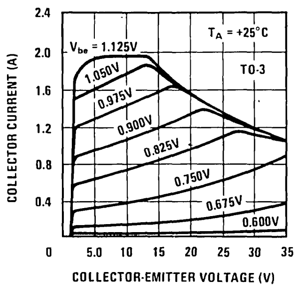
PARAMETER	CONDITIONS	LM195, LM295			LM395			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Collector-Emitter Operating Voltage	$I_Q \le I_C \le I_{MAX}$			42			36	V
Base to Emitter Breakdown Voltage	$0 \le V_{CE} \le V_{CEMAX}$	42			36	60		V
Collector Current								
TO-3	$V_{CE} \le 15V$	1.2	2.0		1.0	2.0		A
TO-5	$V_{CE} \le 7.0V$	1.2	2.0		1.0	2.0		A
Saturation Voltage	$I_C \le 1.0A$		1.8	2.0		1.8	2.2	V
Base Current	$0 \le I_C \le I_{MAX}$ $0 \le V_{CE} \le V_{CEMAX}$		3.0	5.0		3.0	10	μA
Quiescent Current	$V_{be} = 0$ $0 \le V_{CE} \le V_{CEMAX}$		2.0	5.0		2.0	10	mA
Base to Emitter Voltage	$I_C = 1.0A, T_A = +25°C$		0.9			0.9		V
Switching Time	$V_{CE} = 36V, R_L = 36\Omega$, $T_A = +25°C$		500			500		ns
Thermal Resistance Junction to Case (Note 2)	TO-3 Package TO-5 Package		2.3 12	3.0 15		2.3 12	3.0 15	°C/W °C/W

Note 1: Unless otherwise specified, these specifications apply for $-55°C \le T_j \le +150°C$ for the LM195, $-25°C \le T_j \le +150°C$ for the LM295 and $0°C \le +125°C$ for the LM395.

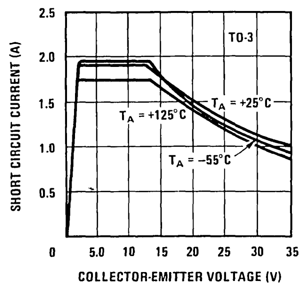
Note 2: Without a heat sink, the thermal resistance of the TO-5 package is about +150°C/W, while that of the TO-3 package is +35°C/W.

typical performance characteristics

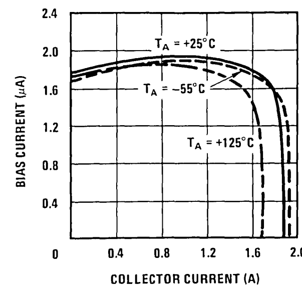
Collector Characteristics



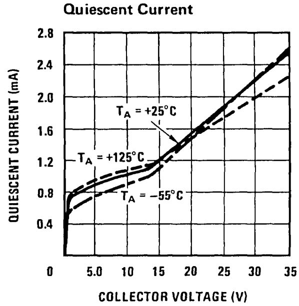
Short Circuit Current



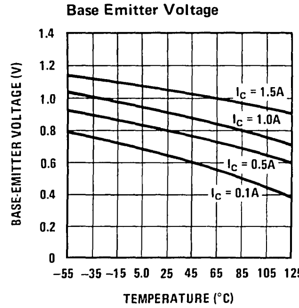
Bias Current



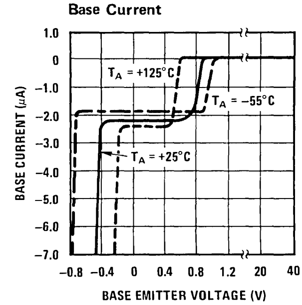
Quiescent Current



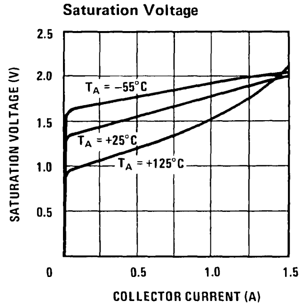
Base Emitter Voltage



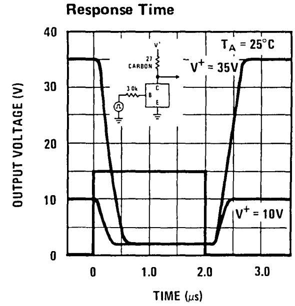
Base Current



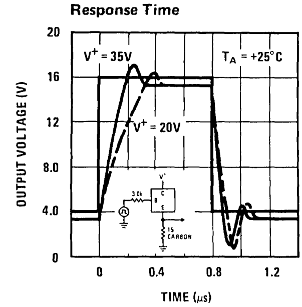
Saturation Voltage



Response Time

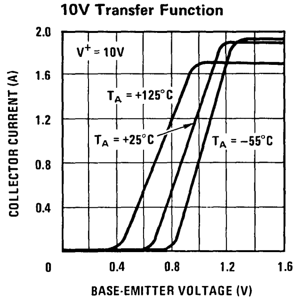


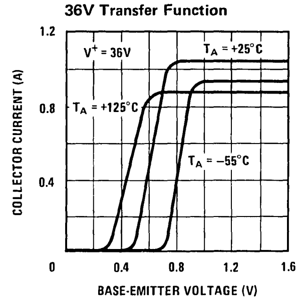
Response Time

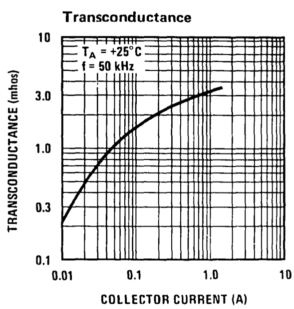


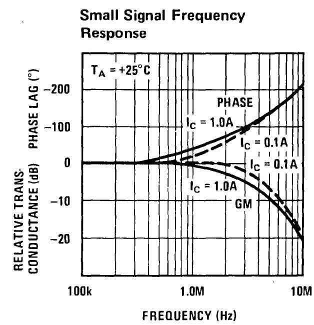
6

typical performance characteristics (con't)

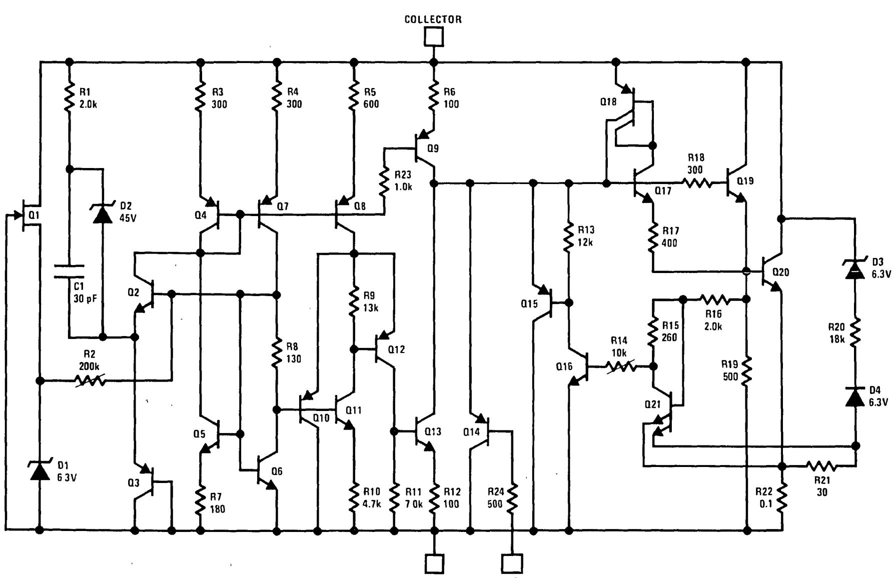




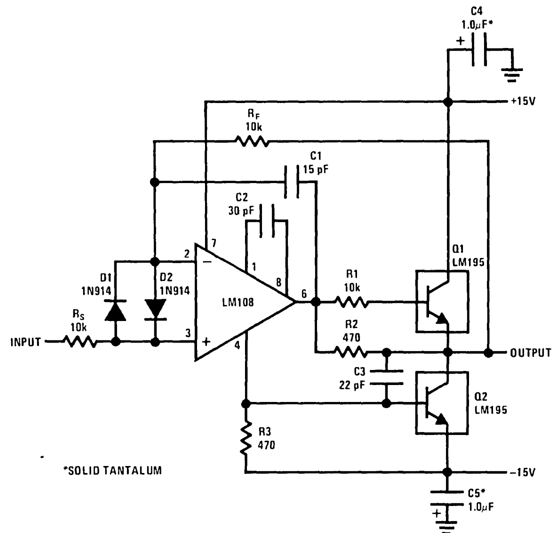




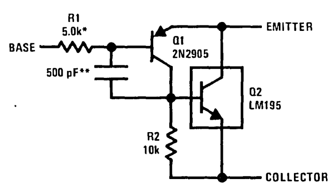
schematic diagram



typical applications

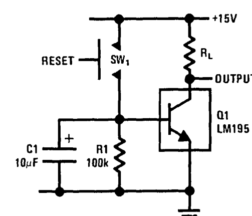


1.0 Amp Voltage Follower

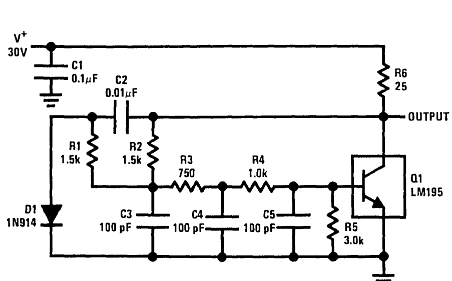


*PROTECTS AGAINST EXCESSIVE BASE DRIVE
**NEEDED FOR STABILITY

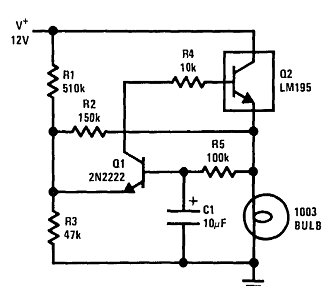
Power PNP



Time Delay



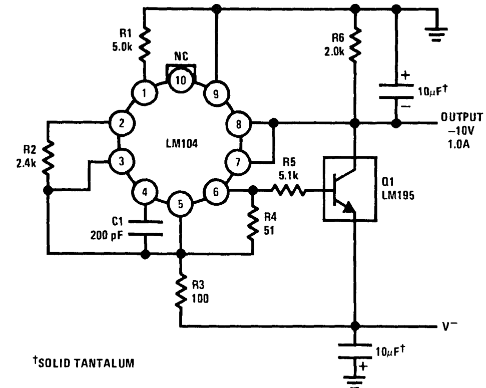
1.0 MHz Oscillator



1.0 Amp Lamp Flasher

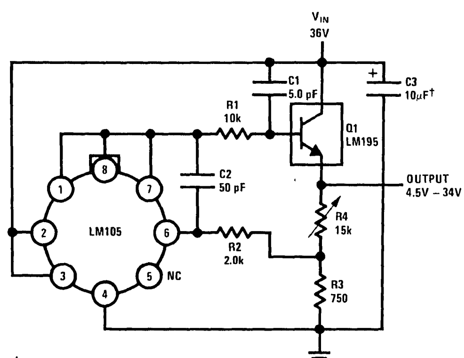
6

typical applications (con't)



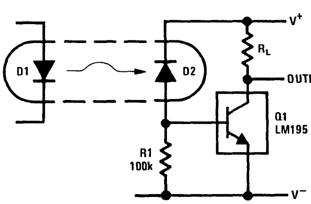
†SOLID TANTALUM

1.0 Amp Negative Regulator

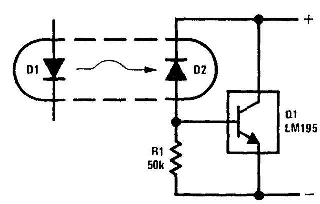


†SOLID TANTALUM

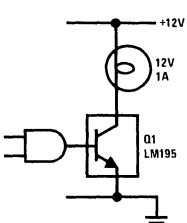
1.0 Amp Positive Voltage Regulator



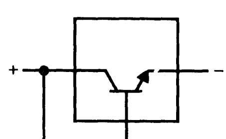
Fast Optically Isolated Switch



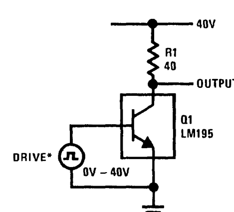
Optically Isolated Power Transistor



CMOS or TTL Lamp Interface



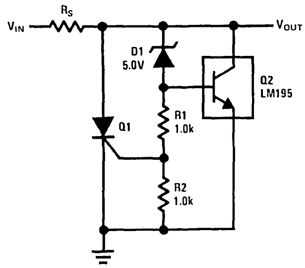
Two Terminal Current Limiter



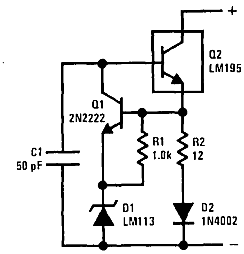
*DRIVE VOLTAGE 0V TO ≥ 1.0V ≤ 42V

40V Switch

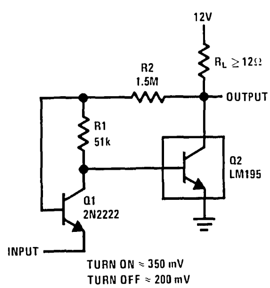
typical applications (con't)



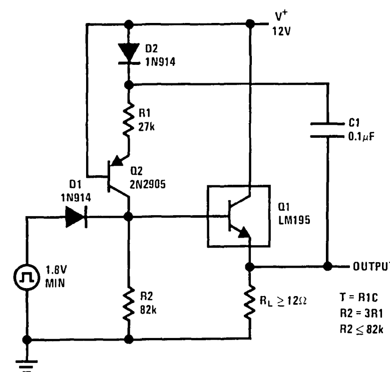
6.0V Shunt Regulator with Crowbar



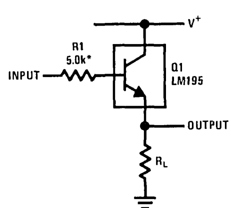
Two Terminal 100 mA Current Regulator



Low Level Power Switch

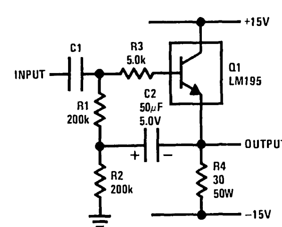


Power One-Shot

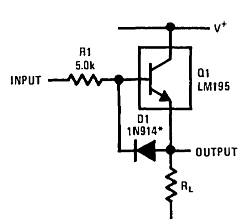


*NEED FOR STABILITY

Emitter Follower



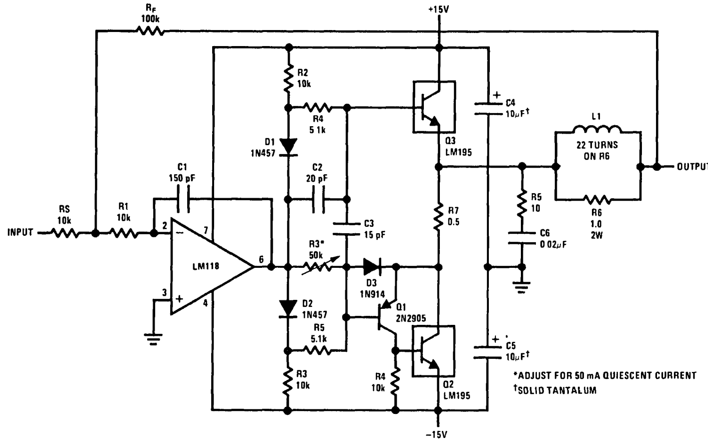
High Input Impedance AC Emitter Follower



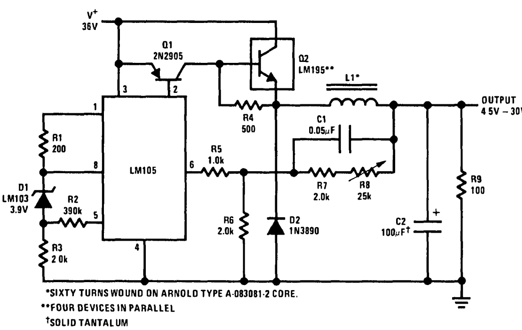
*PREVENTS STORAGE WITH FAST FALL TIME SQUARE WAVE DRIVE

Fast Follower

typical applications (con't)



Power Op Amp



6.0 Amp Variable Output Switching Regulator

Transistor/Diode Arrays

LM3018/LM3018A matched monolithic transistor arrays

general description

The LM3018 and LM3018A consist of four general purpose silicon NPN transistors on a common monolithic substrate. Two of the four transistors are connected in the Darlington configuration. The substrate is connected to a separate terminal for maximum flexibility. The transistors are well suited to a wide variety of applications in low-power systems in the DC through VHF range. They may be used as discrete transistors in conventional circuits but in addition they provide the advantages of close electrical and thermal matching inherent in integrated circuit construction.

features

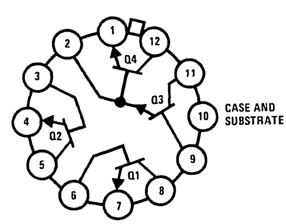
- Matched monolithic general purpose transistors
- H_{FE} matched ±10%
- V_{BE} matched
  - LM3018 ±5 mV
  - LM3018A ±2 mV
- Operation from DC to 120 MHz
- Wide operating current range
- LM3018A performance controlled from 10μA to 10 mA
- Low noise figure 3.2 dB typical at 1 kHz
- Full military temperature range capability −55°C to +125°C

applications

- General use in signal processing systems in DC through VHF range
- Custom designed differential amplifiers
- Temperature compensated amplifiers

schematic and connection diagram

Metal Can Package



TOP VIEW

Order Number LM3018H or LM3018AH
See Package 7

absolute maximum ratings

	LM3018	LM3018A
Power Dissipation (Note 1)		
Any One Transistor	300	300 mW
Total Package	450	450 mW
Operating Temperature Range		−55°C to +125°C
Storage Temperature Range		−65°C to +150°C
Lead Temperature (Soldering, 10 sec)		300°C

The following ratings apply for each transistor in the device:

	LM3018	LM3018A
Collector to Emitter Voltage, V_{CEO}	15	15V
Collector to Base Voltage, V_{CBO}	20	30V
Collector to Substrate Voltage, V_{CIO} (Note 2)	20	40V
Emitter to Base Voltage, V_{EBO}	5	5V
Collector Current, I_C	50	50 mA

dc electrical characteristics $T_A = 25°C$

PARAMETER	CONDITIONS	LIMITS LM3018 MIN	LM3018 TYP	LM3018 MAX	LM3018A MIN	LM3018A TYP	LM3018A MAX	UNITS
STATIC CHARACTERISTICS								
Collector Cutoff Current (I_{CBO})	$V_{CB} = 10V, I_E = 0$		002	100		002	40	nA
Collector Cutoff Current (I_{CEO})	$V_{CE} = 10V, I_B = 0$			5			5	μA
Collector Cutoff Current Darlington Pair (I_{CEOD})	$V_{CE} = 10V, I_B = 0$						5	μA
Collector to Emitter Breakdown Voltage ($V_{(BR)CEO}$)	$I_C = 1$ mA, $I_B = 0$	15	24		15	24		V
Collector to Base Breakdown Voltage ($V_{(BR)CBO}$)	$I_C = 10 μA, I_E = 0$	20	60		30	60		V
Emitter to Base Breakdown Voltage ($V_{(BR)EBO}$)	$I_E = 10 μA, I_C = 0$	5	7		5	7		V
Collector to Substrate Breakdown Voltage ($V_{(BR)CIO}$)	$I_C = 10 μA, I_{CI} = 0$	20	60		40	60		V
Collector to Emitter Saturation Voltage (V_{CES})	I_B 1 mA, I_C 10 mA		23			.23	5	V
Static Forward Current Transfer Ratio (h_{FE})	$V_{CE} = 3V$, $I_C = 10$ mA $I_C = 1$ mA $I_C = 10 μA$	30	100 100 54		50 60 30	100 100 54		
Magnitude of Static Beta Ratio (Isolated Transistors Q_1 and Q_2)	V_{CE} 3V, $I_{C1} = I_{C2} = 1$ mA	.9	.97		9	97		
Static Forward Current Transfer Ratio Darlington Pair (Q_3 and Q_4) (h_{FED})	$V_{CE} = 3V$, $I_C = 1$ mA $I_C = 100 μA$	1500	5400		2000 1000	5400 2800		
Base to Emitter Voltage (V_{BE})	$V_{CE} = 3V$, $I_E = 1$ mA $I_E = 10$ mA		.715 .800		600	.715 800	800 .900	V
Input Offset Voltage $\left(\left\lvert V_{BE_1} - V_{BE_2} \right\rvert\right)$	$V_{CE} = 3V, I_E = 1$ mA		48	5		48	2	mV
Temperature Coefficient: Base to Emitter Voltage Q_1, Q_2 $\left(\frac{\lvert\Delta V_{BE}\rvert}{\Delta T}\right)$	$V_{CE} = 3V, I_E = 1$ mA		−1 9			−1 9		mV/ C
Base (Q_3) to Emitter (Q_4) Voltage Darlington Pair (V_{BED} ($V_{9\,1}$))	$V_{CE} = 3V$, $I_E = 10$ mA $I_E = 1$ mA		1 46 1 32		1 10	1 46 1.32	1 60 1 50	V
Temperature Coefficient Base to Emitter Voltage Darlington Pair Q_3, Q_4 $\left(\frac{\lvert\Delta V_{BED}\rvert}{\Delta T}\right)$	$V_{CE} = 3V, I_E = 1$ mA		4 4			4 4		mV/°C
Temperature Coefficient Magnitude of Input Offset Voltage $\left(\frac{\lvert V_{BE_1} - V_{BE_2}\rvert}{\Delta T}\right)$	$V_{CC} = +6, V_{EE} = -6V$ $I_{C_1} = I_{C_2} = 1$ mA		10			.10		μV/°C

ac electrical characteristics $T_A = 25°C$

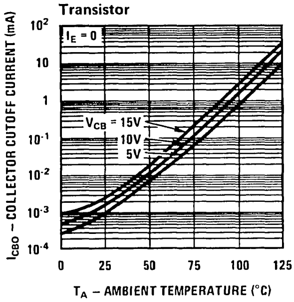
PARAMETER	CONDITIONS	LM3018 MIN	LM3018 TYP	LM3018 MAX	LM3018A MIN	LM3018A TYP	LM3018A MAX	UNITS
DYNAMIC CHARACTERISTICS								
Low Frequency Noise Figure (NF)	f = 1 kHz, $V_{CE} = 3V$, $I_C = 100 μA$, Source Resistance = 1 kΩ		3.25			3.25		dB
Low Frequency, Small-Signal Equivalent Circuit Characteristics:								
Forward Current Transfer Ratio (h_{fe})	f = 1 kHz, $V_{CE} = 3V$, $I_C = 1$ mA		110			110		
Short Circuit Input Impedance (h_{ie})			3.5			3 5		kΩ
Open Circuit Output Impedance (h_{oe})			15.6			15.6		μmho
Open Circuit Reverse Voltage Transfer Ratio (h_{re})			1.8×10^{-4}			1.8×10^{-4}		
Admittance Characteristics:								
Forward Transfer Admittance (Y_{fe})	f = 1 MHz, $V_{CE} = 3V$, $I_C = 1$ mA		31 −j1.5			31 −j1.5		mmho
Input Admittance (Y_{ie})			.3 +j0.04			.3 +j0 04		mmho
Output Admittance (Y_{oe})			.001 +j0.03			.001 +j0 03		mmho
Reverse Transfer Admittance (Y_{re})			See Curve			See Curve		mmho
Gain Bandwidth Product (f_T)	$V_{CE} = 3V, I_C = 3$ mA	300	500		300	500		MHz
Emitter to Base Capacitance (C_{EB})	$V_{EB} = 3V, I_E = 0$		.6			6		pF
Collector to Base Capacitance (C_{CB})	$V_{CB} = 3V, I_C = 0$		.58			.58		pF
Collector to Substrate Capacitance (C_{CI})	$V_{CI} = 3V, I_C = 0$		2.8			2.8		pF

Note 1: Derate at 5 mW/°C for $T_A > 85°C$

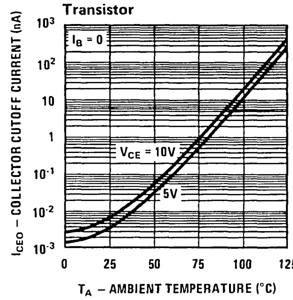
Note 2: The collector of each transistor of the LM3018 and LM3018A is isolated from the substrate by an integral diode. The substrate (terminal 10) must be connected to the most negative point in the external circuit to maintain isolation between transistors and to provide for normal transistor action.

typical performance characteristics

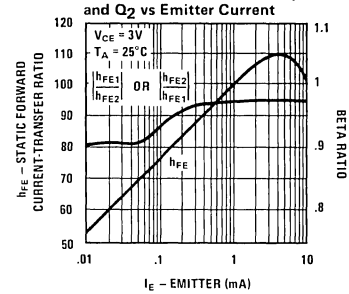
Typical Collector-To-Base Cutoff Current vs Ambient Temperature for Each Transistor



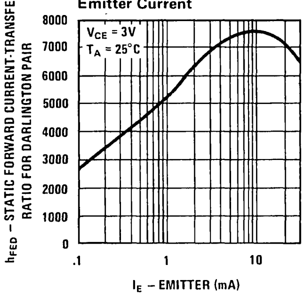
Typical Collector-To-Emitter Cutoff Current vs Ambient Temperature for Each Transistor



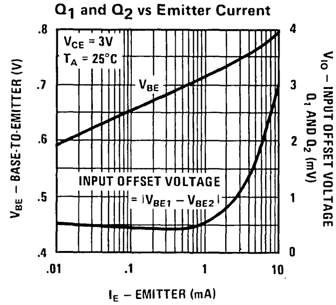
Typical Static Forward Current-Transfer Ratio and Beta Ratio for Transistors Q_1 and Q_2 vs Emitter Current



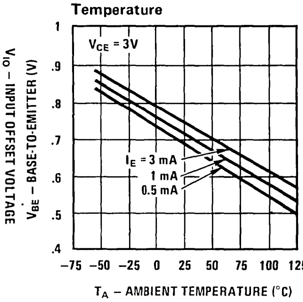
Typical Static Forward Current-Transfer Ratio for Darlington-connected Transistors Q_3 and Q_4 vs Emitter Current



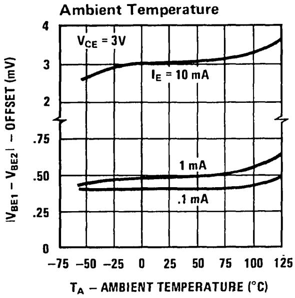
Typical Static Base-To-Emitter Voltage Characteristic and Input Offset Voltage for Q_1 and Q_2 vs Emitter Current



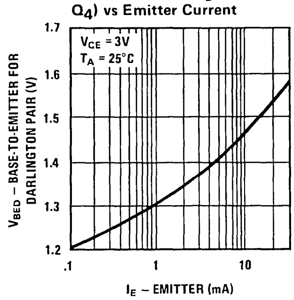
Typical Base-To-Emitter Voltage Characteristic for Each Transistor vs Ambient Temperature



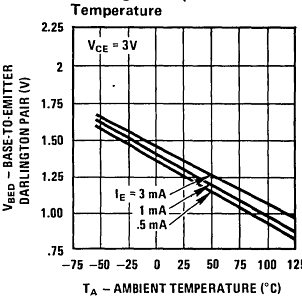
Typical Offset Voltage Characteristic vs Ambient Temperature



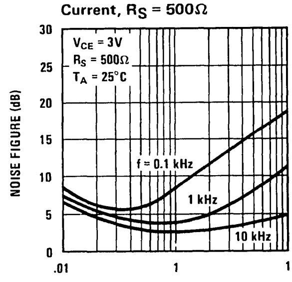
Typical Static Input Voltage Characteristic for Darlington Pair (Q_3 and Q_4) vs Emitter Current



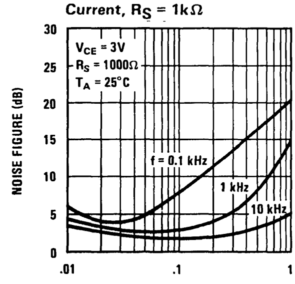
Typical Static Input Voltage Characteristic for Darlington Pair (Q_3 and Q_4) vs Ambient Temperature



Noise Figure vs Collector Current, R_S = 500Ω

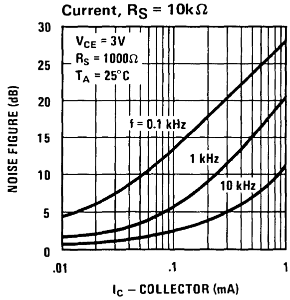


Noise Figure vs Collector Current, R_S = 1kΩ

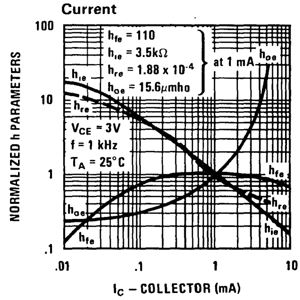


typical performance characteristics (con't)

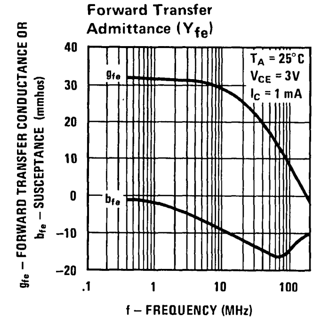
Noise Figure vs Collector Current, R_S = 10kΩ



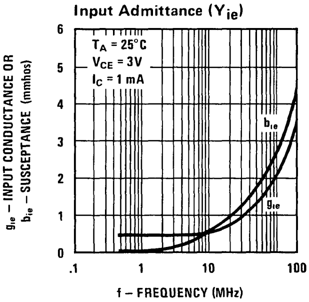
Forward Current-Transfer Ratio (h_{fe}), Short-Circuit Input Impedance (h_{ie}), Open-Circuit Output Impedance (h_{oe}), and Open-Circuit Reverse Voltage-Transfer Ratio (h_{re}) vs Collector Current



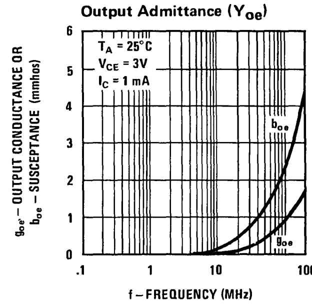
Forward Transfer Admittance (Y_{fe})



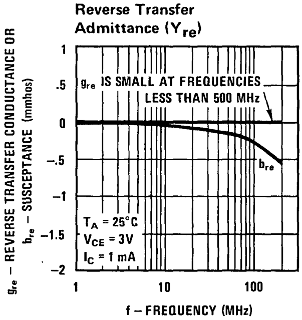
Input Admittance (Y_{ie})



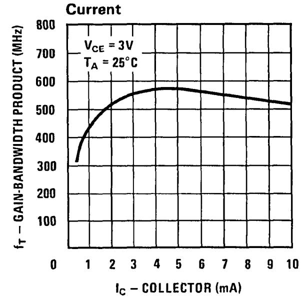
Output Admittance (Y_{oe})



Reverse Transfer Admittance (Y_{re})



Typical Gain-Bandwidth Product (f_T) vs Collector Current



Transistor/Diode Arrays

LM3019 diode array

general description

The LM3019 consists of one silicon diode "quad" and two isolated silicon diodes on a common monolithic substrate.

- 10-pin TO-5 package
- Hermetically sealed

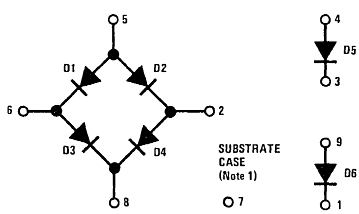
features

- Excellent diode match
- Low leakage current
- Low pedestal voltage when gating
- Built-in temperature stability for operation from −55°C to +125°C

applications

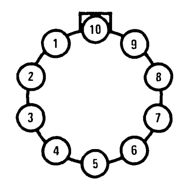
- Modulator
- Mixer
- Balanced modulator
- Analog switch
- Diode gate for chopper-modulator applications

schematic and connection diagrams



NOTE 1: CONNECT TO MOST NEGATIVE CIRCUIT POTENTIAL.

Metal Can Package



Order Number LM3019H
See Package 13

absolute maximum voltage limits $T_A = 25°C$

TERMINAL	VOLTAGE LIMITS		CONDITIONS	
	NEGATIVE	POSITIVE	TERMINAL	VOLTAGE
1	-3	+12	7	-6
2	-3	+12	7	-6
3	-3	+12	7	-6
4	-3	+12	7	-6
5	-3	+12	7	-6
6	-3	+12	7	-6
7	-18	0	1, 2, 3, 6, 8	0
8	-3	+12	7	-6
9	-3	+12	7	-6
10	NO CONNECTION			
CASE	INTERNALLY CONNECTED TO TERMINAL 7 DO NOT GROUND			

absolute maximum ratings

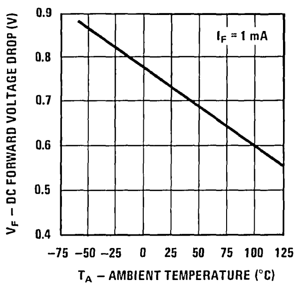
Power Dissipation	
Any One Diode Unit	20 mW
Total For Device	120 mW
Storage Temperature Range	−65°C to +200°C
Operating Temperature Range	−55°C to +125°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics for each diode unit, unless otherwise specified, $T_A = 25°C$.

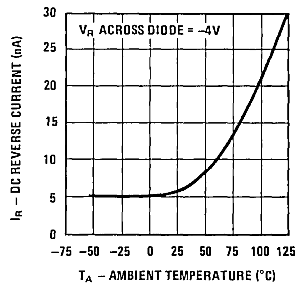
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
DC Forward Voltage Drop (V_F)	DC Forward Current I_F = 1 mA		.73	.78	V
DC Reverse Breakdown Voltage ($V_{(BR)R}$)	DC Reverse Current I_R = −10μA	4	6		V
DC Reverse Breakdown Voltage Between Any Diode Unit and Substrate ($V_{(BR)R}$)	DC Reverse Current I_R = −10μA	25	80		V
DC Reverse (Leakage) Current (I_R)	DC Reverse Voltage V_R = −4V		.0055	10	μA
DC Reverse (Leakage) Current Between Any Diode Unit and Substrate (I_R)	DC Reverse Voltage V_R = −4V		.010	10	μA
Magnitude of Diode Offset Voltage (Difference in DC Forward Voltage Drops of Any Two Diode Units) ($\lvert V_{F_1} - V_{F_2} \rvert$)	DC Forward Current I_F = 1 mA		1	5	mV
Single Diode Capacitance	Frequency f = 1 MHz DC Reverse Voltage V_R = −2V		1.8		pF
Diode Quad-to-Substrate Capacitance (C_{DQ-1})	Frequency f = 1 MHz DC Reverse Voltage V_R Between Terminal 2, 5, 6 or 8 of Diode Quad and Terminal 7 Substrate = −2V				
	Terminal 2 or 6 to Terminal 7		4.4		pF
	Terminal 5 or 8 to Terminal 7		2.7		pF
Series Gate Switching Pedestal Voltage (V_S)			10		mV

typical performance characteristics

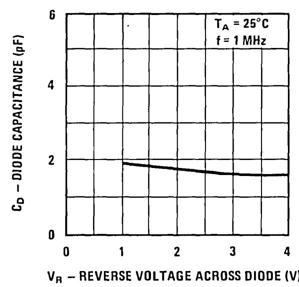
DC Forward Voltage Drop (Any Diode) vs Temperature



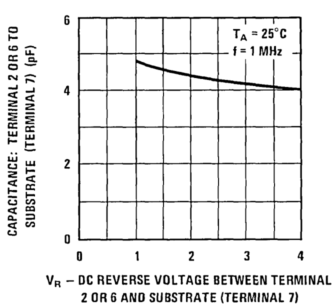
Reverse (Leakage) Current (Any Diode) vs Temperature



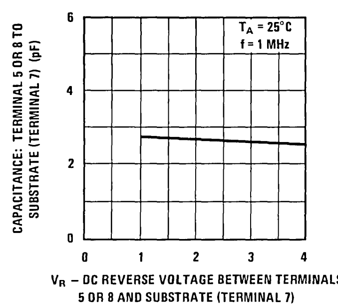
Diode Capacitance (Any Diode) vs Reverse Voltage



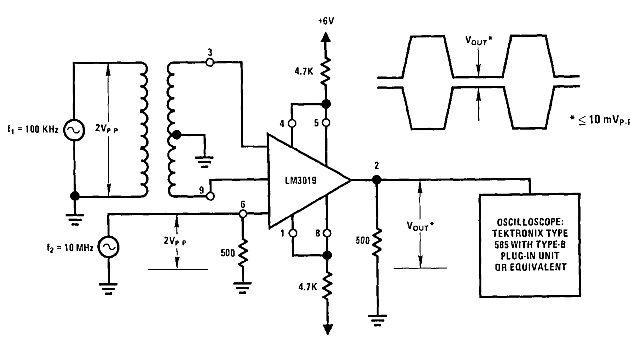
Diode Quad-To-Substrate Capacitance vs Reverse Voltage



Diode Quad-To-Substrate Capacitance vs Reverse Voltage



series gate switching test setup



6

Transistor/Diode Arrays

LM3026, LM3054 transistor arrays

general description

The LM3026 and LM3054 each consists of two independent differential amplifiers with associated constant-current transistors on a common monolithic substrate. The six NPN transistors which comprise the amplifiers are general purpose devices which exhibit low 1/f noise and a value of f_T in excess of 300 MHz. These features make the LM3026 and LM3054 useful from DC to 120 MHz. Bias and load resistors have been omitted to provide maximum application flexibility.

The monolithic construction of the LM3026 and LM3054 provides close electrical and thermal matching of the amplifiers. This feature makes these devices particularly useful in dual channel applications where matched performance of the two channels is required.

The LM3026 is supplied in a hermetic 12-lead TO-5 style package and is rated for full military operating temperature range of −55°C to +125°C.

The LM3054 is supplied in a 14-lead molded dual-in-line package with a limited temperature range. The availability of extra terminals allows the introduction of an independent substrate connection for maximum flexibility.

features

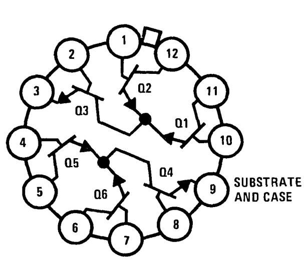
- Two differential amplifiers on a common substrate
- Independently accessible inputs and outputs
- Maximum input offset voltage ±5 mV
- Full military temperature range capability −55°C to +125°C
- Limited temperature range, LM3054 0°C to +85°C

applications

- Dual sense amplifiers
- Dual Schmitt triggers
- Multifunction combinations RF mixer oscillator converter IF
- IF amplifiers (differential and or cascade)
- Product detectors
- Doubly balanced modulators and demodulators
- Balanced quadrature detectors
- Cascade limiters
- Synchronous detectors
- Pairs of balanced mixers
- Synthesizer mixers
- Balanced (push-pull) cascode amplifiers

schematic and connection diagrams

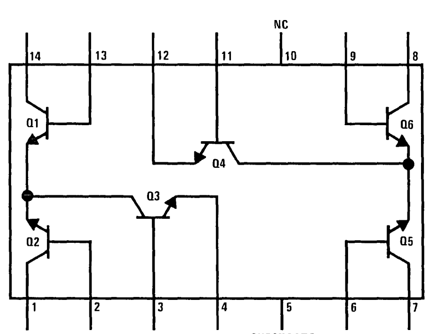
Metal Can Package



TOP VIEW

Order Number LM3026H
See Package 7

Dual-In-Line Package



TOP VIEW

Order Number LM3054N
See Package 22

absolute maximum ratings ($T_A = 25°C$)

	LM3026	LM3054
Power Dissipation		
Any One Transistor	300 mW	300 mW
Total Package	600 mW	750 mW
For $T_A > 55°C$	Derate at 5 mW/°C	6.67 mW/°C
Operating Temperature Range	−55°C to +125°C	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)		300°C

The following ratings apply for each transistor in the device:

Collector to Emitter Voltage (V_{CEO})	15V
Collector to Base Voltage (V_{CBO})	20V
Collector to Substrate Voltage (V_{CIO}) (Note)	20V
Emitter to Base Voltage (V_{EBO})	5V
Collector Current	50 mA

dc electrical characteristics ($T_A = 25°C$)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
STATIC CHARACTERISTICS					
For Each Differential Amplifier					
Input Offset Voltage (V_{IO})	$V_{CB} = 3V$, $I_{E(Q3)} = I_{E(Q4)} = 2$ mA		.45	5	mV
Input Offset Current (I_{IO})			.3	2	μA
Input Bias Current (I_I)			10	24	μA
Quiescent Operating Current Ratio $\left(\frac{I_{C(Q1)}}{I_{C(Q2)}} \text{ or } \frac{I_{C(Q5)}}{I_{C(Q6)}}\right)$			.98 to 1.02		
Temperature Coefficient Magnitude of Input Offset Voltage $\left(\frac{\lvert\Delta V_{IO}\rvert}{\Delta T}\right)$			1.1		μV/°C
For Each Transistor					
DC Forward Base to Emitter Voltage (V_{BE})	$V_{CB} = 3V$, $I_C = 50\ \mu A$		.630	.700	V
	1 mA		.715	.800	
	3 mA		.750	.850	
	10 mA		.800	.900	
Temperature Coefficient of Base to Emitter Voltage $\left(\frac{\Delta V_{BE}}{\Delta T}\right)$	$V_{CB} = 3V$, $I_C = 1$ mA		−1.9		μV/°C
Collector Cutoff Current (I_{CBO})	$V_{CB} = 10V$, $I_E = 0$		.002	100	nA
Collector to Emitter Breakdown Voltage ($V_{(BR)CEO}$)	$I_C = 1$ mA, $I_B = 0$	15	24		V
Collector to Base Breakdown Voltage ($V_{(BR)CBO}$)	$I_C = 10\mu A$, $I_E = 0$	20	60		V
Collector to Substrate Breakdown Voltage ($V_{(BR)CIO}$)	$I_C = 10\mu A$, $I_{CI} = 0$	20	60		V
Emitter to Base Breakdown Voltage ($V_{(BR)EBO}$)	$I_E = 10\mu A$, $I_C = 0$	5	7		V

ac electrical characteristics

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
DYNAMIC CHARACTERISTICS					
Common Mode Rejection Ratio For Each Amplifier (CMR)	$V_{CC} = 12V$, $V_{EE} = -6V$, $V_x = -3.3V$, f = 1 kHz		100		dB
AGC Range, One Stage (AGC)			75		dB
Voltage Gain, Single Stage Double Ended Output (A)			32		dB
AGC Range, Two Stage (AGC)			105		dB
Voltage Gain, Two Stage Double Ended Output (A)			60		dB
Low-Frequency, Small Signal Equivalent Circuit Characteristics: (For Single Transistor)					
Forward Current Transfer Ratio (h_{fe})	f = 1 kHz, $V_{CE} = 3V$, $I_C = 1$ mA		110		
Short Circuit Input Impedance (h_{ie})			3.5		kΩ
Open Circuit Output Impedance (h_{oe})			15.6		μmho
Open Circuit Reverse Voltage Transfer Ratio (h_{re})			1.8×10^{-4}		
1/f Noise Figure (For Single Transistor) (NF)	f = 1 kHz, $V_{CE} = 3V$		3.25		dB
Gain Bandwidth Product (For Single Transistor) (f_T)	$V_{CE} = 3V$, $I_C = 3$ mA		550		MHz
Admittance Characteristics; Differential Circuit Configuration: (For Each Amplifier)					

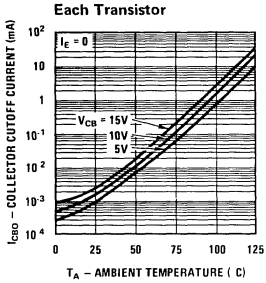
Note: The collector of each transistor of the LM3026 and LM3054 is isolated from the substrate by an integral diode. The substrate must be connected to a voltage which is more negative than any collector voltage in order to maintain isolation between transistors and provide for normal transistor action. The substrate should be maintained at signal (AC) ground by means of a suitable grounding capacitor, to avoid undesired coupling between transistors.

ac electrical characteristics (con't)

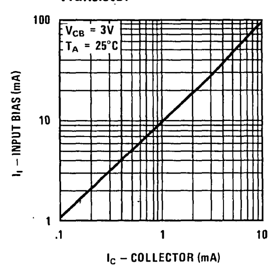
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Forward Transfer Admittance (y_{21})			−20 + j0		mmho
Input Admittance (y_{11})	V_{CB} = 3V		.22 + j0.1		mmho
Output Admittance (y_{22})	Each Collector $I_C \approx 1.25$ mA		.01 + j0		mmho
Reverse Transfer Admittance (y_{12})	f = 1 MHz		−0.003 + j0		mmho
Admittance Characteristics; Cascode Circuit Configuration: (For Each Amplifier)					
Forward Transfer Admittance (y_{21})			68 − j0		mmho
Input Admittance (y_{11})	V_{CB} = 3V		.55 + j0		mmho
Output Admittance (y_{22})	Total Stage $I_C \approx 2.5$ mA		0 + j0.02		mmho
Reverse Transfer Admittance (y_{12})	f = 1 MHz		.004 − j.005		μmho
Noise Figure (NF)	f = 100 MHz		8		dB

typical performance characteristics

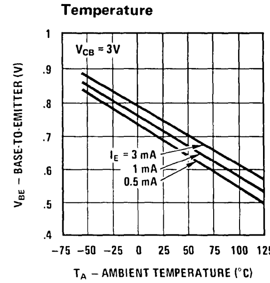
Collector-To-Base Cutoff Current vs Ambient Temperature for Each Transistor



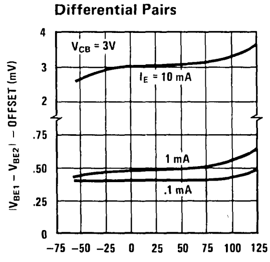
Input Bias Current Characteristic vs Collector Current for Each Transistor



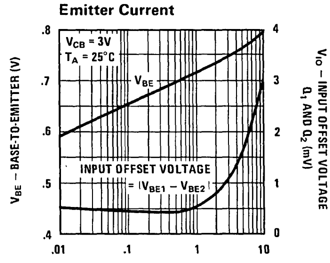
Base-To-Emitter Voltage Characteristic for Each Transistor vs Ambient Temperature



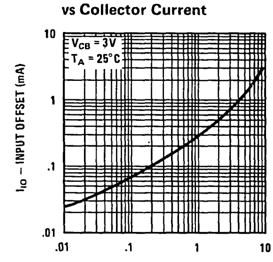
Offset Voltage Characteristic vs Ambient Temperature for Differential Pairs



Static Base-To-Emitter Voltage Characteristic and Input Offset Voltage for Differential Pairs vs Emitter Current

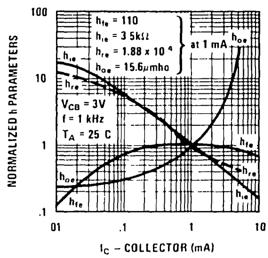


Input Offset Current for Matched Differential Pairs vs Collector Current

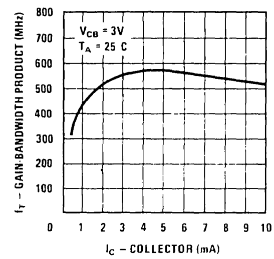


typical performance characteristics (con't)

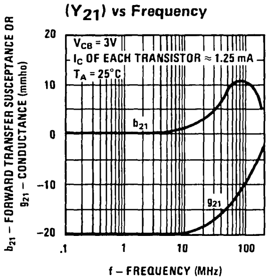
Forward Current-Transfer Ratio (h_{fe}), Short-Circuit Input Impedance (h_{ie}), Open-Circuit Output Impedance (h_{oe}), and Open-Circuit Reverse Voltage-Transfer Ratio (h_{re}) vs Collector Current for Each Transistor



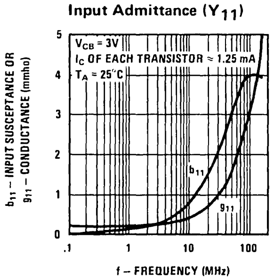
Gain-Bandwidth Product (f_T) vs Collector Current



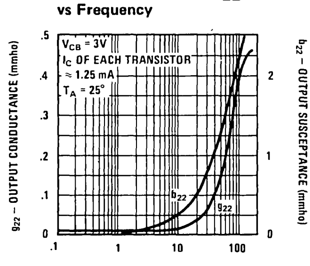
Forward Transfer Admittance (Y_{21}) vs Frequency



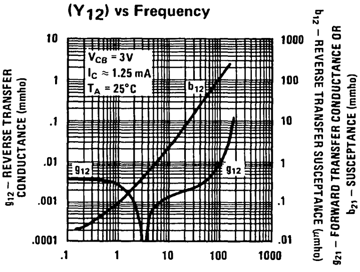
Input Admittance (Y_{11})



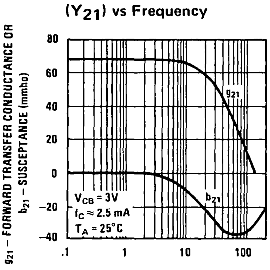
Output Admittance (Y_{22}) vs Frequency



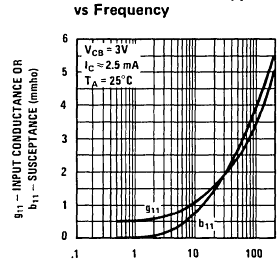
Reverse Transfer Admittance (Y_{12}) vs Frequency



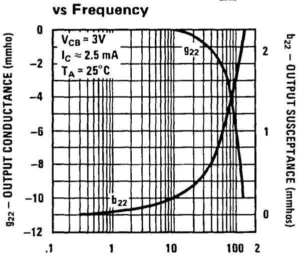
Forward Transfer Admittance (Y_{21}) vs Frequency



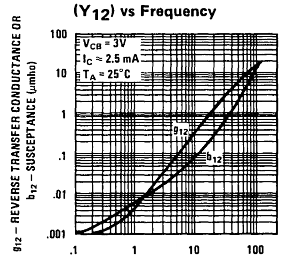
Input Admittance (Y_{11}) vs Frequency



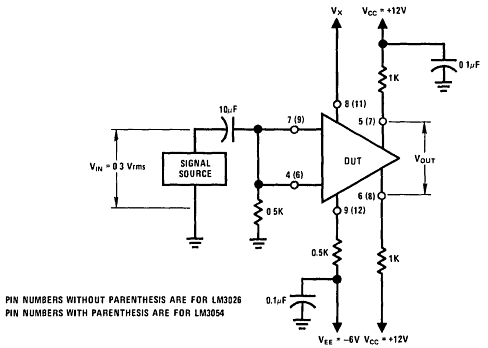
Output Admittance (Y_{22}) vs Frequency

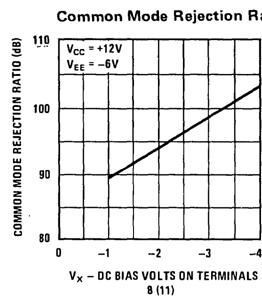


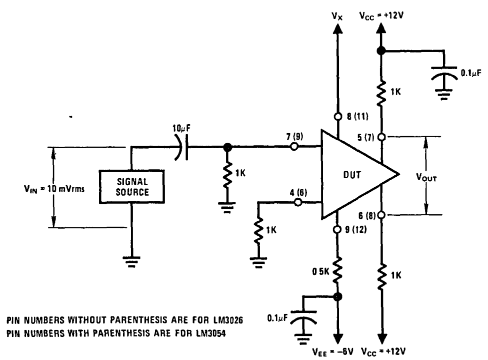
Reverse Transfer Admittance (Y_{12}) vs Frequency

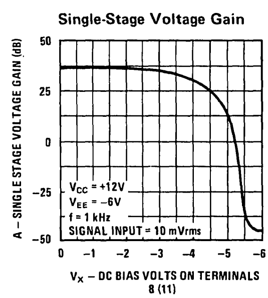


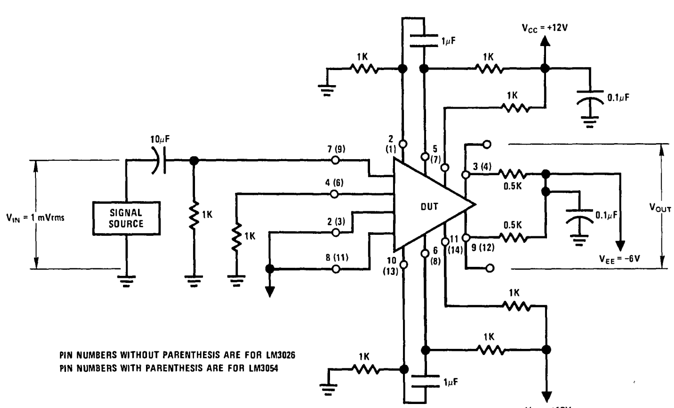
typical performance characteristics (con't)

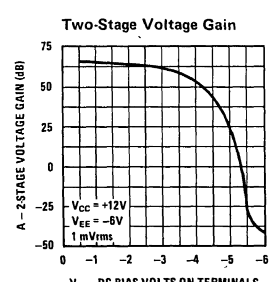












The following chart gives the range of voltages which can be applied to the terminals listed vertically with respect to the terminals listed horizontally. For example, the voltage range between vertical terminal 1† and horizontal terminal 3† is +15V to −5V.

LM3054 TERMINAL NO. →		13	14	1	2	3	4	6	7	8	9	11	12	5
↓	LM3026 TERMINAL NO.	10	11	12	1	2	3	4	5	6	7	8	(Note 2) 9	(Note 2) 9
13	10		0 −20	*	+5 −5	*	+15 −5	*	*	*	*	*	*	*
14	11			*	*	*	+20 0	*	*	*	*	*	*	+20 0
1	12				+20 0	*	+20 0	*	*	*	*	*	*	+20 0
2	1					*	+15 −5	*	*	*	*	*	*	*
3	2						+1 −5	*	*	*	*	*	*	*
4	3							*	*	*	*	*	*	*
6	4								0 −20	*	+5 −5	*	+15 −5	*
7	5									*	*	*	*	+20 0
8	6										−20 0	*	*	+20 0
9	7											*	+15 −5	*
11	8												+1 −5	*
12	9													*
5	9													Ref Substrate

LM3054 TERMINAL NO. (Note 2)	LM3026 TERMINAL NO.	I_{IN} mA	I_{OUT} mA
13	10	5	.1
14	11	50	.1
1	12	50	.1
2	1	5	.1
3	2	5	.1
4	3	.1	−50
6	4	5	.1
7	5	50	.1
8	6	50	.1
9	7	5	.1
11	8	5	.1
12	9	.1	50

Note 1: In the LM3026 terminal No. 9 is connected to the emitter of Q_4, the reference substrate, and the case; therefore, the case should not be grounded. Two terminal 9 columns LM3026 appear in the voltage rating chart because it is a composite chart for both the LM3026 and the LM3054. Wherever an asterisk is shown in one column 9 and a rating is shown in the other column 9, the asterisk should be ignored.

Note 2: Terminal No. 10 of LM3054 is not used.

†LM3026; corresponding terminals for LM3054 are vertical terminal 2 and horizontal terminal 4.

*Voltages are not normally applied between these terminals. Voltages appearing between these terminals will be safe if the specified limits between all other terminals are not exceeded.

Transistor/Diode Arrays

LM3039 diode array

general description

The LM3039 consists of six ultra-fast, low capacitance silicon diodes on a common monolithic substrate. Five of the diodes are independently accessible, the sixth shares a common terminal with the substrate. Integrated circuit construction assures excellent static and dynamic matching of the diodes, making the array extremely useful for a wide variety of applications in communication and switching systems.

features

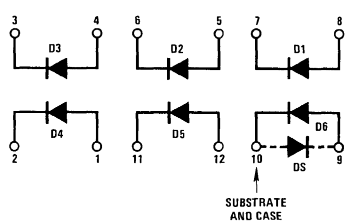
- Excellent reverse recovery time — 1 ns typ
- Matched monolithic construction — V_F matched within 5 mV
- Low diode capacitance — C_D = .65 pF typ at V_R = −2V

applications

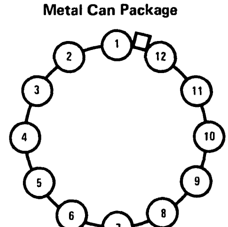
- Balanced modulators or demodulators
- Ring modulators
- High speed diode gates
- Analog switches

For applications such as balanced modulators or ring modulators where capacitive balance is important, the substrate should be returned to a DC potential which is significantly more negative (with respect to the active diodes) than the peak signal applied.

schematic and connection diagrams



Metal Can Package



TOP VIEW

Order Number LM3039H

See Package 7

absolute maximum ratings

Power Dissipation	
Any One Diode	100 mW
Total For Device	600 mW
For $T_A > 55°C$	Derate Linearly 5.7 mW/°C
Operating Temperature Range	−55°C to +125°C
Storage Temperature Range	−65°C to +150°C
Peak Inverse Voltage, PIV for: D1 – D5	5V
D6	.5V
Peak Diode to Substrate Voltage, V_{DI} for D1 – D5 (Term. 1, 4, 5, 8 or 12 to Term. 10)	+20, −1V
DC Forward Current, I_F	25 mA
Peak Recurrent Forward Current, I_f	100 mA
Peak Forward Surge Current, $I_{f\,(SURGE)}$	100 mA

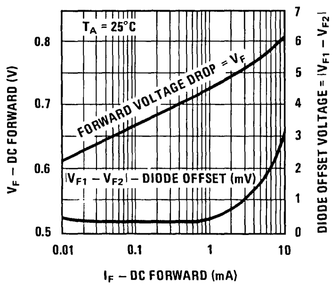
electrical characteristics

(T_A = 25°C) Characteristics apply for each diode unit, unless otherwise specified.

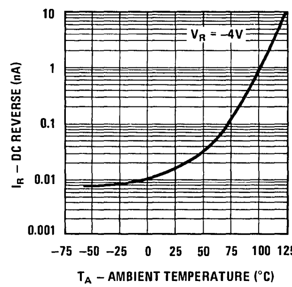
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
DC Forward Voltage Drop (V_F)	$I_F = 50\mu A$		.65	.69	V
	1 mA		.73	.78	V
	3 mA		.76	.80	V
	10 mA		.81	.90	V
DC Reverse Breakdown Voltage ($V_{(BR)R}$)	$I_R = -10\mu A$	5	7		V
DC Reverse Breakdown Voltage Between Any Diode Unit and Substrate ($V_{(BR)R}$)	$I_R = -10\mu A$	20			V
DC Reverse (Leakage) Current (I_R)	$V_R = -4V$		.016	100	nA
DC Reverse (Leakage) Current Between Any Diode Unit and Substrate (I_R)	$V_R = -10V$		.022	100	nA
Magnitude of Diode Offset Voltage (Difference in DC Forward Voltage Drops of Any Two Diode Units) ($\|V_{F_1} - V_{F_2}\|$)	I_F = 1 mA		.5	5	mV
Temperature Coefficient of $\|V_{F_1} - V_{F_2}\|$ $\left(\frac{\Delta\|V_{F_1} - V_{F_2}\|}{\Delta T}\right)$	I_F = 1 mA		1		µV/°C
Temperature Coefficient of Forward Drop $\left(\frac{\Delta V_F}{\Delta T}\right)$	I_F = 1 mA		-1.9		mV/°C
DC Forward Voltage Drop for Anode-to-Substrate Diode (D_S) (V_F)	I_F = 1 mA		.65		V
Reverse Recovery Time (t_{rr})	I_F = 10 mA, I_R = 10 mA		1		ns
Diode Resistance (R_D)	f = 1 kHz, I_F = 1 mA	25	30	45	Ω
Diode Capacitance (C_D)	$V_R = -2V$, $I_F = 0$		.65		pF
Diode-to-Substrate Capacitance (C_{DI})	$V_{DI} = +4V$, $I_F = 0$		3.2		pF

typical performance characteristics

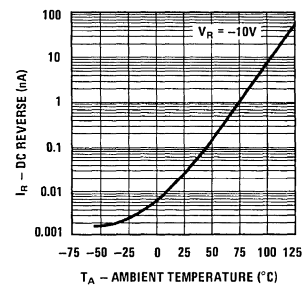
DC Forward Voltage Drop (Any Diode) and Diode Offset Voltage vs DC Forward Current



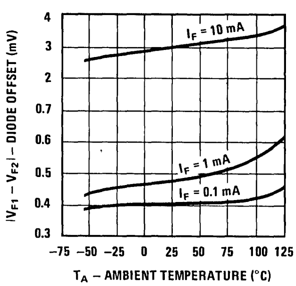
DC Reverse (Leakage) Current (Diodes 1, 2, 3, 4, 5) vs Temperature



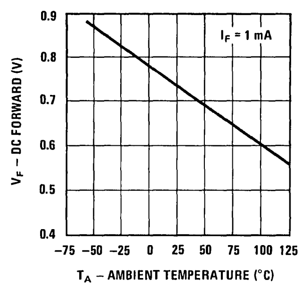
DC Reverse (Leakage) Current Between Diodes (1, 2, 3, 4, 5) and Substrate vs Temperature



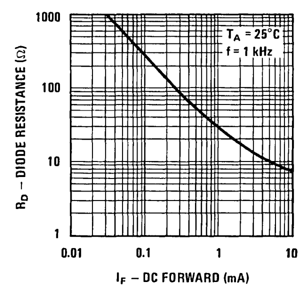
Diode Offset Voltage (Any Diode) vs Temperature



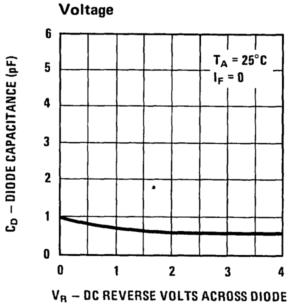
DC Forward Voltage Drop (Any Diode) vs Temperature



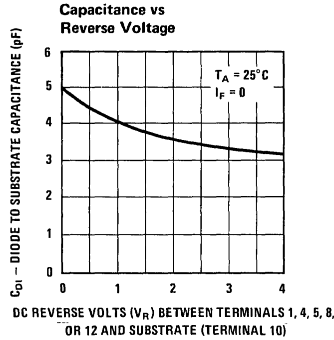
Diode Resistance (Any Diode) vs DC Forward Current



Diode Capacitance (Diodes 1, 2, 3, 4, 5) vs Reverse Voltage



Diode-to-Substrate Capacitance vs Reverse Voltage



Transistor/Diode Arrays

LM3045, LM3046, LM3086 transistor arrays

general description

The LM3045, LM3046, and LM3086 each consist of five general purpose silicon NPN transistors on a common monolithic substrate. Two of the transistors are internally connected to form a differentially-connected pair. The transistors are well suited to a wide variety of applications in low power system in the DC through VHF range. They may be used as discrete transistors in conventional circuits however, in addition, they provide the very significant inherent integrated circuit advantages of close electrical and thermal matching. The LM3045 is supplied in a 14-lead cavity dual-in-line package rated for operation over the full military temperature range. The LM3046 and LM3086 are electrically identical to the LM3045 but are supplied in a 14-lead molded dual-in-line package for applications requiring only a limited temperature range.

features

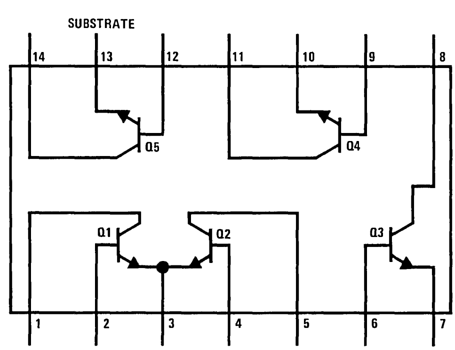
- Two matched pairs of transistors
  - V_{BE} matched ±5 mV
  - Input offset current 2μA max at I_C = 1 mA
- Five general purpose monolithic transistors
- Operation from DC to 120 MHz
- Wide operating current range
- Low noise figure 3.2 dB typ at 1 kHz
- Full military temperature range (LM3045) −55°C to +125°C

applications

- General use in all types of signal processing systems operating anywhere in the frequency range from DC to VHF
- Custom designed differential amplifiers
- Temperature compensated amplifiers

schematic and connection diagram

Dual-In-Line Package



TOP VIEW

Order Number LM3045D
See Package 1
or
Order Number LM3046N or LM3086N
See Package 22

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absolute maximum ratings ($T_A = 25°C$)

	LM3045 Each Transistor	LM3045 Total Package	LM3046/LM3086 Each Transistor	LM3046/LM3086 Total Package	Units
Power Dissipation:					
$T_A = 25°C$	300	750	300	750	mW
$T_A = 25°C$ to 55°C			300	750	mW
$T_A > 55°C$			Derate at 6.67		mW/°C
$T_A = 25°C$ to 75°C	300	750			mW
$T_A > 75°C$	Derate at 8				mW/°C
Collector to Emitter Voltage, V_{CEO}	15		15		V
Collector to Base Voltage, V_{CBO}	20		20		V
Collector to Substrate Voltage, V_{CIO} (Note 1)	20		20		V
Emitter to Base Voltage, V_{EBO}	5		5		V
Collector Current, I_C	50		50		mA
Operating Temperature Range	−55°C to +125°C		0°C to +85°C		
Storage Temperature Range	−65°C to +150°C		−25°C to +85°C		
Lead Temperature (Soldering, 10 sec)	300		300		°C

electrical characteristics ($T_A = 25°C$ unless otherwise specified)

PARAMETER	CONDITIONS	LIMITS LM3045, LM3046 MIN	TYP	MAX	LIMITS LM3086 MIN	TYP	MAX	UNITS
Collector to Base Breakdown Voltage ($V_{(BR)CBO}$)	$I_C = 10\mu A$, $I_E = 0$	20	60		20	60		V
Collector to Emitter Breakdown Voltage ($V_{(BR)CEO}$)	$I_C = 1$ mA, $I_B = 0$	15	24		15	24		V
Collector to Substrate Breakdown Voltage ($V_{(BR)CIO}$)	$I_C = 10\mu A$, $I_{CI} = 0$	20	60		20	60		V
Emitter to Base Breakdown Voltage ($V_{(BR)EBO}$)	$I_E = 10\mu A$, $I_C = 0$	5	7		5	7		V
Collector Cutoff Current (I_{CBO})	$V_{CB} = 10V$, $I_E = 0$		.002	40		.002	100	nA
Collector Cutoff Current (I_{CEO})	$V_{CE} = 10V$, $I_B = 0$			.5			5	μA
Static Forward Current Transfer Ratio (Static Beta) (h_{FE})	$V_{CE} = 3V$ $I_C = 10$ mA $I_C = 1$ mA $I_C = 10\mu A$	40	100 100 54		40	100 100 54		
Input Offset Current for Matched Pair Q_1 and Q_2 $\|I_{IO1} - I_{IO2}\|$	$V_{CE} = 3V$, $I_C = 1$ mA		.3	2				μA
Base to Emitter Voltage (V_{BE})	$V_{CE} = 3V$ $I_E = 1$ mA $I_E = 10$ mA		.715 .800			.715 .800		V
Magnitude of Input Offset Voltage for Differential Pair $\|V_{BE1} - V_{BE2}\|$	$V_{CE} = 3V$, $I_C = 1$ mA		.45	5				mV
Magnitude of Input Offset Voltage for Isolated Transistors $\|V_{BE3} - V_{BE4}\|$, $\|V_{BE4} - V_{BE5}\|$, $\|V_{BE5} - V_{BE3}\|$	$V_{CE} = 3V$, $I_C = 1$ mA		.45	5				mV
Temperature Coefficient of Base to Emitter Voltage $\left(\frac{\Delta V_{BE}}{\Delta T}\right)$	$V_{CE} = 3V$, $I_C = 1$ mA		−1.9			−1.9		mV/°C
Collector to Emitter Saturation Voltage ($V_{CE(SAT)}$)	$I_B = 1$ mA, $I_C = 10$ mA		.23			.23		V
Temperature Coefficient of Input Offset Voltage $\left(\frac{\Delta V_{IO}}{\Delta T}\right)$	$V_{CE} = 3V$, $I_C = 1$ mA		1.1					μV/°C

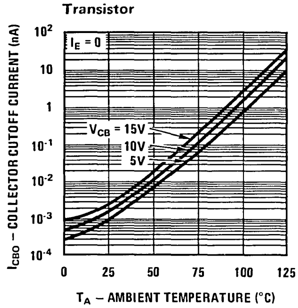
Note 1: The collector of each transistor of the LM3045, LM3046, and LM3086 is isolated from the substrate by an integral diode. The substrate (terminal 13) must be connected to the most negative point in the external circuit to maintain isolation between transistors and to provide for normal transistor action.

electrical characteristics (con't)

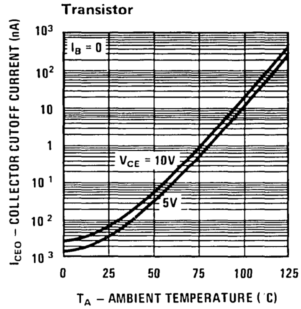
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Low Frequency Noise Figure (NF)	f = 1 kHz, V_{CE} = 3V, I_C = 100μA R_S = 1 kΩ		3.25		dB
Low Frequency, Small Signal Equivalent Circuit Characteristics:					
Forward Current Transfer Ratio (h_{fe})	f = 1 kHz, V_{CE} = 3V, I_C = 1 mA		110 (LM3045, LM3046) (LM3086)		
Short Circuit Input Impedance (h_{ie})			3.5		kΩ
Open Circuit Output Impedance (h_{oe})			15.6		μmho
Open Circuit Reverse Voltage Transfer Ratio (h_{re})			1.8x10^{-4}		
Admittance Characteristics:					
Forward Transfer Admittance (Y_{fe})	f = 1 MHz, V_{CE} = 3V, I_C = 1 mA		31 - j 1.5		
Input Admittance (Y_{ie})			0.3+j 0.04		
Output Admittance (Y_{oe})			0.001+j 0.03		
Reverse Transfer Admittance (Y_{re})			See curve		
Gain Bandwidth Product (f_T)	V_{CE}=3V, I_C = 3 mA	300	550		
Emitter to Base Capacitance (C_{EB})	V_{EB} = 3V, I_E = 0		.6		pF
Collector to Base Capacitance (C_{CB})	V_{CB} = 3V, I_C = 0		.58		pF
Collector to Substrate Capacitance (C_{CI})	V_{CS} = 3V, I_C = 0		2.8		pF

typical performance characteristics

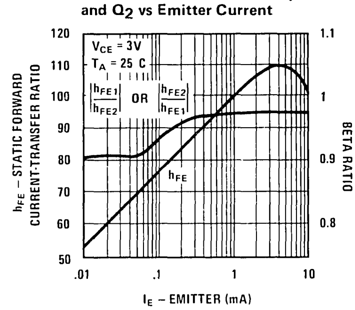
Typical Collector To Base Cutoff Current vs Ambient Temperature for Each Transistor



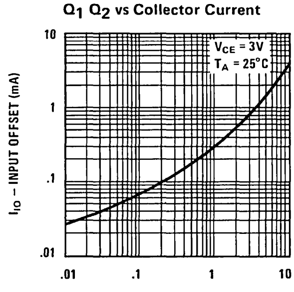
Typical Collector To Emitter Curoff Current vs Ambient Temperature for Each Transistor



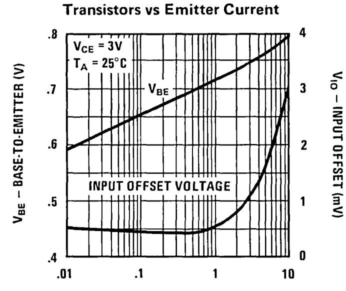
Typical Static Forward Current-Transfer Ratio and Beta Ratio for Transistors Q_1 and Q_2 vs Emitter Current



Typical Input Offset Current for Matched Transistor Pair Q_1 Q_2 vs Collector Current



Typical Static Base To Emitter Voltage Characteristic and Input Offset Voltage for Differential Pair and Paired Isolated Transistors vs Emitter Current



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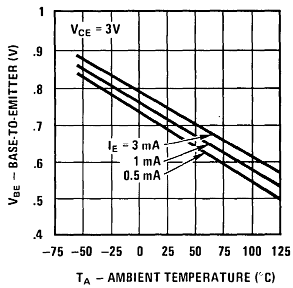
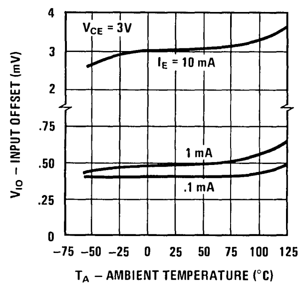
typical performance characteristics (con't)

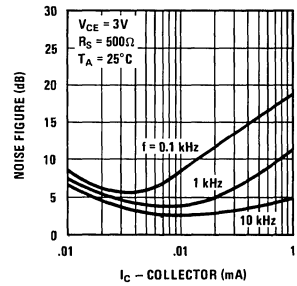
Typical Base To Emitter Voltage Characteristic for Each Transistor vs Ambient Temperature



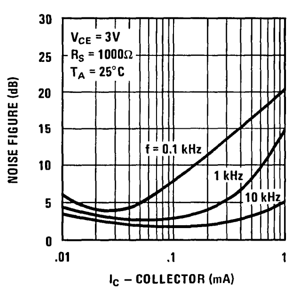
Typical Input Offset Voltage Characteristics for Differential Pair and Paired Isolated Transistors vs Ambient Temperature



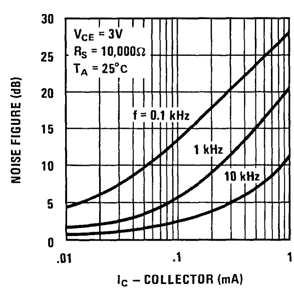
Typical Noise Figure vs Collector Current



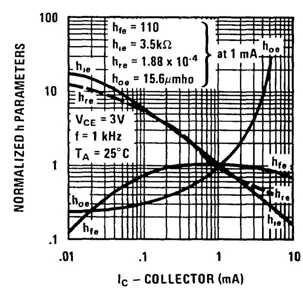
Typical Noise Figure vs Collector Current



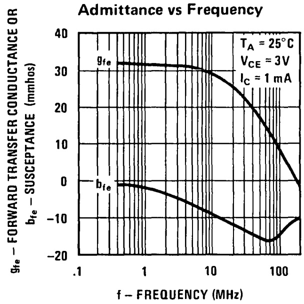
Typical Noise Figure vs Collector Current



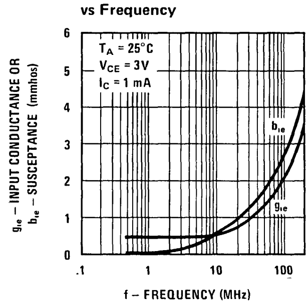
Typical Normalized Forward Current Transfer Ratio, Short Circuit Input Impedance, Open Circuit Output Impedance, and Open Circuit Reverse Voltage Transfer Ratio vs Collector Current



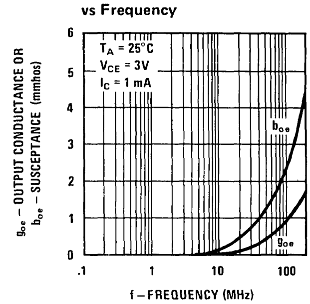
Typical Forward Transfer Admittance vs Frequency



Typical Input Admittance vs Frequency

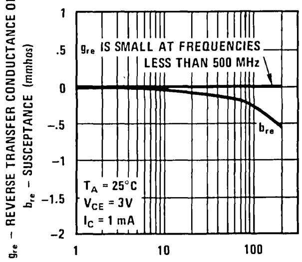


Typical Output Admittance vs Frequency

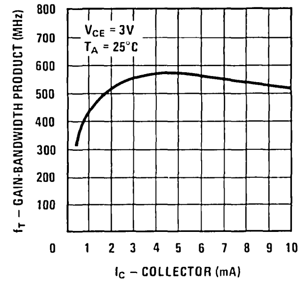


typical performance characteristics (con't)

Typical Reverse Transfer Admittance vs Frequency



Typical Gain-Bandwidth Product vs Collector Current



Transistor/Diode Arrays

LM3118/LM3118A matched monolithic high voltage transistor arrays

general description

The LM3118/LM3118A consist of four general purpose high voltage silicon NPN transistors on a common monolithic substrate. Two of the four transistors are connected in the Darlington configuration. The substrate is connected to a separate terminal for maximum flexibility. The transistors are well suited to a wide variety of applications in low-power systems in the dc through VHF range. They may be used as discrete transistors in conventional circuits but in addition they provide the advantages of close electrical and thermal matching inherent in integrated circuit construction.

features

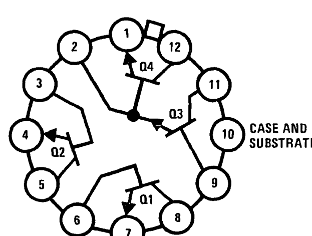
- High voltage matched monolithic general purpose transistors
- h_{FE} matched ±10%
- V_{BE} matched ±5 mV
- Operation from dc to 120 MHz
- Wide operating current range
- Low noise figure 3.2 dB typ at 1 kHz
- Full military temperature range capability −55°C to +125°C

applications

- General use in signal processing systems in dc through VHF range
- Custom designed differential amplifiers
- Temperature compensated amplifiers

connection diagram

Metal Can Package



TOP VIEW

Order Number LM3118H or LM3118AH
See Package 7

absolute maximum ratings

	LM3118A Each Transistor	LM3118 Each Transistor	Units
Power Dissipation (Note 1)			
Any One Transistor	300	300	mW
Total Package	450	450	mW
Operating Temperature Range	−55°C to +125°C	−55°C to +125°C	
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	
Collector to Emitter Voltage, V_{CEO}	40	30	V
Collector to Base Voltage, V_{CBO}	50	40	V
Collector to Substrate Voltage, V_{CIO} (Note 2)	50	40	V
Emitter to Base Voltage, V_{EBO} (Note 3)	5	5	V
Collector Current, I_C	50	50	mA
Lead Temperature (Soldering, 10 seconds)	300	300	°C

dc electrical characteristics $T_A = 25°C$

PARAMETER	CONDITIONS	LIMITS LM3118A MIN	LM3118A TYP	LM3118A MAX	LM3118 MIN	LM3118 TYP	LM3118 MAX	UNITS
Collector Cutoff Current (I_{CBO})	V_{CB} = 10V, I_E = 0		0.002	100		0.002	100	nA
Collector Cutoff Current (I_{CEO})	V_{CE} = 10V, I_B = 0			5			5	μA
Collector Cutoff Current Darlington Pair (I_{CEOD})	V_{CE} = 10V, I_B = 0			5				μA
Collector to Emitter Breakdown Voltage ($V_{(BR)CEO}$)	I_C = 1 mA, I_B = 0	40	56		30	56		V
Collector to Base Breakdown Voltage ($V_{(BR)CBO}$)	I_C = 10μA, I_E = 0	50	72		40	72		V
Emitter to Base Breakdown Voltage ($V_{(BR)EBO}$) (Note 3)	I_E = 10μA, I_C = 0	5	7		5	7		V
Collector to Substrate Breakdown Voltage ($V_{(BR)CIO}$)	I_{CI} = 10μA, I_B = 0, I_E = 0	50	72		40	72		V
Collector to Emitter Saturation Voltage ($V_{CE(SAT)}$)	I_B = 1 mA, I_C = 10 mA		0.33			0.33		V
Static Forward Current Transfer Ratio (h_{FE})	V_{CE} = 5V, I_C = 10 mA V_{CE} = 5V, I_C = 1 mA V_{CE} = 5V, I_C = 10μA	30	85 100 90		30	85 100 90		
Magnitude of Static Beta Ratio (Isolated Transistors Q1 and Q2)	V_{CE} = 5V, I_{C1} = I_{C2} = 1 mA	0.9	1.0	1.1	0.9	1.0	1.1	
Static Forward Current Transfer Ratio Darlington Pair (Q3 and Q4) (h_{FED})	V_{CE} = 5V, I_C = 1 mA	1500	9000		1500	9000		
Base to Emitter Voltage (V_{BE})	V_{CE} = 3V, I_E = 1 mA	0.63	0.73	0.83	0.63	0.73	0.83	V
Input Offset Voltage ($\|V_{BE1} - V_{BE2}\|$)	V_{CE} = 5V, I_E = 1 mA		0.48	5		0.48	5	mV
Temperature Coefficient Base to Emitter Voltage Q1, Q2 ($\|\Delta V_{BE}\|/\Delta T$)	V_{CE} = 5V, I_E = 1 mA		−1.9			−1.9		mV/°C
Base (Q3) to Emitter (Q4) Voltage Darlington Pair [V_{BED} (V_{9-1})]	V_{CE} = 5V, I_E = 10 mA V_{CE} = 5V, I_E = 1 mA		1.46 1.32			1.46 1.32		V V
Temperature Coefficient Base to Emitter Voltage Darlington Pair Q3, Q4 ($\|\Delta V_{BED}\|/\Delta T$)	V_{CE} = 5V, I_E = 1 mA		−4.4			−4.4		mV/°C
Temperature Coefficient Magnitude of Input Offset Voltage ($\|V_{BE1} - V_{BE2}\|/\Delta T$)	V_{CE} = 5V, I_{C1} = I_{C2} = 1 mA		1.1			1.1		μV/°C

ac electrical characteristics $T_A = 25°C$

PARAMETER	CONDITIONS	LIMITS LM3118A MIN	LIMITS LM3118A TYP	LIMITS LM3118A MAX	LIMITS LM3118 MIN	LIMITS LM3118 TYP	LIMITS LM3118 MAX	UNITS
Low Frequency Noise Figure (NF)	f = 1 kHz, V_{CE} = 5V, I_C = 100μA, Source Resistance = 1 kΩ		3.25			3.25		dB
Gain Bandwidth Product (f_T)	V_{CE} = 5V, I_C = 3 mA	300	500		300	500		MHz
Emitter to Base Capacitance (C_{EB})	V_{EB} = 5V, I_E = 0		0.70			0.70		pF
Collector to Base Capacitance (C_{CB})	V_{CB} = 5V, I_C = 0		0.37			0.37		pF
Collector to Substrate Capacitance (C_{CI})	V_{CI} = 5V, I_C = 0		2.2			2.2		pF
LOW FREQUENCY, SMALL SIGNAL EQUIVALENT CIRCUIT CHARACTERISTICS								
Forward Current Transfer Ratio (h_{fe})	f = 1 kHz, V_{CE} = 5V, I_C = 1 mA		100			100		
Short Circuit Input Impedance (h_{ie})	f = 1 kHz, V_{CE} = 5V, I_C = 1 mA		2.7			3.5		kΩ
Open Circuit Output Impedance (h_{oe})	f = 1 kHz, V_{CE} = 5V, I_C = 1 mA		15.6			15.6		μmho
Open Circuit Reverse Voltage Transfer Ratio (h_{re})	f = 1 kHz, V_{CE} = 5V, I_C = 1 mA		1.8×10^{-4}			1.8×10^{-4}		
ADMITTANCE CHARACTERISTICS								
Forward Transfer Admittance (Y_{fe})	f = 1 MHz, V_{CE} = 5V, I_C = 1 mA		31 − j 1.5			31 − j 1.5		mmho
Input Admittance (Y_{ie})	f = 1 MHz, V_{CE} = 5V, I_C = 1 mA		0.35 + j 0.04			0.3 + j 0.04		mmho
Output Admittance (Y_{oe})	f = 1 MHz, V_{CE} = 5V, I_C = 1 mA		0.001 + j 0.03			0.001 + j 0.03		mmho
Reverse Transfer Admittance (Y_{re})	f = 1 MHz, V_{CE} = 5V, I_C = 1 mA		(Note 4)			(Note 4)		mmho

Note 1: Derate at 5 mW/°C for $T_A > +85°C$.

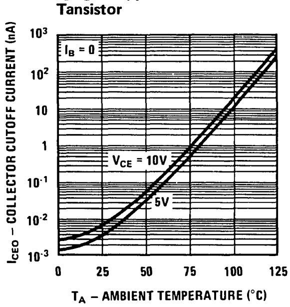
Note 2: The collector of each transistor is isolated from the substrate by an integral diode. The substrate must be connected to a voltage which is more negative than any collector voltage in order to maintain isolation between transistors and provide normal transistor action. To avoid undesired coupling between transistors, the substrate terminal should be maintained at either dc or signal (ac) ground. A suitable bypass capacitor can be used to establish a signal ground.

Note 3: If the transistors are forced into zener breakdown ($V_{(BR)EBO}$) degradation of forward transfer current ratio (h_{FE}) can occur.

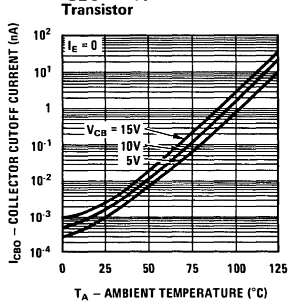
Note 4: See curve.

typical performance characteristics

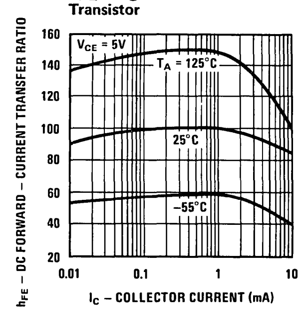
I_{CEO} vs T_A for Any Tansistor



I_{CBO} vs T_A for Any Transistor

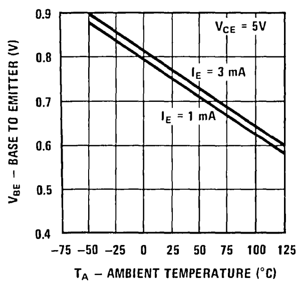


h_{FE} vs I_C for Any Transistor

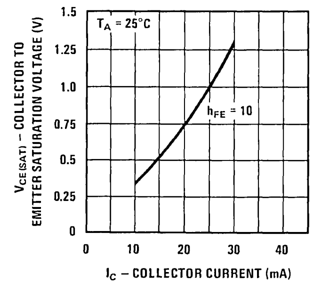


typical performance characteristics (con't)

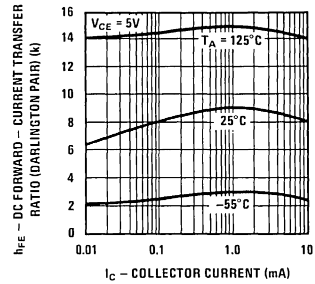
V_{BE} vs T_A for Any Transistor



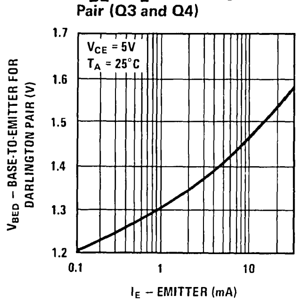
$V_{CE(SAT)}$ vs I_C for Any Transistor



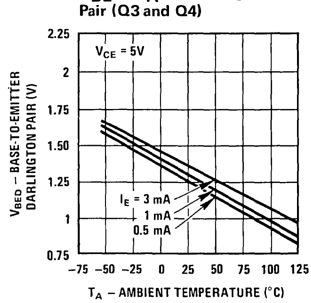
h_{FE} vs I_C for Darlington Pair (Q3 and Q4)



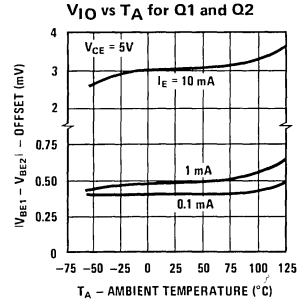
V_{BE} vs I_E for Darlington Pair (Q3 and Q4)



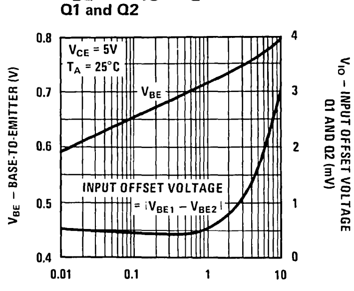
V_{BE} vs T_A for Darlington Pair (Q3 and Q4)



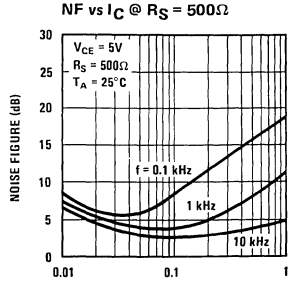
V_{IO} vs T_A for Q1 and Q2



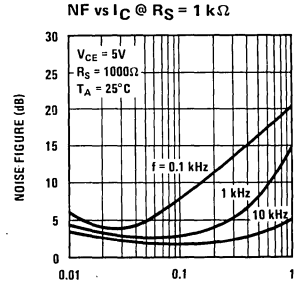
V_{BE} and V_{IO} vs I_E for Q1 and Q2



NF vs I_C @ R_S = 500Ω

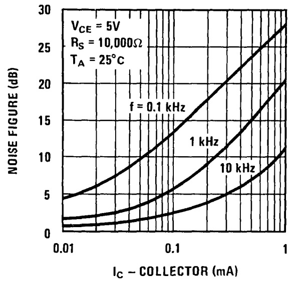


NF vs I_C @ R_S = 1 kΩ

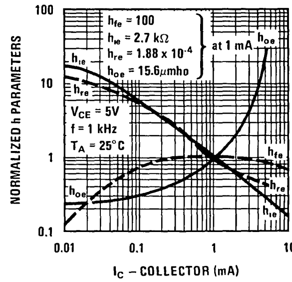


typical performance characteristics (con't)

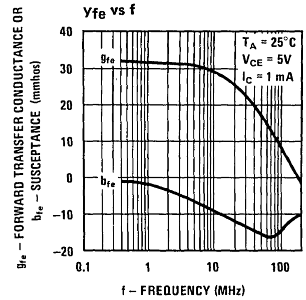
NF vs I_C @ R_S = 10 kΩ



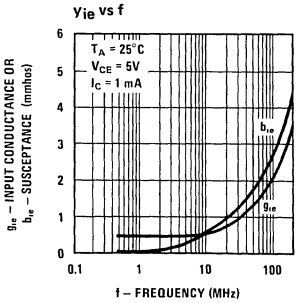
h_{fe}, h_{ie}, h_{oe}, h_{re} vs I_C



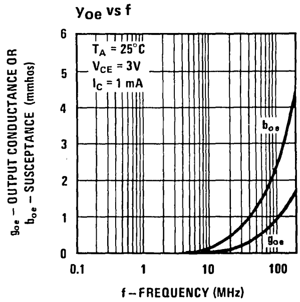
y_{fe} vs f



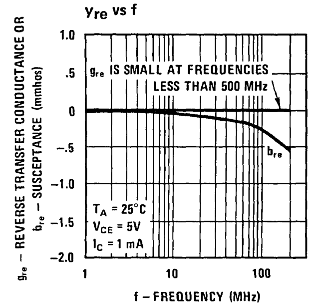
y_{ie} vs f



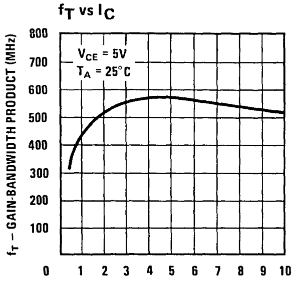
y_{oe} vs f



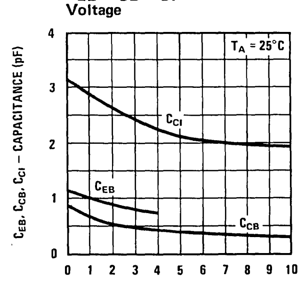
y_{re} vs f



f_T vs I_C



C_{EB}, C_{CB}, C_{CI} vs Bias Voltage



Transistor/Diode Arrays

LM3145/LM3145A, LM3146/LM3146A high voltage transistor arrays

general description

The LM3145/LM3145A and LM3146/LM3146A each consist of five high voltage general purpose silicon NPN transistors on a common monolithic substrate. Two of the transistors are internally connected to form a differentially-connected pair. The transistors are well suited to a wide variety of applications in low power system in the dc through VHF range. They may be used as discrete transistors in conventional circuits however, in addition, they provide the very significant inherent integrated circuit advantages of close electrical and thermal matching. The LM3145 and LM3145A are each supplied in a 14-lead cavity dual-in-line package rated for operation over the full military temperature range. The LM3146 and LM3146A are electrically identical to the LM3145 and LM3145A respectively but are supplied in a 14-lead molded dual-in-line package for applications requiring only a limited temperature range.

features

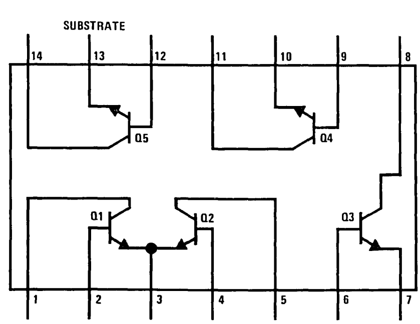
- High voltage matched pairs of transistors, V_{BE} matched ±5 mV, input offset current 2μA max at I_C = 1 mA
- Five general purpose monolithic transistors
- Operation from dc to 120 MHz
- Wide operating current range
- Low noise figure 3.2 dB typ at 1 kHz
- Full military temperature range (LM3145) −55°C to +125°C

applications

- General use in all types of signal processing systems operating anywhere in the frequency range from dc to VHF
- Custom designed differential amplifiers
- Temperature compensated amplifiers

connection diagram

Dual-In-Line Package



TOP VIEW

Order Number LM3145D or LM3145AD
See Package 1

Order Number LM3146N or LM3146AN
See Package 22

absolute maximum ratings

	LM3145A	LM3145	LM3146A	LM3146	UNITS
Power Dissipation: Each Transistor					
T_A = 25°C to 55°C			300	300	mW
$T_A > 55$°C			Derate at 6.67		mW/°C
T_A = 25°C to 75°C	300	300			mW
$T_A > 75$°C	Derate at 8.0				mW/°C
Power Dissipation: Total Package					
T_A = 25°C			500	500	mW
$T_A > 25$°C			Derate at 6.67		mW/°C
T_A = 25°C to 75°C	750	750			mW
$T_A > 75$°C	Derate at 8.0				mW/°C
Collector to Emitter Voltage, V_{CEO}	40	30	40	30	V
Collector to Base Voltage, V_{CBO}	50	40	50	40	V
Collector to Substrate Voltage, V_{CIO} (Note 1)	50	40	50	40	V
Emitter to Base Voltage, V_{EBO} (Note 2)	5	5	5	5	V
Collector Current, I_C	50	50	50	50	mA
Operating Temperature Range	−55°C to +125°C		−40°C to +85°C		
Storage Temperature Range	−65°C to +150°C		−65°C to +150°C		
Lead Temperature (Soldering, 10 seconds)	300		300		°C

dc electrical characteristics T_A = 25°C

PARAMETER	CONDITIONS	LIMITS LM3145A, LM3146A MIN	TYP	MAX	LM3145, LM3146 MIN	TYP	MAX	UNITS
Collector to Base Breakdown Voltage ($V_{(BR)CBO}$)	I_C = 10μA, I_E = 0	50	72		40	72		V
Collector to Emitter Breakdown Voltage ($V_{(BR)CEO}$)	I_C = 1 mA, I_B = 0	40	56		30	56		V
Collector to Substrate Breakdown Voltage ($V_{(BR)CIO}$)	I_{CI} = 10μA, I_B = 0, I_E = 0	50	72		40	72		V
Emitter to Base Breakdown Voltage ($V_{(BR)EBO}$) (Note 2)	I_C = 0, I_E = 10μA	5	7		5	7		V
Collector Cutoff Current (I_{CBO})	V_{CB} = 10V, I_E = 0		0.002	100		0.002	100	nA
Collector Cutoff Current (I_{CEO})	V_{CE} = 10V, I_B = 0		(Note 3)	5		(Note 3)	5	μA
Static Forward Current Transfer Ratio (Static Beta) (h_{FE})	I_C = 10 mA, V_{CE} = 5V I_C = 1 mA, V_{CE} = 5V I_C = 10μA, V_{CE} = 5V	 30 	85 100 90		 30 	85 100 90		
Input Offset Current for Matched Pair Q1 and Q2 $\|I_{B1} - I_{B2}\|$	$I_{C1} = I_{C2}$ = 1 mA, V_{CE} = 5V		0.3	2		0.3	2	μA
Base to Emitter Voltage (V_{BE})	I_C = 1 mA, V_{CE} = 3V	0.63	0.73	0.83	0.63	0.73	0.83	V
Magnitude of Input Offset Voltage for Differential Pair $\|V_{BE1} - V_{BE2}\|$	V_{CE} = 5V, I_E = 1 mA		0.48	5		0.48	5	mV
Temperature Coefficient of Base to Emitter Voltage ($\Delta V_{BE}/\Delta T$)	V_{CE} = 5V, I_E = 1 mA		−1.9			−1.9		mV/°C
Collector to Emitter Saturation Voltage ($V_{CE(SAT)}$)	I_C = 10 mA, I_B = 1 mA		0.33			0.33		V
Temperature Coefficient of Input Offset Voltage ($\Delta V_{10}/\Delta T$)	I_C = 1 mA, V_{CE} = 5V		1.1			1.1		μV/°C

Note 1: The collector of each transistor is isolated from the substrate by an integral diode. The substrate must be connected to a voltage which is more negative than any collector voltage in order to maintain isolation between transitors and provide normal transistor action. To avoid undesired coupling between transistors, the substrate terminal should be maintained at either dc or signal (ac) ground. A suitable bypass capacitor can be used to establish a signal ground.

Note 2: If the transistors are forced into zener breakdown ($V_{(BR)EBO}$), degradation of forward transfer current ratio (h_{FE}) can occur.

Note 3: See curve.

ac electrical characteristics

PARAMETER	CONDITIONS	LIMITS LM3145A, LM3146A MIN	TYP	MAX	LM3145, LM3146 MIN	TYP	MAX	UNITS
Low Frequency Noise Figure (NF)	f = 1 kHz, V_{CE} = 5V, I_C = 100µA, R_S = 1 kΩ		3.25			3.25		dB
Gain Bandwidth Product (f_T)	V_{CE} = 5V, I_C = 3 mA	300	500		300	500		MHz
Emitter to Base Capacitance (C_{EB})	V_{EB} = 5V, I_E = 0		0.70			0.70		pF
Collector to Base Capacitance (C_{CB})	V_{CB} = 5V, I_C = 0		0.37			0.37		pF
Collector to Substrate Capacitance (C_{CI})	V_{CI} = 5V, I_C = 0		2.2			2.2		pF
LOW FREQUENCY, SMALL SIGNAL EQUIVALENT CIRCUIT CHARACTERISTICS								
Forward Current Transfer Ratio (h_{fe})	f = 1 kHz, V_{CE} = 3V, I_C = 1 mA		100			100		
Short Circuit Input Impedance (h_{ie})	f = 1 kHz, V_{CE} = 3V, I_C = 1 mA		2.7			3.5		kΩ
Open Circuit Output Impedance (h_{oe})	f = 1 kHz, V_{CE} = 3V, I_C = 1 mA		15.6			15.6		µmho
Open Circuit Reverse Voltage Transfer Ratio (h_{re})	f = 1 kHz, V_{CE} = 3V, I_C = 1 mA		1.8×10^{-4}			1.8×10^{-4}		
ADMITTANCE CHARACTERISTICS								
Forward Transfer Admittance (Y_{fe})	f = 1 MHz, V_{CE} = 3V, I_C = 1 mA		31 − j 1.5			31 − j 1.5		mmho
Input Admittance (Y_{ie})	f = 1 MHz, V_{CE} = 3V, I_C = 1 mA		0.35 + j 0.04			0.3 + j 0.04		mmho
Output Admittance (Y_{oe})	f = 1 MHz, V_{CE} = 3V, I_C = 1 mA		0.001 + j 0.03			0.001 + j 0.03		mmho
Reverse Transfer Admittance (Y_{re})	f = 1 MHz, V_{CE} = 3V, I_C = 1 mA		(Note 3)			(Note 3)		mmho

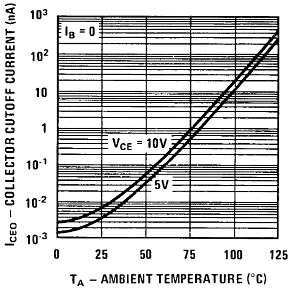
Note 1: The collector of each transistor is isolated from the substrate by an integral diode. The substrate must be connected to a voltage which is more negative than any collector voltage in order to maintain isolation between transitors and provide normal transistor action. To avoid undesired coupling between transistors, the substrate terminal should be maintained at either dc or signal (ac) ground. A suitable bypass capacitor can be used to establish a signal ground.

Note 2: If the transistors are forced into zener breakdown ($V_{(BR)EBO}$), degradation of forward transfer current ratio (h_{FE}) can occur.

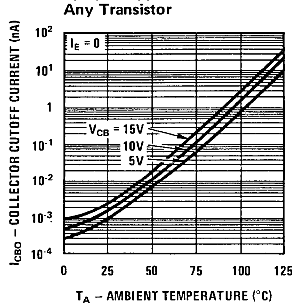
Note 3: See curve.

typical performance characteristics

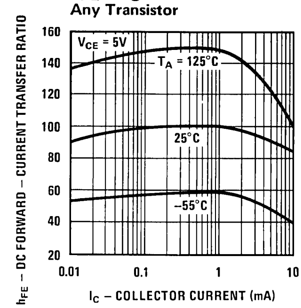
I_{CEO} vs T_A for Any Transistor



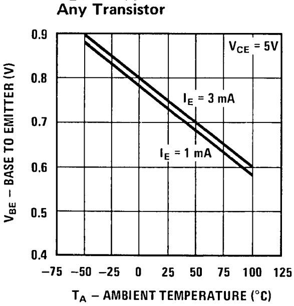
I_{CBO} vs T_A for Any Transistor



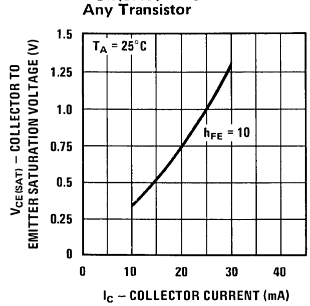
h_{FE} vs I_C for Any Transistor



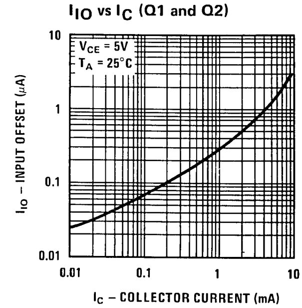
V_{BE} vs T_A for Any Transistor



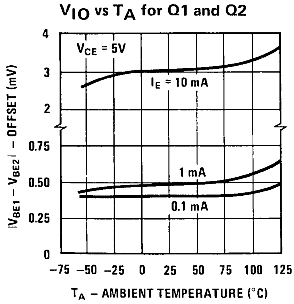
$V_{CE(SAT)}$ vs I_C for Any Transistor



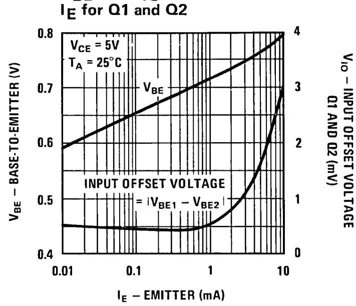
I_{IO} vs I_C (Q1 and Q2)



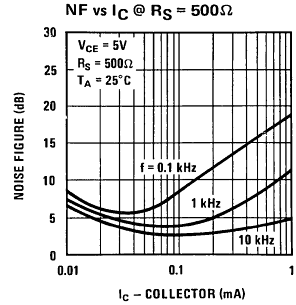
V_{IO} vs T_A for Q1 and Q2



V_{BE} and V_{IO} vs I_E for Q1 and Q2

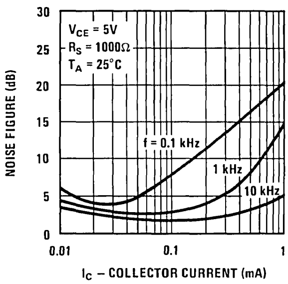


NF vs I_C @ R_S = 500Ω

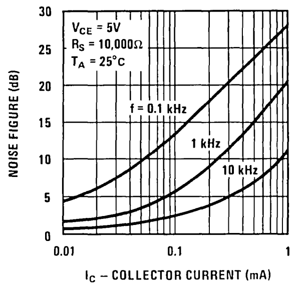


typical performance characteristics (con't)

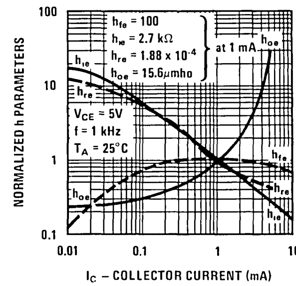
NF vs I_C @ R_S = 1 kΩ



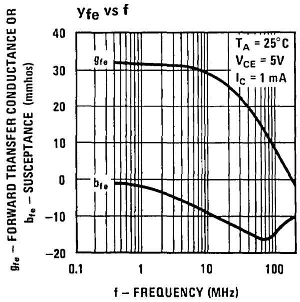
NF vs I_C = R_S = 10 kΩ



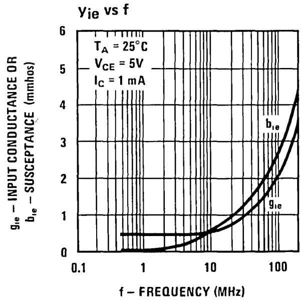
h_{fe}, h_{ie}, h_{oe}, h_{re} vs I_C



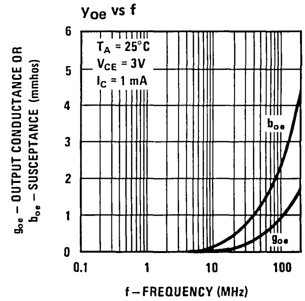
y_{fe} vs f



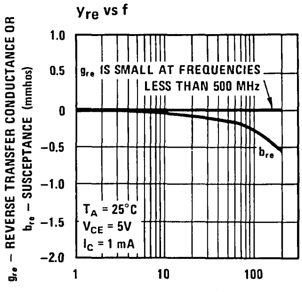
y_{ie} vs f



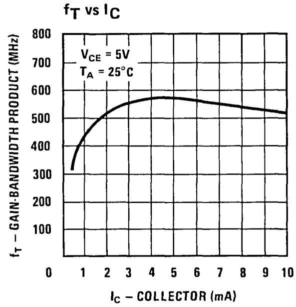
y_{oe} vs f



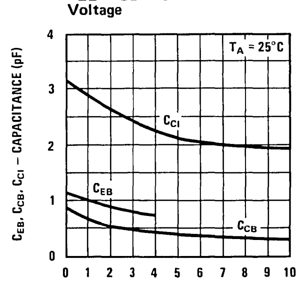
y_{re} vs f



f_T vs I_C



C_{EB}, C_{CB}, C_{CI} vs Bias Voltage



Analog Switches

AH0014/AH0014C* DPDT, AH0015/AH0015C quad SPST, AH0019/AH0019C* dual DPST-TTL/DTL compatible MOS analog switches

general description

This series ot TTL/DTL compatible MOS analog switches feature high speed with internal level shifting and driving. The package contains two monolithic integrated circuit chips: the MOS analog chip is similar to the MM450 type which consists of four MOS analog switch transistors; the second chip is a bipolar I.C. gate and level shifter. The series is available in both hermetic dual-in-line package and flatpack.

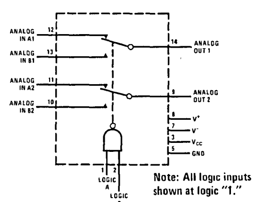
features

- Large analog voltage switching ±10V
- Fast switching speed 500 ns
- Operation over wide range of power supplies
- Low ON resistance 200Ω
- High OFF resistance 10^{11}Ω
- Fully compatible with DTL or TTL logic
- Includes gating and level shifting

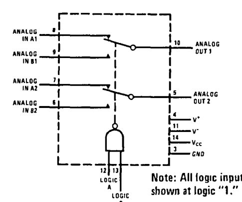
These switches are particularly suited for use in both military and industrial applications such as commutators in data acquisition systems, multiplexers, A/D and D/A converters, long time constant integrators, sample and hold circuits, modulators/demodulators, and other analog signal switching applications. For information on other National analog switches and analog interface elements, see listing on last page.

The AH0014, AH0015 and AH0019 are specified for operation over the –55°C to +125°C military temperature range. The AH0014C, AH0015C and AH0019C are specified for operation over the –25°C to +85°C temperature range.

block and connection diagrams

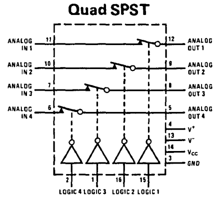


Order Number AH0014F or AH0014CF
See Package 4



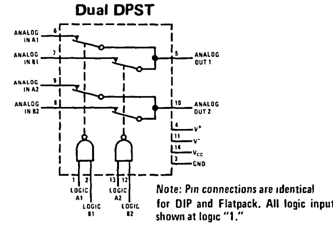
Order Number AH0014D or AH0014CD
See Package 1

Quad SPST



Order Number AH0015D or AH0015CD
See Package 2

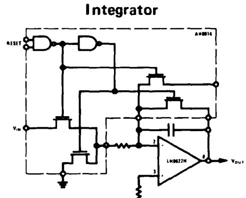
Dual DPST



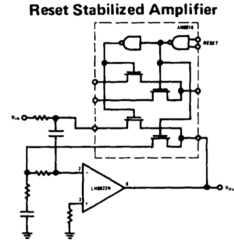
Order Number AH0019F or AH0019CF
See Package 4
Order Number AH0019D or AH0019CD
See Package 1

typical applications

Integrator



Reset Stabilized Amplifier



*Previously called NH0014/NH0014C and NH0019/NH0019C

absolute maximum ratings

V_{CC} Supply Voltage	7.0V
V^- Supply Voltage	−30V
V^+ Supply Voltage	+30V
V^+/V^- Voltage Differential	40V
Logic Input Voltage	5.5V
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	
AH0014, AH0015, AH0019	−55°C to +125°C
AH0014C, AH0015C, AH0019C	−25°C to +85°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Notes 1 and 2)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Logical "1" Input Voltage	V_{CC} = 4.5V		2.0			V
Logical "0" Input Voltage	V_{CC} = 4.5V				0.8	V
Logical "1" Input Current	V_{CC} = 5.5V	V_{IN} = 2.4V			5	μA
Logical "1" Input Current	V_{CC} = 5.5V	V_{IN} = 5.5V			1	mA
Logical "0" Input Current	V_{CC} = 5.5V	V_{IN} = 0.4V		0.2	0.4	mA
Power Supply Current Logical "1" Input – each gate (Note 3)	V_{CC} = 5.5V	V_{IN} = 4.5V		0.85	1.6	mA
Power Supply Current Logical "0" Input – each gate (Note 3)	V_{CC} = 5.5V	V_{IN} = 0V				
AH0014, AH0014C				1.5	3.0	mA
AH0015, AH0015C				0.22	0.41	mA
AH0019, AH0019C				0.22	0.41	mA
Analog Switch ON Resistance – each gate	V_{IN} (Analog) = +10V			75	200	Ω
	V_{IN} (Analog) = −10V			150	600	Ω
Analog Switch OFF Resistance				10^{11}		Ω
Analog Switch Input Leakage Current – each input (Note 4)	V_{IN} = −10V					
AH0014, AH0015, AH0019	T_A = 25°C			25	200	pA
	T_A = 125°C			25	200	nA
AH0014C, AH0015C, AH0019C	T_A = 25°C			0.1	10	nA
	T_A = 70°C			30	100	nA
Analog Switch Output Leakage Current – each output (Note 4)	V_{OUT} = −10V					
AH0014, AH0015, AH0019	T_A = 25°C			40	400	pA
	T_A = 125°C			40	400	nA
AH0014C, AH0015C, AH0019C	T_A = 25°C			0.05	10	nA
	T_A = 70°C			4	50	nA
Analog Input (Drain) Capacitance	1 MHz @ Zero Bias			8	10	pF
Output Source Capacitance	1 MHz @ Zero Bias			11	13	pF
Analog Turn-OFF Time – t_{OFF}	See test circuit; T_A = 25°C			400	500	ns
Analog Turn-ON Time – t_{ON}	See test circuit; T_A = 25°C					
AH0014, AH0014C				350	425	ns
AH0015, AH0015C				100	150	ns
AH0019, AH0019C				100	150	ns

Note 1: Min/max limits apply across the guaranteed temperature range of −55°C to +125°C for AH0014, AH0015, AH0019 and −25°C to +85°C for AH0014C, AH0015C, AH0019C. V^- = −20V. V^+ = +10V and an analog test current of 1 mA unless otherwise specified.

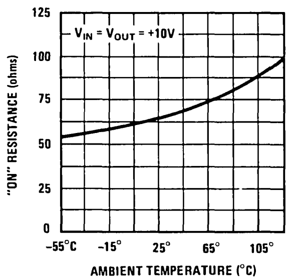
Note 2: All typical values are measured at T_A = 25°C with V_{CC} = 5.0V. V^+ = +10V, V^- = −22V.

Note 3: Current measured is drawn from V_{CC} supply.

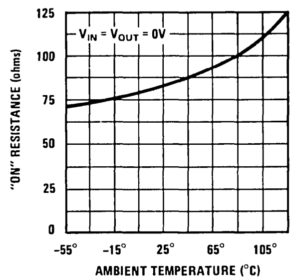
Note 4: All analog switch pins except measurement pin are tied to V^+.

analog switch characteristics (Note 2)

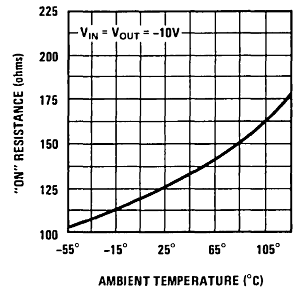
R_{ON} vs Temperature



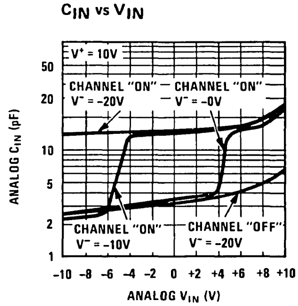
R_{ON} vs Temperature



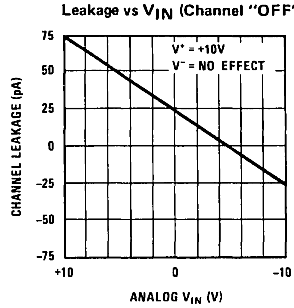
R_{ON} vs Temperature



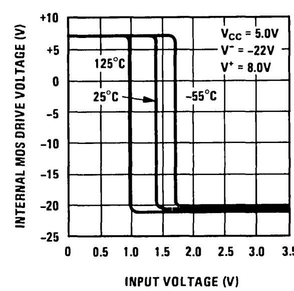
C_{IN} vs V_{IN}



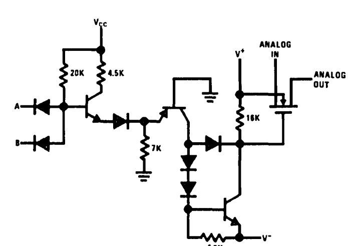
Leakage vs V_{IN} (Channel "OFF")



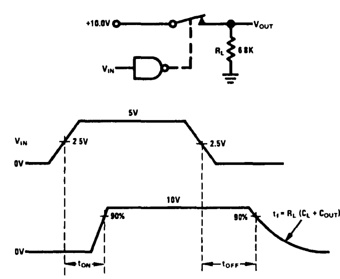
Driver Gate V_{IN} vs V_{OUT}



Schematic (Single Driver Gate and MOS Switch Shown)

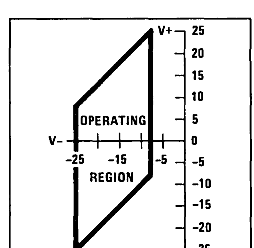


Analog Switching Time Test Circuit



selecting power supply voltage

The graph shows the boundary conditions which must be used for proper operation of the unit. The range of operation for power supply V⁻ is shown on the X axis. It must be between −25V and −8V. The allowable range for power supply V⁺ is governed by supply V⁻. With a value chosen for V⁻, V⁺ may be selected as any value along a vertical line passing through the V⁻ value and terminated by the boundaries of the operating region. A voltage difference between power supplies of at least 5V should be maintained for adequate signal swing.



7

Analog Switches

AH0120/AH0130/AH0140/AH0150/AH0160 series analog switches

general description

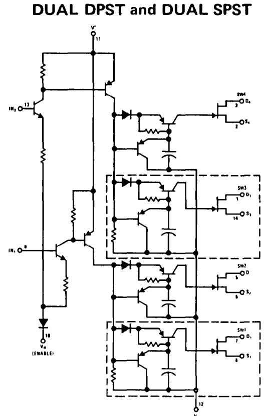
The AH0100 series represents a complete family of junction FET analog switches. The inherent flexibility of the family allows the designer to tailor the device selection to the particular application. Switch configurations available include dual DPST, dual SPST, DPDT, and SPDT. $r_{ds(ON)}$ ranges from 10 ohms through 100 ohms. The series is available in both 14 lead flat pack and 14 lead cavity DIP. Important design features include:

- TTL/DTL and RTL compatible logic inputs
- Up to 20V p-p analog input signal
- $r_{ds(ON)}$ less than 10Ω (AH0140, AH0141, AH0145, AH0146)
- Analog signals in excess of 1 MHz
- "OFF" power less than 1 mW
- Gate to drain bleed resistors eliminated
- Fast switching, t_{ON} is typically .4 μs, t_{OFF} is 1.0 μs
- Operation from standard op amp supply voltages, ±15V, available (AH0150/AH0160 series)
- Pin compatible with the popular DG 100 series.

The AH0100 series is designed to fulfill a wide variety of analog switching applications including commutators, multiplexers, D/A converters, sample and hold circuits, and modulators/demodulators. The AH0100 series is guaranteed over the temperature range −55°C to +125°C; whereas, the AH0100C series is guaranteed over the temperature range −25°C to +85°C.

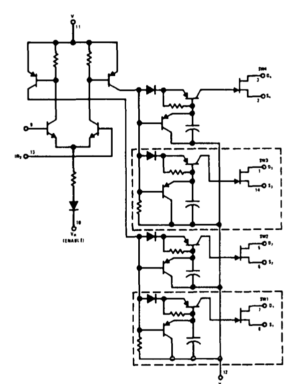
schematic diagrams

DUAL DPST and DUAL SPST



Note: Dotted line portions are not applicable to the dual SPST.

DPDT (diff.) and SPDT (diff.)

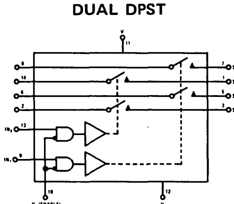


Note: Dotted line portions are not applicable to the SPDT (differential).

logic and connection diagrams

Order any of the devices below using the part number with a D or F suffix. See Packages 1 and 4.

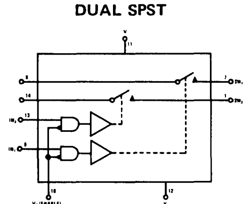
DUAL DPST



HIGH LEVEL (±10V)
AH0140 (10Ω)
AH0129 (30Ω)
AH0126 (80Ω)

MEDIUM LEVEL (±7.5V)
AH0153 (15Ω)
AH0154 (50Ω)

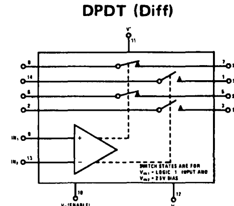
DUAL SPST



HIGH LEVEL (±10V)
AH0141 (10Ω)
AH0133 (30Ω)
AH0134 (80Ω)

MEDIUM LEVEL (±7.5V)
AH0151 (15Ω)
AH0152 (50Ω)

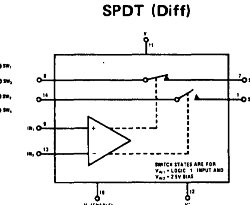
DPDT (Diff)



HIGH LEVEL (±10V)
AH0145 (10Ω)
AH0139 (30Ω)
AH0142 (80Ω)

MEDIUM LEVEL (±7.5)
AH0163 (15Ω)
AH0164 (50Ω)

SPDT (Diff)



HIGH LEVEL (±10V)
AH0146 (10Ω)
AH0144 (30Ω)
AH0143 (80Ω)

MEDIUM LEVEL (±7.5V)
AH0161 (15Ω)
AH0162 (50Ω)

absolute maximum ratings

		High Level	Medium Level
Total Supply Voltage ($V^+ - V^-$)		36V	34V
Analog Signal Voltage ($V^+ - V_A$ or $V_A - V^-$)		30V	25V
Positive Supply Voltage to Reference ($V^+ - V_R$)		25V	25V
Negative Supply Voltage to Reference ($V_R - V^-$)		22V	22V
Positive Supply Voltage to Input ($V^+ - V_{IN}$)		25V	25V
Input Voltage to Reference ($V_{IN} - V_R$)		±6V	±6V
Differential Input Voltage ($V_{IN} - V_{IN2}$)		±6V	±6V
Input Current, Any Terminal		30 mA	30 mA
Power Dissipation		See Curve	
Operating Temperature Range	AH0100 Series	−55°C to +125°C	
	AH0100C Series	−25°C to +85°C	
Storage Temperature Range		−65°C to +150°C	
Lead Temperature (Soldering, 10 sec)		300°C	

electrical characteristics for "HIGH LEVEL" Switches (Note 1)

PARAMETER	SYMBOL	DEVICE TYPE: DUAL DPST	DEVICE TYPE: DUAL SPST	DEVICE TYPE: DPDT (DIFF)	DEVICE TYPE: SPDT (DIFF)	CONDITIONS: $V^+ = 12.0V$, $V^- = -18.0V$, $V_R = 0.0V$		LIMITS: TYP	LIMITS: MAX	UNITS
Logic "1" Input Current	$I_{IN(ON)}$	All Circuits				Note 2	$T_A = 25°C$	2.0	60	μA
							Over Temp. Range		120	μA
Logic "0" Input Current	$I_{IN(OFF)}$	All Circuits				Note 2	$T_A = 25°C$	01	.1	μA
							Over Temp. Range		2.0	μA
Positive Supply Current Switch ON	$I^+_{(ON)}$	All Circuits				One Driver ON Note 2	$T_A = 25°C$	2 2	3.0	mA
							Over Temp. Range		3.3	mA
Negative Supply Current Switch ON	$I^-_{(ON)}$	All Circuits				One Driver ON Note 2	$T_A = 25°C$	-1.0	-1.8	mA
							Over Temp. Range		-2.0	mA
Reference Input (Enable) ON Current	$I_{R(ON)}$	All Circuits				One Driver ON Note 2	$T_A = 25°C$	-1.0	-1.4	mA
							Over Temp. Range		-1.6	mA
Positive Supply Current Switch OFF	$I^+_{(OFF)}$	All Circuits				$V_{IN1} = V_{IN2} = 0.8V$	$T_A = 25°C$	1.0	10	μA
							Over Temp. Range		25	μA
Negative Supply Current Switch OFF	$I^-_{(OFF)}$	All Circuits				$V_{IN1} = V_{IN2} = 0.8V$	$T_A = 25°C$	-1.0	-10	μA
							Over Temp. Range		-25	μA
Reference Input (Enable) OFF Current	$I_{R(OFF)}$	All Circuits				$V_{IN1} = V_{IN2} = 0.8V$	$T_A = 25°C$	-1.0	-10	μA
							Over Temp. Range		-25	μA
Switch ON Resistance	$r_{ds(ON)}$	AH0126	AH0134	AH0142	AH0143	$V_D = 10V$	$T_A = 25°C$	45	80	Ω
						$I_D = 1$ mA	Over Temp. Range		150	Ω
Switch ON Resistance	$r_{ds(ON)}$	AH0129	AH0133	AH0139	AH0144	$V_D = 10V$	$T_A = 25°C$	25	30	Ω
						$I_D = 1$ mA	Over Temp. Range		60	Ω
Switch ON Resistance	$r_{ds(ON)}$	AH0140	AH0141	AH0145	AH0146	$V_D = 10V$	$T_A = 25°C$	8	10	Ω
						$I_F = 1$ mA	Over Temp. Range		20	Ω
Driver Leakage Current	$(I_D + I_S)_{ON}$	All Circuits				$V_D = V_S = -10V$	$T_A = 25°C$	.01	1	nA
							Over Temp. Range		100	nA
Switch Leakage Current	$I_{S(OFF)}$ OR $I_{D(OFF)}$	AH0126 AH0129	AH0134 AH0133	AH0142 AH0139	AH0143 AH0144	$V_{DS} = \pm 20V$	$T_A = 25°C$	0 8	1	nA
							Over Temp. Range		100	nA
Switch Leakage Current	$I_{S(OFF)}$ OR $I_{D(OFF)}$	AH0140	AH0141	AH0145	AH0146	$V_{DS} = \pm 20V$	$T_A = 25°C$	4	10	nA
							Over Temp. Range		1.0	μA
Switch Turn-ON Time	t_{ON}	AH0126 AH0129	AH0134 AH0133	AH0142 AH0139	AH0143 AH0144	See Test Circuit $V_A = \pm 10V$	$T_A = 25°C$	0.5	0.8	μs
Switch Turn-ON Time	t_{ON}	AH0140	AH0141	AH0145	AH0146	See Test Circuit $V_A = \pm 10V$	$T_A = 25°C$	0.8	1.0	μs
Switch Turn-OFF Time	t_{OFF}	AH0126 AH0129	AH0134 AH0133	AH0142 AH0139	AH0143 AH0144	See Test Circuit $V_A = \pm 10V$	$T_A = 25°C$	0.9	1.6	μs
Switch Turn-OFF Time	t_{OFF}	AH0140	AH0141	AH0145	AH0146	See Test Circuit $V_A = \pm 10V$	$T_A = 25°C$	1.1	2.5	μs

Note 1: Unless otherwise specified these limits apply for −55°C to +125°C for the AH0100 series and −25°C to +85°C for the AH0100C series. All typical values are for $T_A = 25°C$.

Note 2: For the DPST and Dual DPST, the ON condition is for $V_{IN} = 2.5V$; the OFF condition is for $V_{IN} = 0.8V$. For the differential switches and SW1 and 2 ON, $V_{IN2} = 2.5V$, $V_{IN1} = 3.0V$. For SW3 and 4 ON, $V_{IN2} = 2.5V$, $V_{IN1} = 2.0V$.

electrical characteristics for "MEDIUM LEVEL" Switches (Note 1)

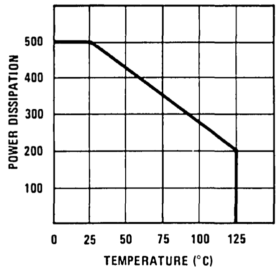
PARAMETER	SYMBOL	DEVICE TYPE: DUAL DPST	DUAL SPST	DUAL DPDT	SPDT (DIFF)	CONDITIONS: $V^+ = +15.0V$, $V^- = -15V$, $V_R = 0V$		LIMITS: TYP	MAX	UNITS
Logic "1" Input Current	$I_{IN(ON)}$	All Circuits				Note 2	$T_A = 25°C$	20	60	μA
							Over Temp. Range		120	μA
Logic "0" Input Current	$I_{IN(OFF)}$	All Circuits				Note 2	$T_A = 25°C$	.01	0.1	μA
							Over Temp. Range		2	μA
Positive Supply Current Switch ON	$I^+_{(ON)}$	All Circuits				One Driver ON Note 2	$T_A = 25°C$	2.2	3.0	mA
							Over Temp. Range		3.3	mA
Negative Supply Current Switch ON	$I^-_{(ON)}$	All Circuits				One Driver ON Note 2	$T_A = 25°C$	-1.0	-1.8	mA
							Over Temp. Range		-2.0	mA
Reference Input (Enable) ON Current	$I_{R(ON)}$	All Circuits				One Driver ON Note 2	$T_A = 25°C$	-1.0	-1.4	mA
							Over Temp. Range		-1.6	mA
Positive Supply Current Switch OFF	$I^+_{(OFF)}$	All Circuits				$V_{IN1} = V_{IN2} = 0.8V$	$T_A = 25°C$	1.0	10	μA
							Over Temp. Range		25	μA
Negative Supply Current Switch OFF	$I^-_{(OFF)}$	All Circuits				$V_{IN1} = V_{IN2} = 0.8V$	$T_A = 25°C$	-1.0	-10	μA
							Over Temp Range		-25	μA
Reference Input (Enable) OFF Current	$I_{R(OFF)}$	All Circuits				$V_{IN1} = V_{IN2} = 0.8V$	$T_A = 25°C$	-1.0	-10	μA
							Over Temp. Range		-25	μA
Switch ON Resistance	$r_{ds(ON)}$	AH0153	AH0151	AH0163	AH0161	$V_D = 7.5V$, $I_D = 1\ mA$	$T_A = 25°C$	10	15	Ω
							Over Temp. Range		30	Ω
Switch ON Resistance	$r_{ds(ON)}$	AH0154	AH0152	AH0164	AH0162	$V_D = 7.5V$, $I_D = 1\ mA$	$T_A = 25°C$	45	50	Ω
							Over Temp. Range		100	Ω
Driver Leakage Current	$(I_D + I_S)_{ON}$	All Circuits				$V_D = V_S = -7.5V$	$T_A = 25°C$	.01	2	nA
							Over Temp. Range		500	nA
Switch Leakage Current	$I_{D(OFF)}$ OR $I_{S(OFF)}$	AH0153	AH0151	AH0163	AH0161	$V_{DS} = \pm 15V$	$T_A = 25°C$	5	10	nA
							Over Temp. Range		1.0	μA
Switch Leakage Current	$I_{D(OFF)}$ OR $I_{S(OFF)}$	AH0154	AH0152	AH0164	AH0162	$V_{DS} = \pm 15.0V$	$T_A = 25°C$	1.0	2.0	nA
							Over Temp. Range		200	nA
Switch Turn-ON Time	t_{ON}	AH0153	AH0151	AH0163	AH0161	See Test Circuit, $V_A = \pm 7.5V$, $T_A = 25°C$		0.8	1.0	μs
Switch Turn-ON Time	t_{ON}	AH0154	AH0152	AH0164	AH0162	See Test Circuit, $V_A = \pm 7.5V$, $T_A = 25°C$		0.5	0.8	μs
Switch Turn-OFF Time	t_{OFF}	AH0153	AH0151	AH0163	AH0161	See Test Circuit, $V_A = \pm 7.5V$, $T_A = 25°C$		1.1	2.5	μs
Switch Turn-OFF Time	t_{OFF}	AH0154	AH0152	AH0164	AH0162	See Test Circuit, $V_A = \pm 7.5V$, $T_A = 25°C$		0.9	1.5	μs

Note 1: Unless otherwise specified, these limits apply for −55°C to +125°C for the AH0100 series and −25°C to +85°C for the AH0100C series. All typical values are for $T_A = 25°C$.

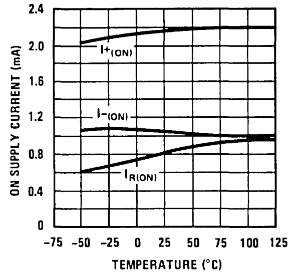
Note 2: For the DPST and Dual DPST, the ON condition is for $V_{IN} = 2.5V$; the OFF condition is for $V_{IN} = 0.8V$. For the differential switches and SW1 and 2 ON, $V_{IN2} = 2.5V$, $V_{IN1} = 3.0V$. For SW3 and 4 ON, $V_{IN2} = 2.5V$, $V_{IN1} = 2.0V$.

typical performance characteristics

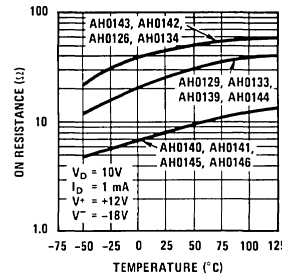
Power Dissipation vs Temperature



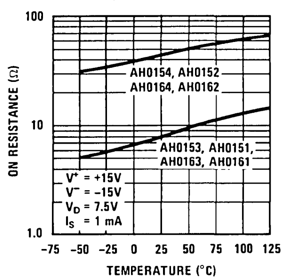
ON Supply Current vs Temperature



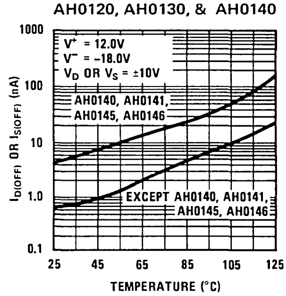
$r_{ds(ON)}$ vs Temperature AH0120 thru AH0140 Series



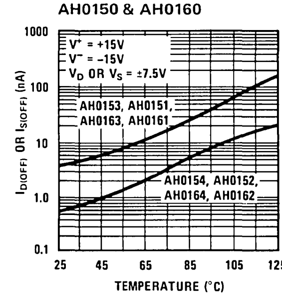
$r_{ds(ON)}$ vs Temperature AH0150/AH0160 Series



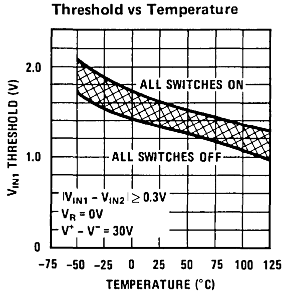
Leakage Current vs Temperature AH0120, AH0130, & AH0140



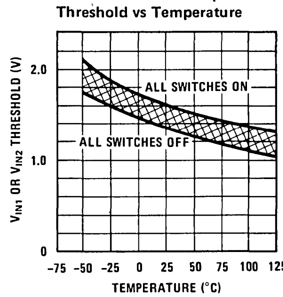
Leakage Current vs Temperature AH0150 & AH0160



Single Ended Switch Input Threshold vs Temperature

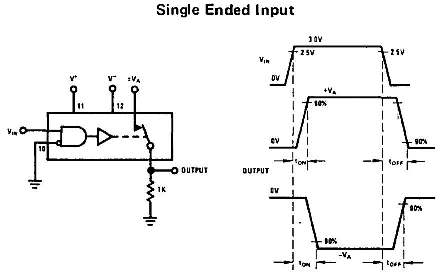


Differential Switch Input Threshold vs Temperature

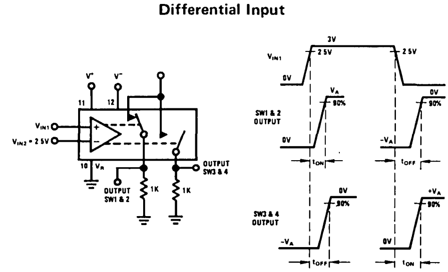


switching time test circuits

Single Ended Input



Differential Input



7

applications information

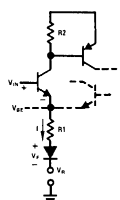
1. INPUT LOGIC COMPATIBILITY

A. Voltage Considerations

In general, the AH0100 series is compatible with most DTL, TTL, and RTL logic families. The ON-input threshold is determined by the V_{BE} of the input transistor plus the V_f of the diode in the emitter leg, plus I x R_1, plus V_R. At room temperature and V_R = 0V, the nominal ON threshold is: 0.7V+0.7V+0.2V,= 1.6V. Over temperature and manufacturing tolerances, the threshold may be as high as 2.5V and as low as 0.8V. The rules for proper operation are:

$V_{IN} - V_R \geq 2.5V$ All switches ON

$V_{IN} - V_R \leq 0.8V$ All switches OFF



B. Input Current Considerations

$I_{IN(ON)}$, the current drawn by the driver with V_{IN} = 2.5V is typically 20 μA at 25°C and is guaranteed less than 120 μA over temperature. DTL, such as the DM930 series can supply 180 μA at logic "1" voltages in excess of 2.5V. TTL output levels are comparable at 400 μA. The DTL and TTL can drive the AH0100 series directly. However, at low temperature, DC noise margin in the logic "1" state is eroded with DTL. A pull-up resistor of 10 kΩ is recommended when using DTL over military temperature range.

If more than one driver is to be driven by a DM930 series (6K) gate, an external pull-up resistor should be added. The value is given by:

$$R_P = \frac{11}{N-1} \text{ for } N > 2$$

where:

R_P = value of the pull-up resistor in kΩ

N = number of drivers.

C. Input Slew Rate

The slew rate of the logic input must be in excess of 0.3V/μs in order to assure proper operation of the analog switch. DTL, TTL, and RTL output rise times are far in excess of the minimum slew rate requirements. Discrete logic designs, however, should include consideration of input rise time.

2. ENABLE CONTROL

The application of a positive signal at the V_R terminal will open all switches. The V_R (ENABLE) signal must be capable of rising to within 0.8V of $V_{IN(ON)}$ in the OFF state and of sinking $I_{R(ON)}$ milliamps in the ON state (at $V_{IN(ON)} - V_R > 2.5V$). The V_R terminal can be driven from most TTL and DTL gates.

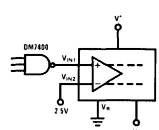
3. DIFFERENTIAL INPUT CONSIDERATIONS

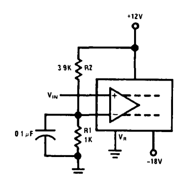
The differential switch driver is essentially a differential amplifier. The input requirements for proper operation are:

$$|V_{IN1} - V_{IN2}| \geq 0.3V$$

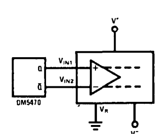
$$2.5 \leq (V_{IN1} \text{ or } V_{IN2}) - V_R \leq 5V$$

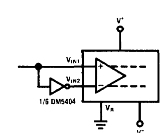
The differential driver may be furnished by a DC level as shown below. The level may be derived from a voltage divider to V^+ or the 5V V_{CC} of the DTL logic. In order to assure proper operation, the divider should be "stiff" with respect to I_{IN2}. Bypassing R1 with a 0.1 μF disc capacitor will prevent degradation of t_{ON} and t_{OFF}.



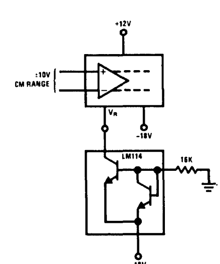


Alternatively, the differential driver may be driven from a TTL flip-flop or inverter.





Connection of a 1 mA current source between V_R and V^- will allow operation over a ±10V common mode range. Differential input voltage must be less than the 6V breakdown, and input threshold of 2.5V and 300mV differential overdrive still prevail.



4. ANALOG VOLTAGE CONSIDERATIONS

The rules for operating the AH0100 series at supply voltages other than those specified essentially breakdown into OFF and ON considerations. The OFF considerations are dictated by the maximum negative swing of the analog signal and the pinch off of the JFET switch. In the OFF state, the gate of the FET is at $V^- + V_{BE} + V_{SAT}$ or about 1.0V above the V^- potential. The maximum V_P of the FET switches is 7V. The most negative analog voltage, V_A, swing which can be accomodated for any given supply voltage is:

$$|V_A| \leq |V^-| - V_P - V_{BE} - V_{SAT} \text{ or}$$

$$|V_A| \leq |V^-| - 8.0 \text{ or } |V^-| \geq |V_A| + 8.0V$$

For the standard high level switches, $V_A \leq |-18| + 8 = -10V$. The value for V^+ is dictated by the maximum positive swing of the analog input voltage. Essentially the collector to base junction of the turn-on PNP must remain reversed biased for all positive value of analog input voltage. The base of the PNP is at $V^+ - V_{SAT} - V_{BE}$ or $V^+ - 1.0V$. The PNP's collector base junction should have at least 1.0V reverse bias. Hence, the most positive analog voltage swing which may be accommodated for a given value of V^+ is:

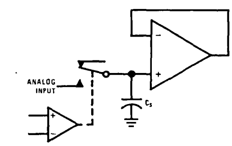
$$V_A \leq V^+ - V_{SAT} - V_{BE} - 1.0V \text{ or}$$

$$V_A \leq V^+ - 2.0V \text{ or } V^+ \geq V_A + 2.0V$$

For the standard high level switches, $V_A = 12 - 2.0V = +10V$.

5. SWITCHING TRANSIENTS

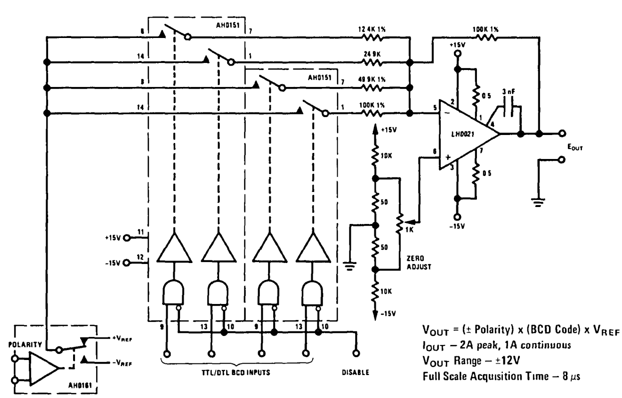
Due to charge stored in the gate-to-source and gate-to-drain capacitances of the FET switch, transients may appear in the output during switching. This is particularly true during the OFF to ON transition. The magnitude and duration of the transient may be minimized by making source and load impedance levels as small as practical.



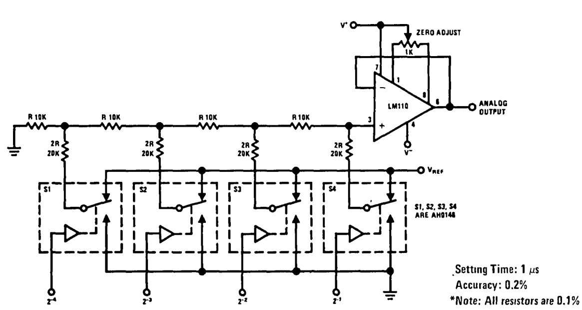
Furthermore, transients may be minimized by operating the switches in the differential mode; i.e., the charge delivered to the load during the ON to OFF transition is, to a large extent, cancelled by the OFF to ON transition.

typical applications

Programmable One Amp Power Supply

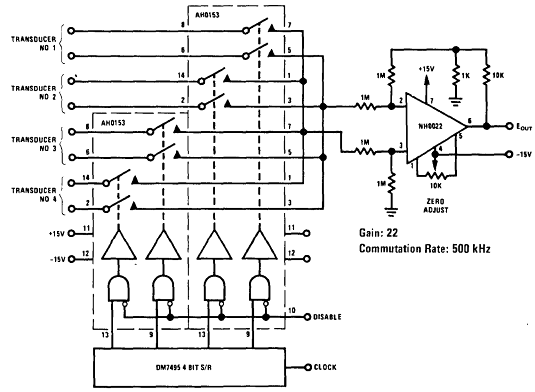


Four to Ten Bit D to A Converter (4 Bits Shown)



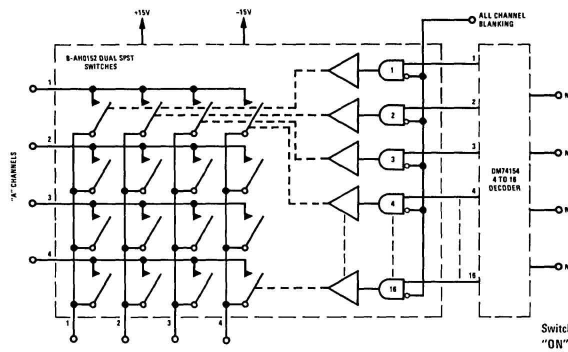
typical applications (con't)

Four Channel Differential Transducer Commutator



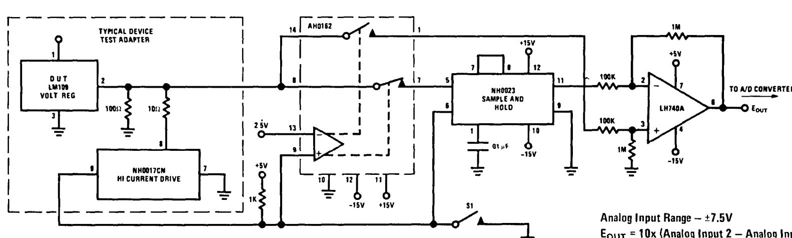
Gain: 22
Commutation Rate: 500 kHz

4 x 4 Cross Point Analog Switch



Switching Time – 800 ns
"ON" Resistance – 45Ω
"OFF" Resistance – 10^{10}Ω

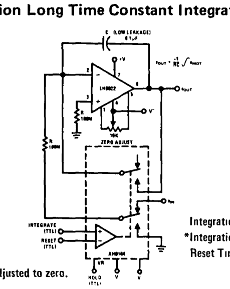
Delta Measurement System for Automatic Linear Circuit Tester



Note: S1 must be open for 50μs min to take first reading with I_L = 50 mA. Second reading is taken with S2 closed. With S1 and other set-up forcing functions under computer control, system will measure line and load regulation on voltage regulators, voltage gain, offset current, CMRR and PSRR on op amps as well as other circuits requiring measurement of the change of a parameter with the change of a forcing function.

Analog Input Range – ±7.5V
E_{OUT} = 10x (Analog Input 2 – Analog Input 1)
Error Rate – 0.01% F.S./sec

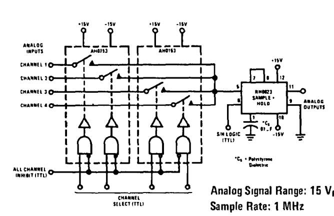
Precision Long Time Constant Integrator with Reset



Integration Internal = 10 sec
*Integration Error = 100μV
Reset Time: 30μs

*Note: V_{OS} adjusted to zero.

Four Channel Commutator



Analog Signal Range: 15 V_{P-P}
Sample Rate: 1 MHz
Acquisition Time: 20μs
Drift Rate: 0.5 mV/sec

Analog Switches

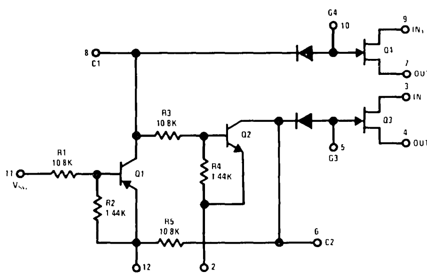
AH2114/AH2114C DPST analog switch general description

The AH2114 is a DPST analog switch circuit comprised of two junction FET switches and their associated driver. The AH2114 is designed to fulfill a wide variety of high level analog switching applications including multiplexers, A to D Converters, integrators, and choppers. Design features include:

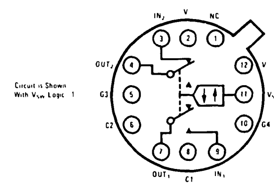
- Low ON resistance, typically 75Ω
- High OFF resistance, typically $10^{11}\Omega$
- Large output voltage swing, typically ±10V
- Powered from standard op-amp supply voltages of ±15V
- Input signals in excess of 1 MHz
- Turn-ON and turn-OFF times typically 1 μs

The AH2114 is guaranteed over the temperature range −55°C to +125°C whereas the AH2114C is guaranteed over the temperature range 0°C to +85°C.

schematic and connection diagrams



Metal Can Package



Order Number AH2114G or AH2114CG
See Package 6A

ac test circuit and waveforms

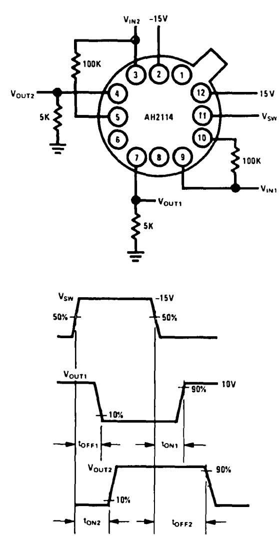


FIGURE 1.

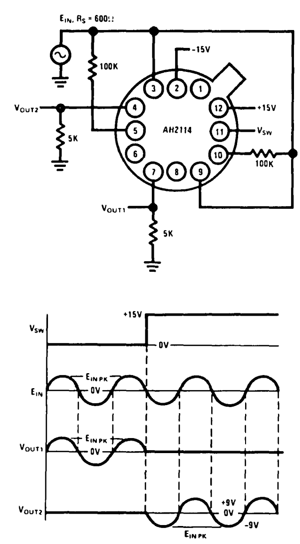


FIGURE 2.

absolute maximum ratings

Vplus Supply Voltage	+25V
Vminus Supply Voltage	−25V
Vplus−Vminus Differential Voltage	40V
Logic Input Voltage	25V
Power Dissipation (Note 3)	1.36W
Operating Temperature Range	
AH2114	−55°C to +125°C
AH2114C	0°C to +85°C
Storage Temperature Range	−65°C to +125°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Notes 1 and 2)

PARAMETER	CONDITIONS	AH2114			AH2114C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Static Drain-Source "On" Resistance	I_D = 1.0 mA, V_{GS} = 0V, T_A = 25°C		75	100		75	125	Ω
	I_D = 1.0 mA, V_{GS} = 0V			150			160	Ω
Drain-Gate Leakage Current	V_{DS} = 20V, V_{GS} = −7V, T_A = 25°C		0.2	1.0		0.2	5.0	nA
				60			60	nA
FET Gate-Source Breakdown Voltage	I_G = 1.0 μA, V_{DS} = 0V	35			35			V
Drain-Gate Capacitance	V_{DG} = 20V, I_S = 0, f = 1.0 MHz, T_A = 25°C		4.0	5.0		4.0	5.0	pF
Source-Gate Capacitance	V_{DG} = 20V, I_D = 0, f = 1.0 MHz, T_A = 25°C		4.0	5.0		4.0	5.0	pF
Input 1 Turn-ON Time	V_{IN1} = 10V, T_A = 25°C (See Figure 1)		35	60		35	60	ns
Input 2 Turn-ON Time	V_{IN2} = 10V, T_A = 25°C (See Figure 1)		1.2	1.5		1.2	1.2	μs
Input 1 Turn-OFF Time	V_{IN1} = 10V, T_A = 25°C (See Figure 1)		0.6	0.75		0.6	0.75	μs
Input 2 Turn-OFF Time	V_{IN2} = 10V, T_A = 25°C (See Figure 1)		50	80		50	80	ns
DC Voltage Range	T_A = 25°C (See Figure 2)	±9.0	±10.0		±9.0	±10.0		V
AC Voltage Range	T_A = 25°C (See Figure 2)	±9.0	±10.0		±9.0	±10.0		V

Note 1: Unless otherwise specified these specifications apply for pin 12 connected to +15V, pin 2 connected to −15V, −55°C to 125°C for the AH2114, and 0°C to 85°C for the AH2114C.

Note 2: All typical values are for T_A = 25°C.

Note 3: Derate linearly at 100°C/W above 25°C.

Analog Switches

AH5009 series low cost analog current switches

general description

The AH5009 series is a versatile family of analog switches designed to economically fulfill a wide variety of multiplexing and analog switching applications.

Even numbered switches (AH5010, AH5012, AH5014, etc.,) may be driven directly from standard (5V) TTL; whereas the odd numbered switches (AH5009, AH5011, AH5013, etc.,) are intended for applications utilizing open-collector (15V) structures.

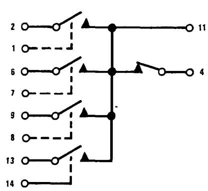
features

■ Large analog signal range	±10V peak
■ Excellent isolation between channels	80 dB at 1 kHz
■ Very low leakage	50 pA
■ High switching speed	150 ns
■ Low on resistance	100Ω
■ Interfaces with standard TTL	

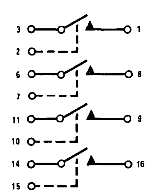
functional and schematic diagrams

(See additional types on page 7-18.)

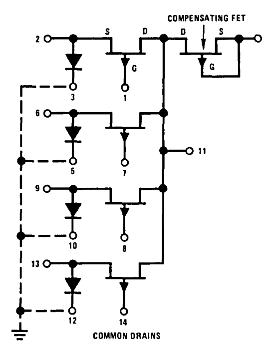
MUX Switches
(4 channel version shown)



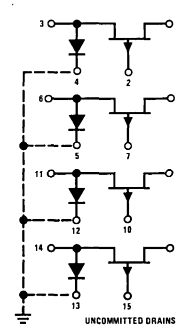
SPST Switches
(quad version shown)



MUX Switches
(4 channel version shown)

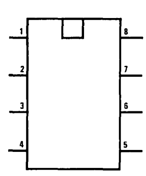


SPST Switches
(quad version shown)



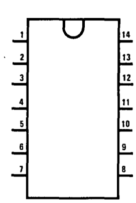
connection diagrams

Dual-In-Line Package



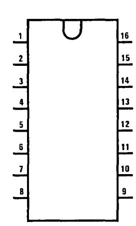
Order Number:
AH5017CN
AH5018CN
AH5019CN
AH5020CN
AH5020CN
AH5021CN
AH5022CN
AH5023CN
AH5024CN
See Package 20

Dual-In-Line Package



Order Number:
AH5009CN
AH5010CN
AH5013CN
AH5014CN
See Package 22

Dual-In-Line Package



Order Number
AH5011CN
AH5012CN
AH5015CN
AH5016CN
See Package 23

absolute maximum ratings

Input Voltage (V_{IN})	±30V
Positive Analog Signal Voltage (V_A)	30V
Negative Analog Signal Voltage (V_A)	−15V
Diode Current	10 mA
Drain Current (I_D)	30 mA
Power Dissipation (see graph)	500 mW
Operating Temperature Range	−25°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec.)	300°C

electrical characteristics (each channel)

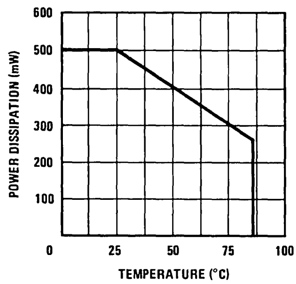
PARAMETER (Note 2)	CIRCUIT TYPE	CONDITIONS (Note 1)	TYP	MAX	UNITS
Input Current "ON" ($I_{IN(ON)}$)	All	V_{IN} = 0V, I_D = 2 mA, T_A = 25°C V_{IN} = 0V, I_D = 2 mA	.01	.1 100	μA μA
Input Current "OFF" ($I_{IN(OFF)}$)	5VTTL	V_{IN} = 4.5V, V_A = ±10V, T_A = 25°C V_{IN} = 4.5V, V_A = ±10V	.04	.2 10	nA nA
Input Current "OFF" ($I_{IN(OFF)}$)	15VTTL	V_{IN} = 11V, V_A = ±10V, T_A = 25°C	.04	.2 10	nA nA
Channel Control Voltage "ON" ($V_{IN(ON)}$)	5VTTL 15VTTL	V_A = ±10V, I_D = 1 mA V_A = ±10V, I_D = 1 mA		.5 1.5	V V
Channel Control Voltage "OFF" ($V_{IN(OFF)}$)	5VTTL 15VTTL	V_A = ±10V V_A = ±10V		4.5 11	V V
Leakage Current "OFF" ($I_{D(OFF)}$)	5VTTL	V_{IN} = 4.5V, V_A = ±10V, T_A = 25°C V_{IN} = 4.5V, V_A = ±10V	.02	.2 10	nA nA
Leakage Current "OFF" ($I_{D(OFF)}$)	15VTTL	V_{IN} = +11V, V_A = ±10V, T_A = 25°C V_{IN} = +11V, V_A = ±10V	.02	.2 10	nA nA
Leakage Current "ON" ($I_{D(ON)}$)	5VTTL	V_{IN} = 0V, I_S = 1mA, T_A = 25°C V_{IN} = 0V, I_S = 1 mA	.3	1 .2	nA μA
Leakage Current "ON" ($I_{D(ON)}$)	15VTTL	V_{IN} = 0V, I_S = 1 mA, T_A = 25°C V_{IN} = 0V, I_S = 1 mA	.1	.5 .1	nA μA
Leakage Current "ON" ($I_{D(ON)}$)	5VTTL	V_{IN} = 0V, I_S = 2 mA, T_A = 25°C V_{IN} = 0V, I_S = 2 mA		1 10	μA μA
Leakage Current "ON" ($I_{D(ON)}$)	15VTTL	V_{IN} = 0V, I_S = 2 mA, T_A = 25°C V_{IN} = 0V, I_S = 2 mA		2 1	nA μA
Drain-Source Resistance "ON" ($r_{DS(ON)}$)	5VTTL	V_{IN} = 0.5V, I_D = 2 mA, T_A = 25°C V_{IN} = 0.5V, I_D = 2 mA	90	150 240	Ω Ω
Drain-Source Resistance "ON" ($r_{DS(ON)}$)	15VTTL	V_{IN} = 1.5V, I_D = 2 mA, T_A = 25°C V_{IN} = 1.5V, I_D = 2 mA	60	100 160	Ω Ω
$r_{DS(ON)}$ Match (Effective $r_{DS(ON)}$)($r_{DS(ON)}$ EFF.)	15VTTL MUX 5VTTL MUX	V_{IN} = 1.5V, I_D = 2 mA V_{IN} = 0.5V, I_D = 2 mA		50	Ω
Turn-On Time ($t_{(ON)}$)	All	See AC Test Circuits, T_A = 25°C	150	500	ns
Turn-Off Time ($t_{(OFF)}$)	All	See AC Test Circuits, T_A = 25°C	300	500	ns
Cross Talk (CT)	All	See AC Test Circuits, T_A = 25°C	120		dB

Note 1: Unless otherwise noted, these specifications apply for −25°C to +85°C for AH5009C through AH5012C.

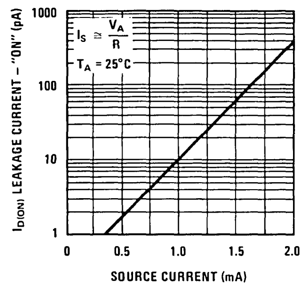
Note 2: "OFF" and "ON" notation refers to the conduction state of the FET switch.

typical performance characteristics

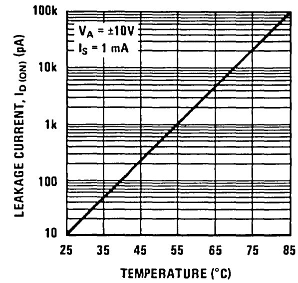
Maximum Power Dissipation



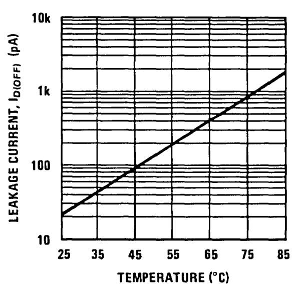
Leakage Current, $I_{D(ON)}$ vs I_S



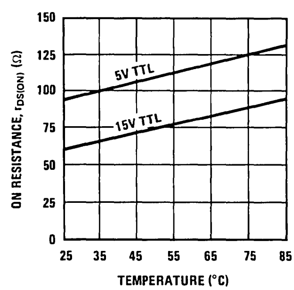
Leakage Current, $I_{D(ON)}$ vs Temperature



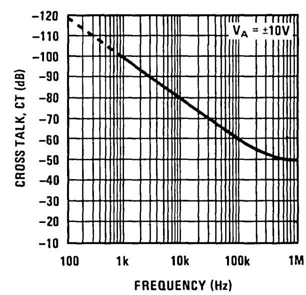
Leakage Current, $I_{D(OFF)}$ vs Temperature



On Resistance, $r_{DS(ON)}$ vs Temperature

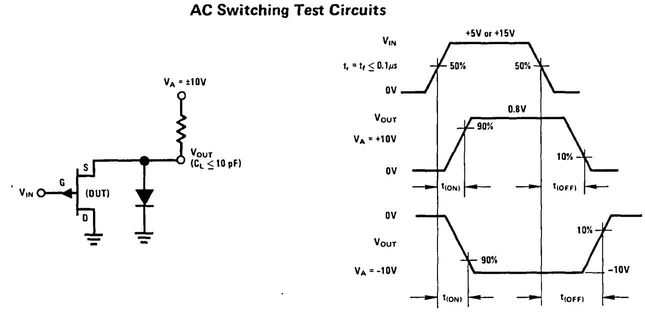


Cross Talk, CT vs Frequency

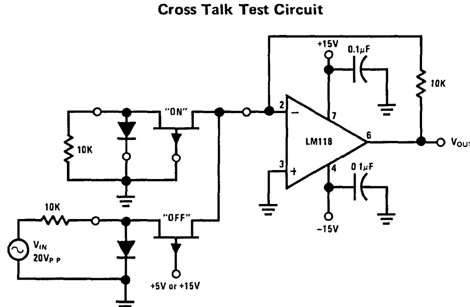


test circuits

AC Switching Test Circuits



Cross Talk Test Circuit



applications information

Theory of Operation

The AH5009 series of analog switches are primarily intended for operation in current mode switch applications; i.e., the drains of the FET switch are held at or near ground by operating into the summing junction of an operational amplifier. Limiting the drain voltage to under a few hundred mV eliminates the need for a special gate driver. Thus, the switch may be controlled with conventional TTL elements (5V) or with the open collector (15V) structures.

Two basic switch configurations are available: multiple independent switches (N by SPST) and multiple pole switches used for multiplexing (NPST-MUX). The MUX versions such as the AH5009 offer common drains and include a series FET operated at V_{GS} = 0V. The additional FET is placed in feedback path in order to compensate for the "ON" resistance of the switch FET as shown in Figure 1.

The closed-loop gain of Figure 1 is:

$$A_{VCL} = \frac{R_2 + r_{DS(ON)Q2}}{R_1 + r_{DS(ON)Q1}}$$

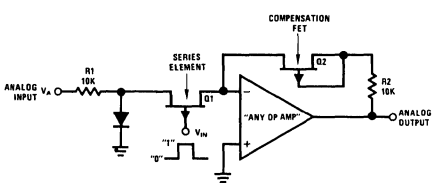


FIGURE 1. Use of Compensation FET

For R_1 = R_2, gain accuracy is determined by the $r_{DS(ON)}$ match between Q_1 and Q_2. Standard match between Q_1 and Q_2 is 50Ω resulting in a gain accuracy of 0.5% (for R_1 = R_2 = 10k). Tighter $r_{DS(ON)}$ match versions are available.

Noise Immunity

The switches with the source diodes grounded exhibit improved noise immunity for positive analog signals in the "OFF" state. With V_{IN} = 15V and the V_A = +10V, the source of Q_1 is clamped to about 0.6V by the diode (V_{GS} = 14.4V). The "ON" impedance of the diode is about 26Ω ensuring that AC signals imposed on the +10V will not gate the FET "ON."

Selection of Gain Setting Resistors

Since the AH5009 series of analog switches are operated current mode, it is generally advisable to make the signal current as large as possible. However, current through the FET switch tends to forward bias the gate to channel (source) diode resulting in leakage across the diode. This leakage, $I_{D(ON)}$, increases exponentially with increasing I_S. As shown in Figure 2, $I_{D(ON)}$ represents a finite error in the current reaching the summing junction of the op amp.

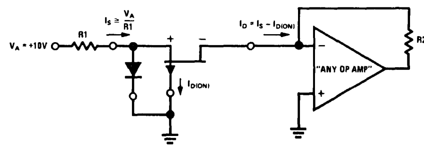


FIGURE 2. On Leakage Current, $I_{D(ON)}$

Secondly, the $r_{DS(ON)}$ of the FET begins to "round" as I_S approaches I_{DSS}. A practical rule of thumb is to maintain I_S at less than 1/10 of I_{DSS}.

Combining the criteria from the above discussion yields:

$$R_{1(MIN)} \geq \frac{V_{A(MAX)}\ A_D}{I_{D(ON)}} \qquad (2a)$$

or:

$$\geq \frac{V_{A(MAX)}}{I_{DSS}/10} \qquad (2b)$$

which ever is worse.

Where: $V_{A(MAX)}$ = Peak amplitude of the analog input signal

A_D = Desired accuracy

$I_{D(ON)}$ = Leakage at a given I_S

I_{DSS} = Saturation current of the FET switch

≅ 20 mA

In a typical application, V_A might = ±10V, A_D = 0.1%, 0°C ≤ T_A ≤ 85°C. The criterion of equation (2b) predicts:

$$R_{1(MIN)} \geq \frac{10V}{\frac{20MA}{10}} = 5k\Omega$$

For R_1 = 5k, I_S ≅ 10V/5k or 2 mA. The electrical characteristics guarantee an $I_{D(ON)} \leq 1\mu A$ at 85°C for the AH5010C. Per the criterion of equation (2a):

$$R_{1(MIN)} \geq \frac{(10V)(10^{-3})}{1 \times 10^{-6}} \geq 10k\Omega$$

Since equation (2a) predicts a higher value, the 10k resistor should be used.

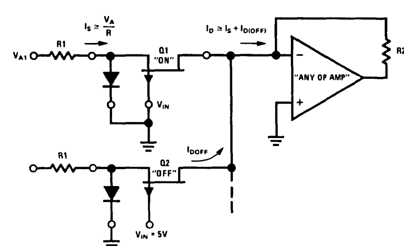


FIGURE 3.

The "OFF" condition of the FET also effects gain accuracy. As shown in Figure 3, the leakage across Q_2, $I_{D(OFF)}$ represents a finite error in the current arriving at the summing junction of the op amp.

applications information (con't)

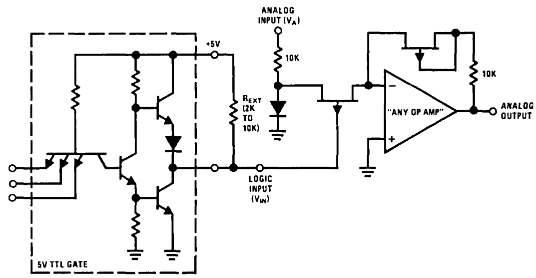


FIGURE 4. Interfacing with +5V Logic

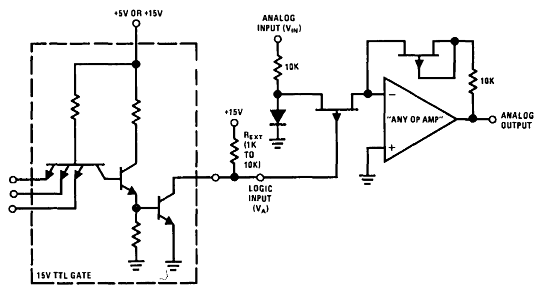


FIGURE 5. Interfacing with +15V Open Collector Logic

Accordingly:

$$R_{1(MAX)} \leq \frac{V_{A(MIN)}\ A_D}{(N)\ I_{D(OFF)}}$$

Where: $V_{A(MIN)}$ = Minimum value for the analog input signal

A_D = Desired accuracy

N = Number of channels

$I_{D(OFF)}$ = OFF leakage of a given FET switch

As an example, if N = 10, A_D = 0.1%, and $I_{D(OFF)}$ $\leq$ 10 nA at 85°C for the AH5009C, $R_{1(MAX)}$ is:

$$R_{1(MAX)} \leq \frac{(1V)(10^{-3})}{(10)(10 \times 10^{-9})} = 10k$$

Selection of R_2, of course, depends on the gain desired and for unity gain $R_1 = R_2$.

Lastly, the foregoing discussion has ignored resistor tolerances, input bias current and offset voltage of the op amp — all of which should be considered in setting the overall gain accuracy of the circuit.

TTL Compatibility

Two input logic drive versions of AH5009 series are available: the even numbered part types are specified to be driven from standard 5V-TTL logic and the odd numbered types from 15V open collector TTL.

Standard TTL gates pull-up to about 3.5V (no load). In order to ensure turn-off of the even numbered switches such as AH5010, a pull-up resistor, R_{EXT}, of at least 10 kΩ should be placed between the 5V V_{CC} and the gate output as shown in Figure 4.

Likewise, the open-collector, high voltage TTL outputs should use a pull-up resistor as shown in Figure 5. In both cases, $t_{(OFF)}$ is improved for lower values of R_{EXT} and the expense of power dissipation in the low state.

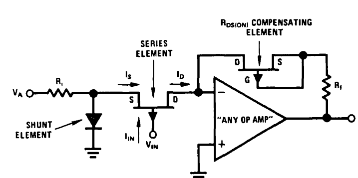


FIGURE 6. Definition of Terms

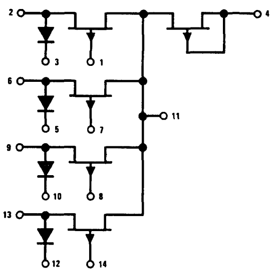
Definition of Terms

The terms referred to in the electrical characteristics tables are as defined in Figure 6.

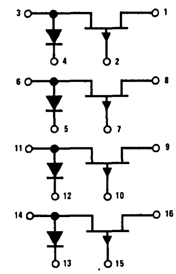
device schematics and pin connections

FOUR CHANNEL

AH5009CN ($R_{DS(ON)} \leq 100\Omega$ 15V - TTL)
AH5010CN ($R_{DS(ON)} \leq 150\Omega$ 5V - TTL)
14 PIN DIP

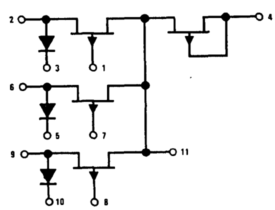


AH5011CN ($R_{DS(ON)} \leq 100\Omega$ 15V - TTL)
AH5012CN ($R_{DS(ON)} \leq 150\Omega$ 5V - TTL)
16 PIN DIP

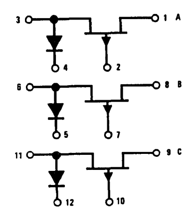


THREE CHANNEL

AH5013CN ($R_{DS(ON)} \leq 100\Omega$ 15V - TTL)
AH5014CN ($R_{DS(ON)} \leq 150\Omega$ 5V - TTL)
14 PIN DIP

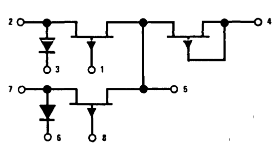


AH5015CN ($R_{DS(ON)} \leq 100\Omega$ 15V - TTL)
AH5016CN ($R_{DS(ON)} \leq 150\Omega$ 5V - TTL)
16 PIN DIP

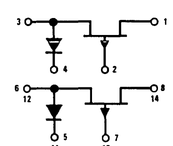


TWO CHANNEL

AH5017CN ($R_{DS(ON)} \leq 100\Omega$ 15V - TTL)
AH5018CN ($R_{DS(ON)} \leq 150\Omega$ 5V - TTL)
8 PIN DIP

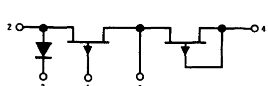


AH5019CN ($R_{DS(ON)} \leq 100\Omega$ 15V - TTL)
AH5020CN ($R_{DS(ON)} \leq 150\Omega$ 5V - TTL)
8 PIN DIP

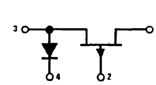


SINGLE CHANNEL

AH5021CN ($R_{DS(ON)} \leq 100\Omega$ 15V - TTL)
AH5022CN ($R_{DS(ON)} \leq 150\Omega$ 5V - TTL)
8 PIN DIP



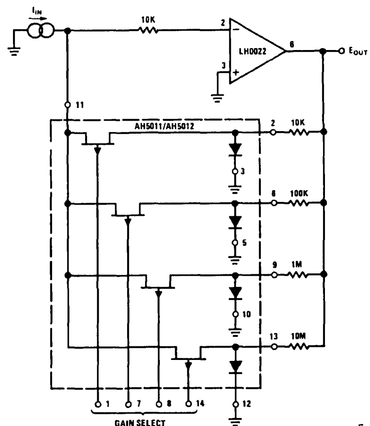
AH5023CN ($R_{DS(ON)} \leq 100\Omega$ 15V - TTL)
AH5024CN ($R_{DS(ON)} \leq 150\Omega$ 5V - TTL)
8 PIN DIP



Package Types — 8, 14, 16 pin epoxy "B"

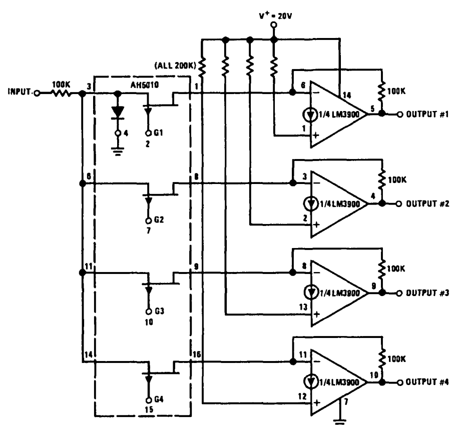
typical applications

Gain Programmable Amplifier

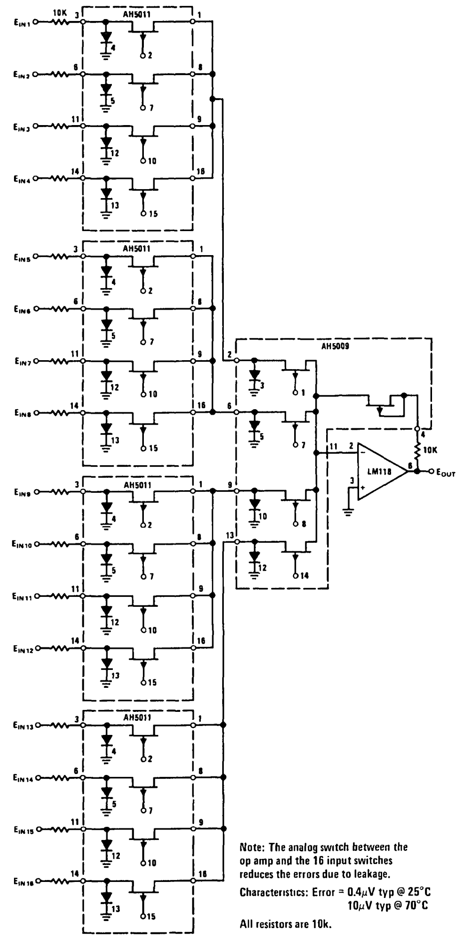


Characteristics: Gain = $\frac{-E_{OUT}}{I_{IN}} = R_{FB}$

Low Cost Demultiplexer



16-Channel Multiplexer

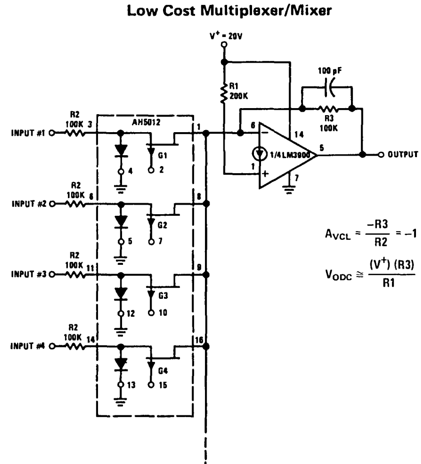


Note: The analog switch between the op amp and the 16 input switches reduces the errors due to leakage.

Characteristics: Error = 0.4μV typ @ 25°C
10μV typ @ 70°C

All resistors are 10k.

Low Cost Multiplexer/Mixer



$A_{VCL} = \frac{-R3}{R2} = -1$

$V_{ODC} \cong \frac{(V^+)(R3)}{R1} = +10V$

7

Analog Switches

AM1000,AM1001,AM1002 silicon N-channel high speed analog switch

general description

The AM1000 series are junction FET integrated circuit analog switches. These devices commutate faster and with less voltage spiking than any other analog switch presently available. By comparison, discrete JFET switches require elaborate drive circuits to obtain reasonable performance for high toggle rates. Encapsulated in a four pin TO-72 package, these units require a minimum of circuit board area. Switching transients are greatly reduced by a monolithic integrated circuit process. The resulting analog switch device provides the following features:

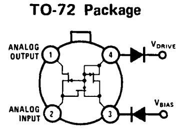
- Low ON Resistance 30Ω
- High Analog Signal Frequency 100 MHz
- High Toggle Rate 4 MHz
- Low Leakage Current 250 pA
- Large Analog Signal Swing ±15V
- Break Before Make Action

The AM1000 series of analog switches are particularly suitable for the following applications:

- High Speed Commutators
- Multiplexers
- Sample and Hold Circuits
- Reset Switching
- Video Switching

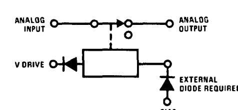
schematic and connection diagram

TO-72 Package



Order Number AM1000H or AM1001H or AM1002H See Package 9A

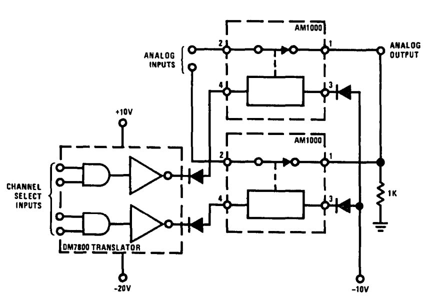
equivalent circuit



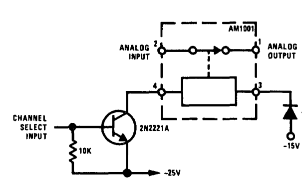
External diode required for drivers with pull-up circuit.

typical applications

±10 Volt Swing Analog Switch 0.5% Accuracy



±15 Volt Swing Analog Switch



absolute maximum ratings

	AM1001	AM1000 AM1002
V_{IN} (Note 1)	+50V	+40V
V_{OUT} (Note 1)	+50V	+40V
V_{DRIVE} (Note 1)	-50V	-40V
V_{BIAS} (Note 1)	+50V	+40V

Power Dissipation @ T_A = 25°C	300 mW
Linear Derating Factor	1.7 mW/°C
Power Dissipation @ T_C = 125°C	150 mW
Linear Derating Factor	6 mW/°C
Maximum Junction Operating Temperature	-55°C to +150°C
Storage Temperature	+200°C
Lead Temperature (Soldering, 10 sec)	+300°C

electrical characteristics

ON CHARACTERISTICS (Note 2)

PARAMETER	CONDITION		MIN	TYP	MAX	UNITS
R_{ON}	V_{DRIVE} = +15V, V_{BIAS} = −15V I_{IN} = 1 mA, V_{OUT} = 0V	AM1001	20	40	50	Ω
R_{ON}	V_{DRIVE} = +10V, V_{BIAS} = −10V I_{IN} = 1 mA, V_{OUT} = 0V	AM1000 AM1002	20 20	25 50	30 100	Ω Ω

OFF CHARACTERISTICS

PARAMETER	CONDITION	AM1000 AM1001			AM1002			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
$I_{OUT(OFF)}$	V_{DRIVE} = −20V, V_{BIAS} = −10V V_{IN} = − 10V, V_{OUT} = +10V							
	T_A = +25°C		.05	.25		0.5	1	nA
	T_A = +125°C		.025	.25		0.2	1	μA
$I_{OUT(OFF)}$	V_{DRIVE} = −20V, V_{BIAS} = −10V V_{IN} = +10V, V_{OUT} = −10V							
	T_A = +25°C		.05	.25		0.5	1	nA
	T_A = +125°C		05	.25		0.2	1	μA

DRIVE CHARACTERISTICS (Note 3)

PARAMETER	CONDITION	MIN	TYP	MAX	UNITS
I_{DRIVE} (Switch OFF)	V_{DRIVE} = −20V, V_{BIAS} = −10V AM1000, 1001, 1002 V_{IN} = ±10V, V_{OUT} = ±10V		5	10	mA

SWITCHING CHARACTERISTICS

PARAMETER	CONDITION	AM1000 MAX	AM1001 MAX	AM1002 MAX	UNITS
t_{ON}	See Switching Time Test Circuit	100	150	200	ns
t_{OFF}		100	100	100	ns

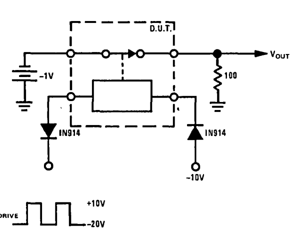
Note 1: The maximum voltage ratings may be applied between any pin or pins simultaneously. Power dissipation may be exceeded in some modes if the voltage pulse exceeds 10 ms. Normal operation will not cause excessive power dissipation even in a "D.C." switching application.

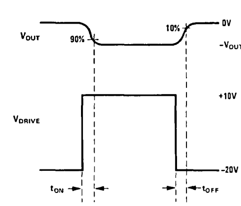
Note 2: All parameters are measured with external silicon diodes. See electrical connection diagram for proper diode placement.

Note 3: $I_{(BIAS)}$ (Switch OFF) is equal to $I_{(DRIVE)}$ (Switch OFF). $I_{(BIAS)}$ (Switch ON), is equal to external diode leakage.

Note 4: Rise and fall times of V_{DRIVE} shall be 15 ns maximum for switching time testing.

switching time test circuit and waveforms





7

Analog Switches

AM2009/AM2009C/MM4504/MM5504
six channel MOS multiplex switches

general description

The AM2009/AM2009C/MM4504/MM5504 are six channel multiplex switches constructed on a single silicon chip using low threshold P-channel MOS process. The gate of each MOS device is protected by a diode circuit.

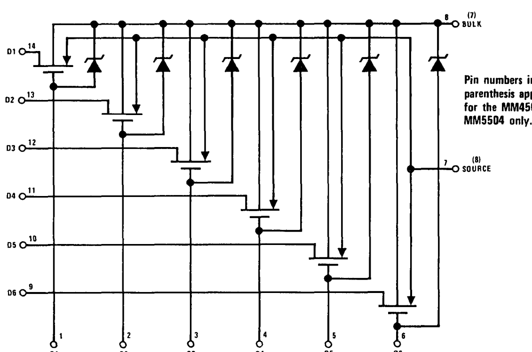
features

- Typical low "on" resistance 150Ω
- Typical low "off" leakage 100 pA
- Typical large analog voltage range ±10V
- Zero inherent offset voltage
- Normally off with zero gate voltage

The AM2009/AM2009C/MM4504/MM5504 are designed for applications such as time division multiplexing of analog or digital signals. Switching speeds are primarily determined by conditions external to the device such as signal source impedance, capacitive loading and the total number of channels used in parallel.

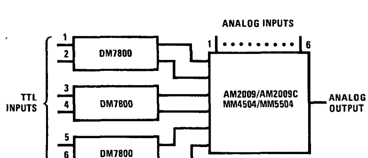
The AM2009/MM4504 are specified for operation over the -55°C to +125°C military temperature range. The AM2009C/MM5504 are specified for operation over the -25°C to +85°C temperature range.

schematic diagram

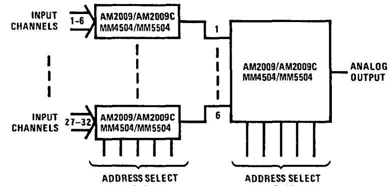


Order Number	Order Number
AM2009F or AM2009CF	AM2009D or AM2009CD
MM4504F or MM5504F	MM4504D or MM5504D
See Package 4	See Package 1

typical applications



TTL Compatible 6 Channel MUX



32 Channel MUX

absolute maximum ratings (V_{BULK} = 0V)

Voltage on Any Source or Drain	-30V	Total Power Dissipation (at T_A = 25°C)	900 mW
Voltage on Any Gate	-35V	Power Dissipation — each gate circuit	150 mW
Positive Voltage on Any Pin	+0.3V	Operating Temperature Range AM2009	-55°C to +125°C
Source or Drain Current	50 mA	AM2009C	-25°C to +85°C
Gate Current (forward direction of zener clamp)	0.1 mA	Storage Temperature Range	-65°C to +150°C
		Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 1)

PARAMETER	CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
Threshold Voltage	$V_{GS} = V_{DS}$, $I_{DS} = -1\ \mu A$	-1.0		-3.0	V
DC ON Resistance	$V_{GS} = -20V$, $I_{DS} = -100\ \mu A$, $T_A = 25°C$		150	250	Ω
DC ON Resistance	$V_{GS} = -10V$, $V_{SB} = -20V$, $I_{DS} = -100\ \mu A$, $T_A = 25°C$		500	1250	Ω
DC ON Resistance	$V_{GS} = -20V$, $I_{DS} = -100\ \mu A$			325	Ω
DC ON Resistance	$V_{GS} = -10V$, $V_{SB} = -20V$, $I_{DS} = -100\ \mu A$			1500	Ω
Gate Leakage	$V_{GS} = -20V$, Note 2			1.0	μA
	$V_{GS} = -20V$, Note 2, $T_A = 25°C$		100		pA
Input Leakage	$V_{DS} = -20V$, Note 2			1.0	μA
	$V_{DS} = -20V$, Note 2, $T_A = 25°C$		100		pA
Output Leakage	$V_{SD} = -20V$, Note 2			3.0	μA
	$V_{SD} = -20V$, Note 2, $T_A = 25°C$		500		pA
Gate-Bulk Breakdown Voltage	$I_{GB} = -10\ \mu A$, Note 2	-35			V
Source-Drain Breakdown Voltage	$I_{SD} = -10\ \mu A$, $V_{GD} = 0$, Note 2	-30			V
Drain-Source Breakdown Voltage	$I_{DS} = -10\ \mu A$, $V_{GS} = 0$, Note 2	-30			V
Transconductance			4000		mhos
Gate Capacitance	Note 3, f = 1 MHz		4.7	8	pF
Input Capacitance	Note 3, f = 1 MHz		4.6	8	pF
Output Capacitance	Note 3, f = 1 MHz		16	20	pF

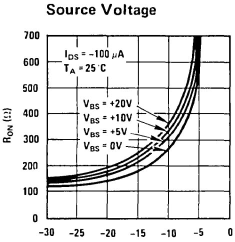
Note 1: Ratings apply over the specified temperature range and V_{BULK} = 0, unless otherwise specified.

Note 2: All other pins grounded.

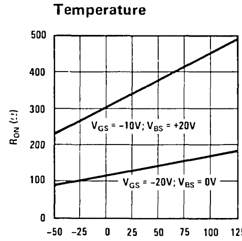
Note 3: Capacitance measured on dual-in-line package between pin under measurement to all other pins. Capacitances are guaranteed by design.

typical performance characteristics

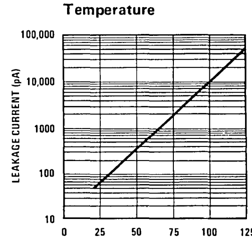
"ON" Resistance vs Gate-to-Source Voltage



"ON" Resistance vs T Temperature



Input Leakage Current vs Temperature



Analog Switches

AM3705/AM3705C 8-channel MOS analog multiplexer

general description

The AM3705/AM3705C is an eight-channel MOS analog multiplex switch. TTL compatible logic inputs that require no level shifting or input pull-up resistors and operation over a wide range of supply voltages is obtained by constructing the device with low threshold P-channel enhancement MOS technology. To simplify external logic requirements, a one-of-eight decoder and an output enable are included in the device.

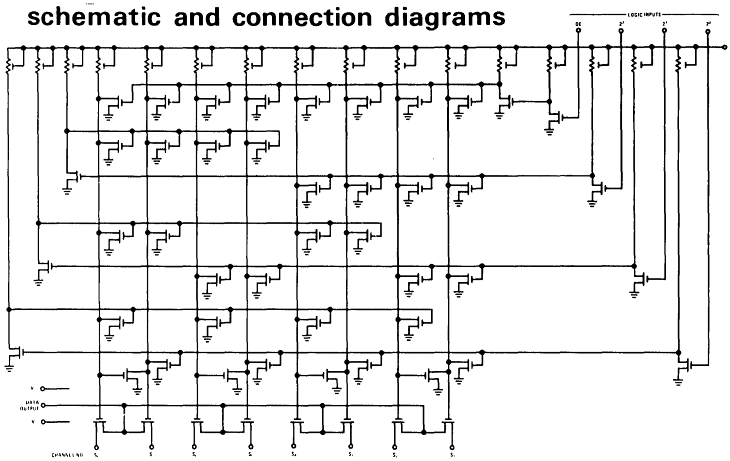
Important design features include:

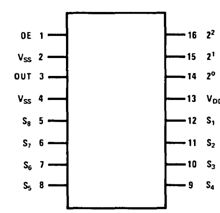
- TTL/DTL compatible input logic levels
- Operation from standard +5V and −15V supplies
- Wide analog voltage range — ±5V
- One-of-eight decoder on chip
- Output enable control
- Low ON resistance — 150Ω
- Input gate protection
- Low leakage currents — 0.5 nA

The AM3705/AM3705C is designed as a low cost analog multiplex switch to fulfill a wide variety of data acquisition and data distribution applications including cross-point switching, MUX front ends for A/D converters, process controllers, automatic test gear, programmable power supplies and other military or industrial instrumentation applications.

The AM3705 is specified for operation over the −55°C to +125°C military temperature range. The AM3705C is specified for operation over the −25°C to +85°C temperature range.

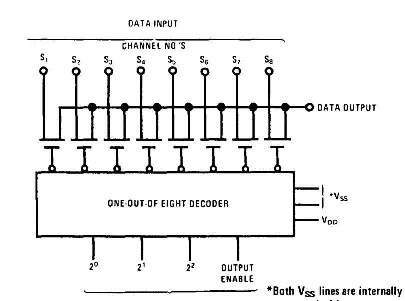
schematic and connection diagrams





Order Number
AM3705D or AM3705CD
See Package 2
AM3705F or AM3705CF
See Package 5

block diagram (MIL-STD-806B)



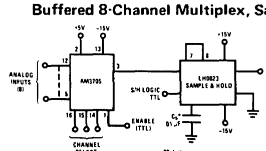
*Both V_{SS} lines are internally connected; either one or both may be used.

truth table

LOGIC INPUTS				CHANNEL
2^0	2^1	2^2	OE	ON
L	L	L	H	S_1
H	L	L	H	S_2
L	H	L	H	S_3
H	H	L	H	S_4
L	L	H	H	S_5
H	L	H	H	S_6
L	H	H	H	S_7
H	H	H	H	S_8
X	X	X	L	OFF

typical application

Buffered 8-Channel Multiplex, Sample and Hold



Analog Signal Range – 0.5V
Acquisition Time – 25 ns
Drift Rate – 0.5 mV/sec
Aperature Time – 250 ns

absolute maximum ratings

Positive Voltage on Any Pin (Note 1)		+0.3V
Negative Voltage on Any Pin (Note 1)		−35V
Source to Drain Current		±30 mA
Logic Input Current		±0.1 mA
Power Dissipation (Note 2)		500 mW
Operating Temperature Range	AM3705	−55°C to +125°C
	AM3705C	−25°C to +85°C
Storage Temperature Range		−65°C to +150°C
Lead Temperature (Soldering, 10 sec)		300°C

electrical characteristics (Note 3)

PARAMETER	SYMBOL	CONDITIONS	LIMITS			UNITS
			MIN	TYP	MAX	
ON Resistance	R_{ON}	$V_{IN} = V_{SS}$; $I_{OUT} = 100\,\mu A$		80	250	Ω
ON Resistance	R_{ON}	$V_{IN} = -5V$; $I_{OUT} = -100\,\mu A$		160	400	Ω
ON Resistance	R_{ON}	$V_{IN} = -5V$; $I_{OUT} = -100\,\mu A$				
AM3705		$T_A = +125°C$			400	Ω
AM3705C		$T_A = +70°C$			400	Ω
ON Resistance	R_{ON}	$V_{IN} = +5V$; $V_{DD} = -15V$; $I_{OUT} = 100\,\mu A$		100		Ω
ON Resistance	R_{ON}	$V_{IN} = 0V$, $V_{DD} = -15V$, $I_{OUT} = -100\,\mu A$		150		Ω
ON Resistance	R_{ON}	$V_{IN} = -5V$; $V_{DD} = -15V$; $I_{OUT} = -100\,\mu A$		250		Ω
OFF Resistance	R_{OFF}			10^{10}		Ω
Output Leakage Current	I_{LO}	$V_{SS} - V_{OUT} = 15V$		0.5	10	nA
AM3705	I_{LO}	$V_{SS} - V_{OUT} = 15V$; $T_A = 125°C$		150	500	nA
AM3705C	I_{LO}	$V_{SS} - V_{OUT} = 15V$; $T_A = 70°C$		35	500	nA
Data Input Leakage Current	I_{LDI}	$V_{SS} - V_{IN} = 15V$		0.1	3.0	nA
AM3705	I_{LDI}	$V_{SS} - V_{IN} = 15V$; $T_A = 125°C$		25	500	nA
AM3705C	I_{LDI}	$V_{SS} - V_{IN} = 15V$; $T_A = 70°C$		0.5	500	nA
Logic Input Leakage Current	I_{LI}	$V_{SS} - V_{Logic\,In} = 15V$		.001	1	μA
AM3705	I_{LI}	$V_{SS} - V_{Logic\,In} = 15V$; $T_A = 125°C$		.05	10	μA
AM3705C	I_{LI}	$V_{SS} - V_{Logic\,In} = 15V$; $T_A = 70°C$		.05	10	μA
Logic Input LOW Level	V_{IL}	$V_{SS} = +5.0V$		0.5	1.0	V
Logic Input LOW Level	V_{IL}		V_{DD}		$V_{SS} - 4.0$	V
Logic Input HIGH Level	V_{IH}	$V_{SS} = +5.0V$	3.0	3.5		V
Logic Input HIGH Level	V_{IH}		$V_{SS} - 2.0$		$V_{SS} + 0.3$	V
Channel Switching Time-Positive	t^+	Switching Time Test Circuit		300		ns
Channel Switching Time-Negative	t^-			600		ns
Channel Separation		f = 1 kHz		62		dB
Output Capacitance	C_{db}	$V_{SS} - V_{OUT} = 0$; f = 1 MHz		35		pF
Data Input Capacitance	C_{sb}	$V_{SS} - V_{DIP} = 0$; f = 1 MHz		6.0		pF
Logic Input Capacitance	C_{cg}	$V_{SS} - V_{Logic\,In} = 0$; f = 1 MHz		6.0		pF
Power Dissipation	P_D	$V_{DD} = -31V$, $V_{SS} = 0V$		125	175	mW

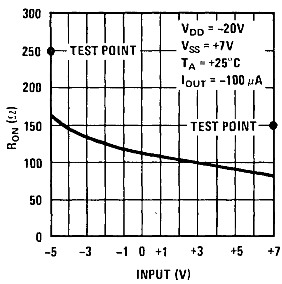
Note 1: All voltages referenced to V_{SS}.

Note 2: Ratings applies for ambient temperatures to +25°C, derate linearly at 3 mW/°C for ambient temperatures above +25°C.

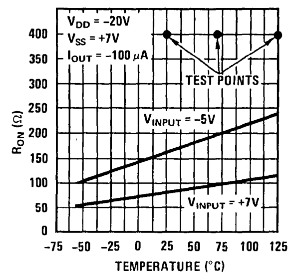
Note 3: Specifications apply for $T_A = 25°C$, $-24V \leq V_{DD} \leq -20V$, and $+5.0V \leq V_{SS} \leq +7.0V$; unless otherwise specified (all voltages are referenced to ground).

typical performance characteristics

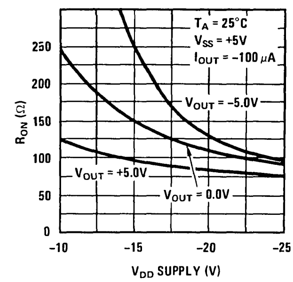
ON Resistance vs Analog Input Voltage



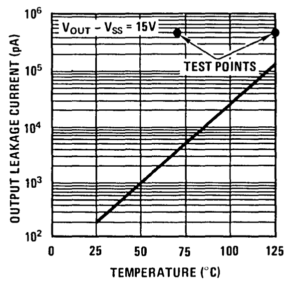
ON Resistance vs Ambient Temperature



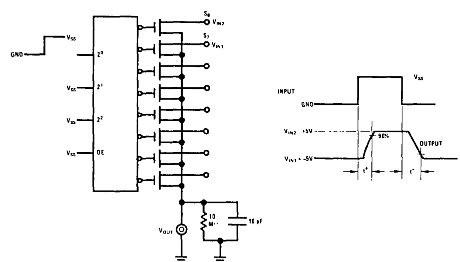
ON Resistance vs V_{DD} Supply Voltage



Output Leakage Current vs Ambient Temperature

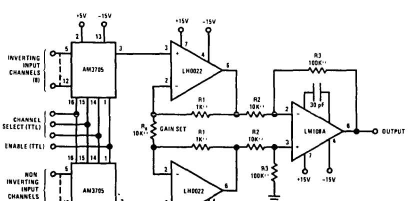


switching time test circuit



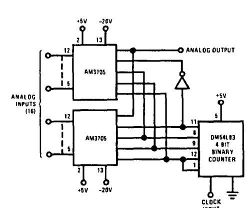
typical applications (con't.)

Differential Input MUX

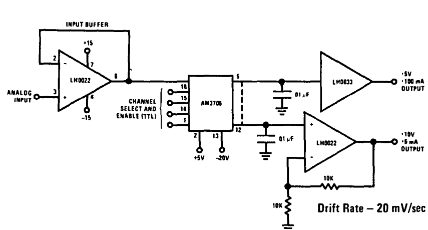


Voltage Gain = 200
Differential Input Resistance = 10^{10}Ω
CMRR = 100 dB
Input Current = 0.5 nA

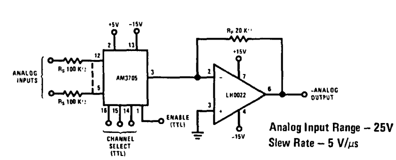
16-Channel Commutator



8-Channel Demultiplexer with Sample and Hold



Wide Input Range Analog Switch



Analog Input Range – 25V
Slew Rate – 5 V/µs

Analog Switches

MM450/MM550, MM451/MM551, MM452/MM552, MM455/MM555 MOS analog switches

general description

The MM450, and MM550 series each contain four p channel MOS enhancement mode transistors built on a single monolithic chip. The four transistors are arranged as follows:

MM450, MM550	Dual Differential Switch
MM451, MM551	Four Channel Switch
MM452, MM552	Four MOS Transistor Package
MM455, MM555	Three MOS Transistor Package

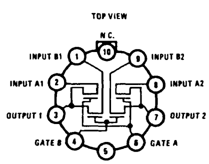
These devices are useful in many airborne and ground support systems requiring multiplexing, analog transmission, and numerous signal routing applications. The use of low threshold transistors (V_{TH} = 2 volts) permits operations with large analog input swings (± 10 volts) at low gate voltages (−20 volts). Significant features, then, include:

- Large Analog Input Swing ±10 Volts
- Low Supply Voltage V_{BULK} = +10 Volts, V_{GG} = −20 Volts
- Low ON Resistance V_{IN} = −10V 150Ω; V_{IN} = +10V 75Ω
- Low Leakage Current 200 pA @ 25°C
- Input Gate Protection
- Zero Offset Voltage

Each gate input is protected from static charge build-up by the incorporation of zener diode protective devices connected between the gate input and device bulk.

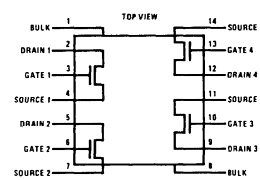
The MM450, MM451, MM452 and MM455 are specified for operation over the −55°C to +125°C military temperature range. The MM550, MM551, MM552 and MM555 are specified for operation over the −25°C to +70°C temperature range.

schematic and connection diagrams



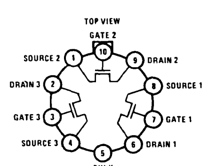
Note: Pin 5 connected to case and device bulk.
MM450, MM550

Order Number MM450H or MM550H
See Package 12



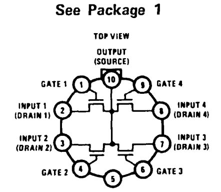
Note 1: Pins 1 and 8 connected to case and device bulk. Drain and Source may be interchanged.
MM452F, MM552F.
Note 2: MM452D and MM552D (dual-in-line packages) have same pin connections as MM452F and MM552F shown above.

Order Number MM452F or MM552F
See Package 4
Order Number MM452D or MM552D
See Package 1



Note: Pin 5 connected to case and device bulk. Drain and Source may be interchanged.
MM455, MM555

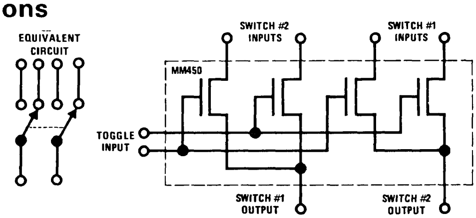
Order Number MM455H or MM555H
See Package 12



Note: Pin 5 connected to case and device bulk.
MM451, MM551

Order Number MM451H or MM551H
See Package 12

typical applications



DPDT Analog Switch

absolute maximum ratings

	MM450, MM451, MM452, MM455	MM550, MM551, MM552, MM555
Gate Voltage (V_{GG})	+10V to −30V	+10V to −30V
Bulk Voltage (V_{BULK})	+10V	+10V
Analog Input (V_{IN})	+10V to −20V	+10V to −20V
Power Dissipation	200 mW	200 mW
Operating Temperature	−55°C to +125°C	−25°C to 70°C
Storage Temperature	−65°C to +150°C	−65°C to +150°C

electrical characteristics

STATIC CHARACTERISTICS (Note 1)

PARAMETER	CONDITION	MIN	TYP	MAX	UNITS
Analog Input Voltage				±10	V
Threshold Voltage ($V_{GS(T)}$)	$V_{DG} = 0$, $I_D = 1\ \mu A$	1.0	2.2	3.0	V
ON Resistance	$V_{IN} = -10V$		150	600	Ω
ON Resistance	$V_{IN} = V_{SS}$		75	200	Ω
OFF Resistance			10^{10}		Ω
Gate Leakage Current (I_{GSB})	$V_{GS} = -25V$, $V_{BS} = 0$, $T_A = 25°C$		20		pA
Input (Drain) Leakage Current					
MM450, MM451, MM452, MM455	$T_A = 25°C$		.025	100	nA
	$T_A = 85°C$		.002	1.0	μA
	$T_A = 125°C$		.025	1.0	μA
Input (Drain) Leakage Current					
MM550, MM551, MM552, MM555	$T_A = 25°C$		0.1	100	nA
	$T_A = 70°C$		.030	1.0	μA
Output (Source) Leakage Current					
MM450, MM451, MM452, MM455	$T_A = 25°C$		.040	100	nA
Output (Source) Leakage Current					
MM450	$T_A = 85°C$			1.0	μA
MM451	$T_A = 85°C$			1.0	μA
MM452, MM455	$T_A = 85°C$			1.0	μA
MM450, MM451, MM452, MM455	$T_A = 125°C$			1.0	μA
Output (Source) Leakage Current					
MM550	$T_A = 70°C$			1.0	μA
MM551	$T_A = 70°C$			1.0	μA
MM552, MM555	$T_A = 70°C$			1.0	μA

DYNAMIC CHARACTERISTICS

Large Signal Transconductance	$V_{DS} = -10V$, $I_D = 10$ mA f = 1 kHz		4000		μmhos

CAPACITANCE CHARACTERISTICS (Note 2)

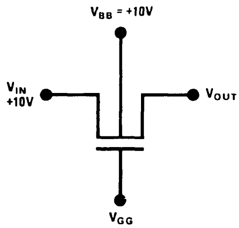
PARAMETER	DEVICE TYPE	MIN	TYP	MAX	UNITS
Analog Input (Drain) Capacitance (C_{DB})	ALL		8	10	pF
Output (Source) Capacitance (C_{SB})	MM450, MM550		11	14	pF
	MM451, MM551		20	24	pF
	MM452, MM552		7.5	11	pF
	MM455, MM555		7.5	11	pF
Gate Input Capacitance (C_{GB})	MM450, MM550		10	13	pF
	MM451, MM551		5.5	8	pF
	MM452, MM552		5.5	9	pF
	MM455, MM555		5.5	9	pF
Gate to Output Capacitance (C_{GS})	ALL		3.0	5	pF

Note 1: The resistance specifications apply for $-55°C \leq T_A \leq +85°C$, $V_{GG} = -20V$, $V_{BULK} = +10V$, and a test current of 1 mA. Leakage current is measured with all pins held at ground except the pin being measured which is biased at −25V.

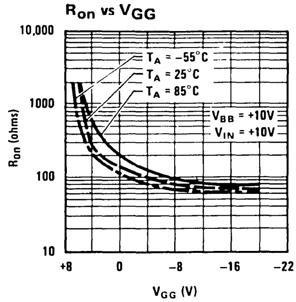
Note 2: All capacitance measurements are made at 0 volts bias at 1 MHz.

typical dynamic input characteristics (T_A = 25°C Unless Otherwise Noted)

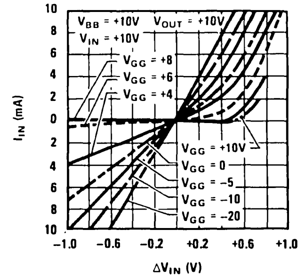
CONDITION 1:
ANALOG INPUT VOLTAGE
AT +10 VOLTS



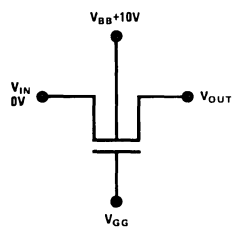
R_{on} vs V_{GG}



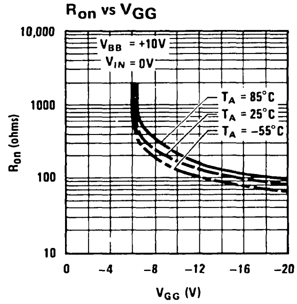
Dynamic R_{on}



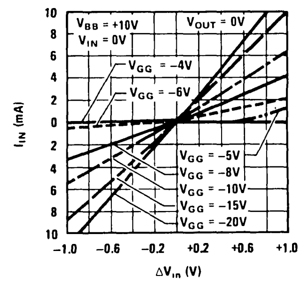
CONDITION 2:
ANALOG INPUT VOLTAGE
AT 0 VOLTS



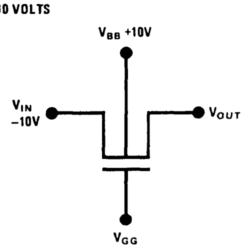
R_{on} vs V_{GG}



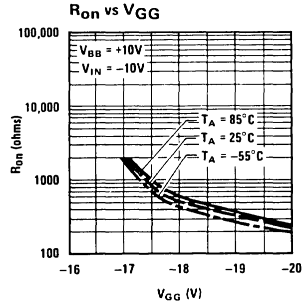
Dynamic R_{on}



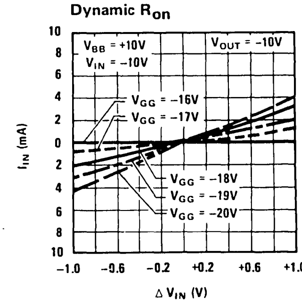
CONDITION 3:
ANALOG INPUT VOLTAGE
AT −10 VOLTS



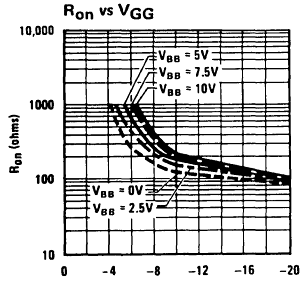
R_{on} vs V_{GG}



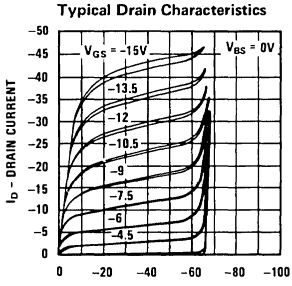
Dynamic R_{on}



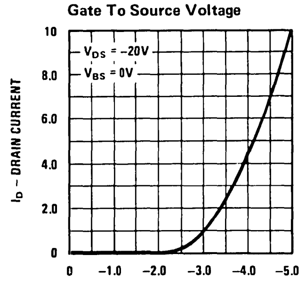
R_{on} vs V_{GG}



Typical Drain Characteristics

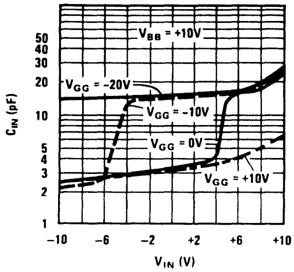


Drain Current vs Gate To Source Voltage

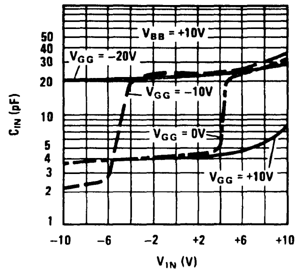


typical input capacitance characteristics

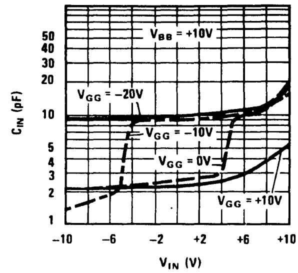
MM450, MM550
C_{IN} vs V_{IN}



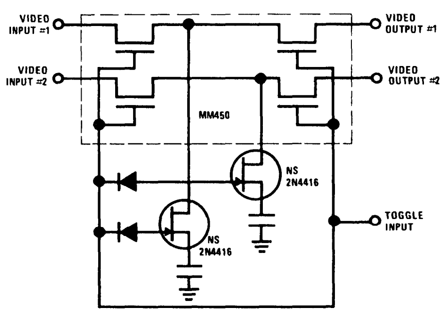
MM451, MM551
C_{IN} vs V_{IN}



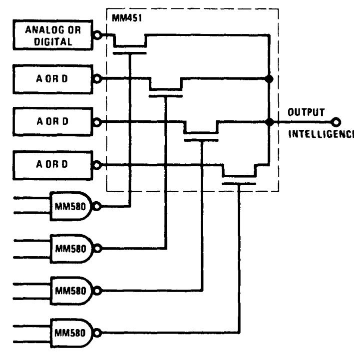
MM452, MM552, MM455, MM555
C_{IN} vs V_{IN}



typical applications (con't)



DPST High-Frequency Switch



4-Channel Multiplexer*

*Expansion in the number of data input lines is possible by using multiple level series switches allowing the same decode gates to be used for all lower rank decoding.

Analog Switches

MM454/MM554 four-channel commutator

general description

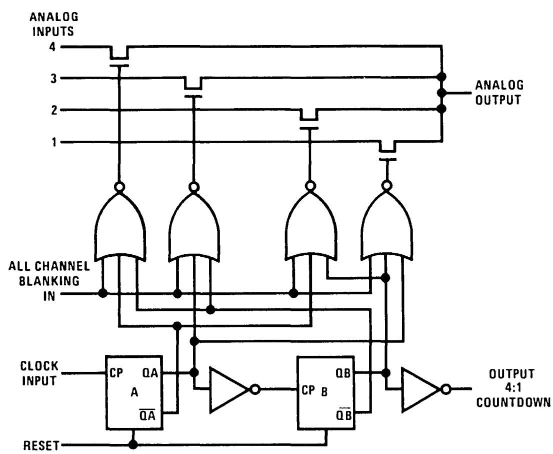
The MM454/MM554 is a four-channel analog commutator capable of switching four analog input channels sequentially onto an output line. The device is constructed on a single silicon chip using MOS P Channel enhancement transistors; it contains all the digital circuitry necessary to sequentially turn ON the four analog switch transistors permitting multiplexing of the analog input data. The device features:

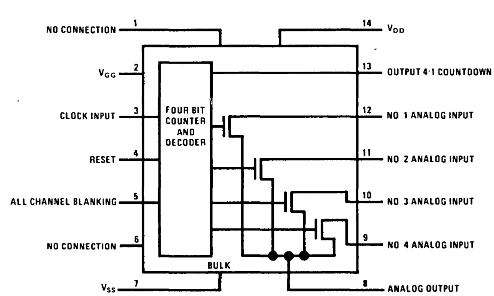
- High Analog Voltage Handling ±10V
- High Commutating Rate 500 kHz
- Low Leakage Current (T_A = 25°C) 200 pA
  (T_A = 85°C) 50 nA
- All Channel Blanking input provided
- Reset capability provided
- Low ON Resistance 200Ω

In addition, the MM454/MM554 can easily be applied where submultiplexing is required since a 4:1 clock countdown signal is provided which can drive the clock input of subsequent MM454/MM554 units.

The MM454 is specified for operation over the −55°C to +125°C military temperature range. The MM554 is specified for operation over the −25°C to +70°C temperature range.

schematic and connection diagrams





Note: Pin 7 connected to case and to device bulk. Nominal Operating Voltages: V_{GG} = −24V; V_{DD} = 0V; V_{SS} = +12V, Reset Bias = +12V (0V for Reset), all channel blanking bias = +12V (0V for blanking)

Order Number MM454F or MM554F
See Package 4

absolute maximum ratings (Note 1)

Gate Voltage (V_{GG})	+10V to −30V
Bulk Voltage (V_{SS})	+10V
Analog Input (V_{IN})	+10V to −20V
Power Dissipation	200 mW
Operating Temperature MM454	−55°C to +125°C
MM554	−25°C to +70°C
Storage Temperature	−65°C to +150°C

static characteristics (Note 2)

PARAMETER		CONDITION	MIN	TYP	MAX	UNITS
Analog Input Voltage					±10	V
ON Resistance		V_{IN} = −10V		170	600	Ω
ON Resistance		$V_{IN} = V_{SS}$		90	200	Ω
OFF Resistance				10^{10}		Ω
Analog Input Leakage Current	MM454	T_A = 25°C		.050	100	nA
	MM454	T_A = 85°C		.006	1.0	μA
	MM554	T_A = 25°C		.0001	100	nA
	MM554	T_A = 70°C		.030	1.0	μA
Analog Output Leakage Current	MM454	T_A = 25°C		0.100	100	nA
	MM454	T_A = 85°C		30	1.0	μA
	MM554	T_A = 25°C		.0001	100	nA
	MM554	T_A = 70°C		.030	1.0	μA
V_{SS} Supply Current Drain		V_{SS} = +12V		3.8	5.5	mA
V_{GG} Supply Current Drain		V_{GG} = −24V		2.4	3.5	mA

capacitance characteristics

PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
Analog Input Capacitance Channel OFF	I_{IN} = 0		4	6	pF
Analog Input Capacitance Channel ON	I_{IN} = 0		20	24	pF
Analog Output Capacitance	I_{IN} = 0		20	24	pF
Clock Input	V_{CL} = +12V		2.0		pF
Reset Input	V_{RESET} = +12V		2.0		pF
Blanking Input	V_{BLANK} = +12V		2.0		pF

clock characteristics (Note 3)

PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
Clock Input (HIGH)(4)		V_{SS} − 2		V_{SS}	V
Clock Input (LOW)		−5	0	+5	V
Clock Input Rise Time (POS GOING)			No requirement		
Clock Input Fall Time (NEG GOING)				20	μsec
Countdown Output (POS) V_{OH}		V_{SS} −2		V_{SS}	V
Countdown Output (NEG) V_{OL}			0		V
Maximum Commutation Rate		0.5	2.0		MHz
V_{SS}		+10.0	+12	+14	V

Note 1: Maximum ratings are limiting values above which the device may be damaged. All voltages referenced to V_{DD} = 0.

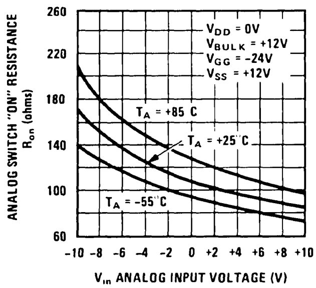
Note 2: These specifications apply over the indicated operating temperature range for V_{GG} = −24V, V_{DD} = 0V, V_{SS} = +12V, V_{RESET} = +12V, V_{BLANK} = +12V. ON resistance measured at 1 mA, OFF resistance and leakage measured with all analog inputs and output common. Capacitance measured at 1 MHz.

Note 3: Operating conditions in Note 2 apply. V_{SS} to V_{DD} (0V) voltage is applied to counting and gating circuits. V_{GG} is required only for analog switch biasing. All logic inputs are high resistance and are essentially capacitive.

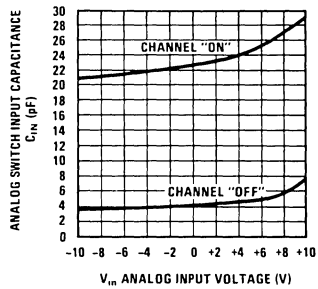
Note 4: Logic input voltage must not be more positive than V_{SS}.

typical performance characteristics

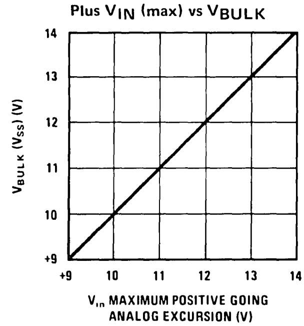
R_{ON} vs Analog Voltage



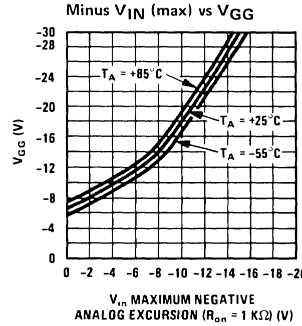
C_{IN} vs V_{IN}



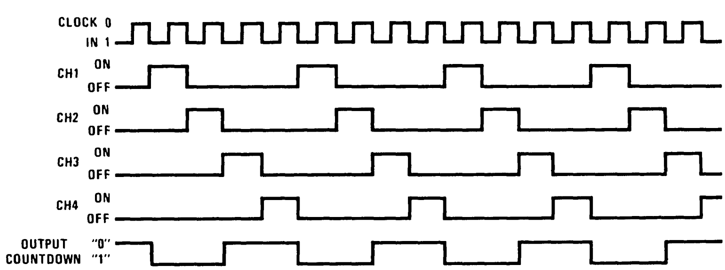
Plus V_{IN} (max) vs V_{BULK}



Minus V_{IN} (max) vs V_{GG}



timing diagram



NOTE: "0" LEVEL = +12V
"1" LEVEL = 0V (GND)

New Products

LF156 monolithic JFET input operational amplifier

general description

The LF156 is the first monolithic JFET input operational amplifier to incorporate well-matched, high voltage JFETs on the same chip with standard bipolar transistors. The amplifier features low input bias and offset currents, low offset voltage and offset voltage drift, coupled with offset adjust which does not degrade drift or common-mode rejection. The device was also designed for high slew rate, wide bandwidth, extremely fast settling time, low voltage and current noise and a low 1/f noise corner.

features

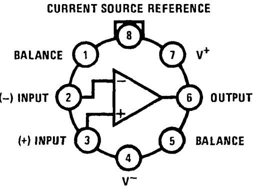
- Low input current 30 pA
- Low offset voltage 3 mV
- Guaranteed offset voltage drift 5μV/°C
- Low input noise voltage 12 nV/√Hz
- Low 1/f noise corner < 100 Hz
- Wide bandwidth 5 mHz
- Fast slew rate 15V/μs
- Fast settling to 0.01% 1.4μs
- Internally compensated
- Stable with large capacitive loads
- Operates from standard op amp supplies

applications

- Precision high speed integrators
- Sample and hold circuits
- Fast D/A and A/D converters
- Low noise amplifiers for high impedance transducers
- Wideband low noise, low drift amplifiers
- High impedance buffers
- High frequency, high impedance active filters

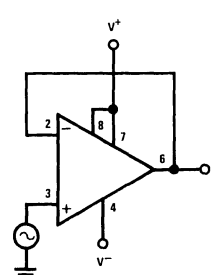
connection diagram

Metal Can Package



TOP VIEW

typical application



Note: Pin 8 must be connected to Pin 7 when offset adjust is not used.

New Products

LM388 1.5 watt audio power amplifier

general description

The LM388 is an audio amplifier designed for use in medium power consumer applications. The gain is internally set to 20 to keep external part count low, but the addition of an external resistor and capacitor between pins 2 and 6 will increase the gain to any value up to 200.

The inputs are ground referenced while the output is automatically biased to one half the supply voltage.

- Self-centering output quiescent voltage
- Variable voltage gain
- Low distortion
- Fourteen pin dual-in-line package

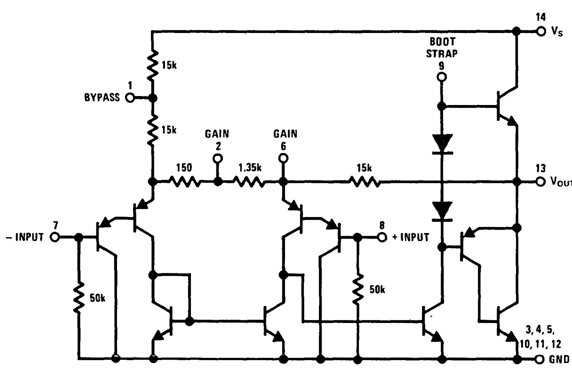
features

- Minimum external parts
- Wide supply voltage range 4V to 12V
- Excellent supply rejection 50 dB
- Ground referenced input

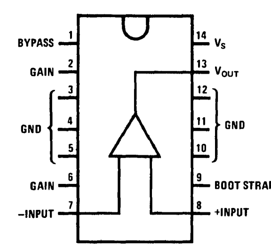
applications

- AM-FM radio amplifiers
- Portable tape player amplifiers
- Intercoms
- TV sound systems
- Lamp drivers
- Line drivers
- Ultrasonic drivers
- Small servo drivers
- Power converters

equivalent schematic and connection diagrams



Dual-In-Line Package



typical applications

Amplifier with Gain = 20

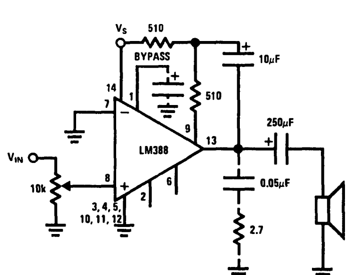


FIGURE 1. Load Returned to Ground

Amplifier with Gain = 200

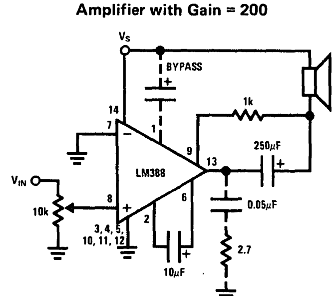


FIGURE 2. Load Returned to V_S

New Products

LM556 dual timer

general description

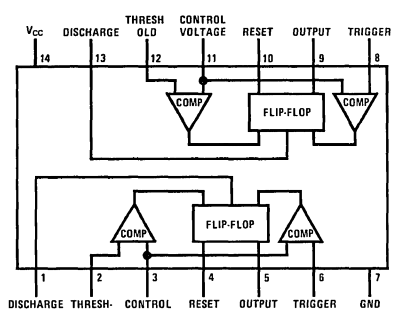
The LM556 dual monolithic timing circuit is a highly stable controller capable of producing accurate time delays or oscillation. The LM556 is a dual LM555. Timing is provided by an external resistor and capacitor for each timing function. The two timers operate independently of each other sharing only V_{CC} and ground. The circuits may be triggered and reset on falling waveforms. The output structures may sink or source 150 mA.

features

- Timing from microseconds to hours
- Replaces two LM555 timers
- Operates in both astable, monostable and time delay modes
- High output current
- Adjustable output current
- TTL compatible
- Temperature stability of 3% over entire temperature range

connection diagram

Dual-In-Line Package



TOP VIEW

New Products

LM3089 FM receiver IF system

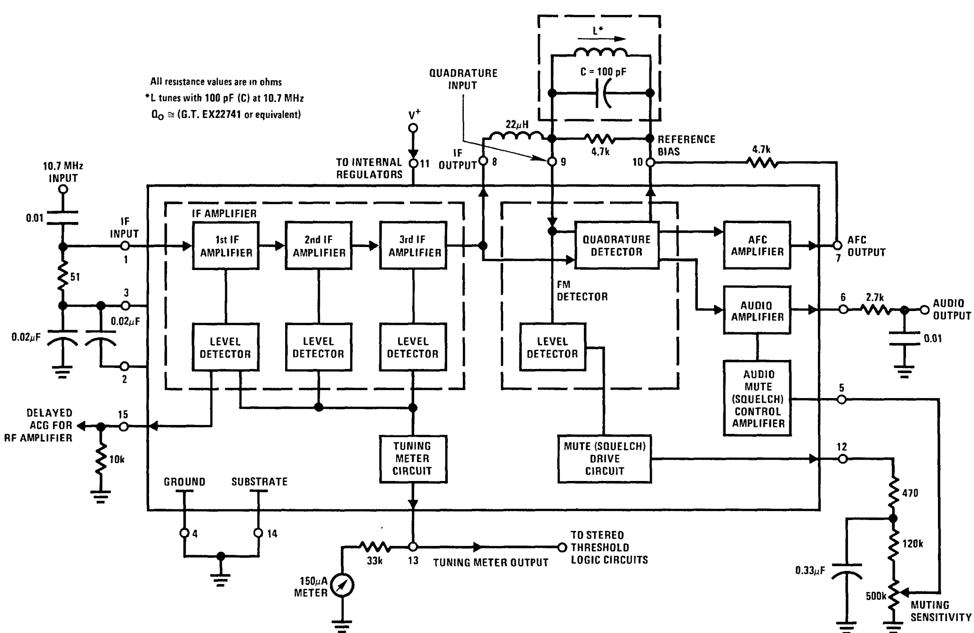
general description

The LM3089 has been designed to provide all the major functions required for modern FM IF designs of automotive, high-fidelity and communications receivers.

features

- Three stage IF amplifier/limiter provides 12μV (typ) −3 dB limiting sensitivity
- Balanced product detector and audio amplifier provide 400 mV (typ) of recovered audio and distortion as low as 0.1% with proper external coil designs.
- Four internal carrier level detectors provide delayed AGC signal to tuner, tuning meter drive current and interchannel mute control.
- AFC amplifier provides AFC current for tuner and/or center tuning meters.
- A direct replacement for CA3089E

block diagram



Definition of Terms

voltage regulators

Current-Limit Sense Voltage: The voltage across the current limit terminals required to cause the regulator to current-limit with a short circuited output. This voltage is used to determine the value of the external current-limit resistor when external booster transistors are used.

Dropout Voltage: The input-output voltage differential at which the circuit ceases to regulate against further reductions in input voltage.

Feedback Sense Voltage: The voltage, referred to ground, on the feedback terminal of the regulator while it is operating in regulation.

Input Voltage Range: The range of DC input voltages over which the regulator will operate within specifications.

Line Regulation: The change in output voltage for a change in the input voltage. The measurement is made under conditions of low dissipation or by using pulse techniques such that the average chip temperature is not significantly affected.

Load Regulation: The change in output voltage for a change in load current at constant chip temperature.

Long Term Stability: Output voltage stability under accelerated life-test conditions at 125°C with maximum rated voltages and power dissipation for 1000 hours.

Maximum Power Dissipation: The maximum total device dissipation for which the regulator will operate within specifications.

Output-Input Voltage Differential: The voltage difference between the unregulated input voltage and the regulated output voltage for which the regulator will operate within specifications.

Output Noise Voltage: The RMS AC voltage at the output with constant load and no input ripple, measured over a specified frequency range.

Output Voltage Range: The range of regulated output voltages over which the specifications apply.

Output Voltage Scale Factor: The output voltage obtained for a unit value of resistance between the adjustment terminal and ground.

Quiescent Current: That part of input current to the regulator that is not delivered to the load.

Ripple Rejection: The line regulation for AC input signals at or above a given frequency with a specified value of bypass capacitor on the reference bypass terminal.

Standby Current Drain: That part of the operating current of the regulator which does not contribute to the load current.

Temperature Stability: The percentage change in output voltage for a thermal variation from room temperature to either temperature extreme.

operational amplifiers

Bandwidth: That frequency at which the voltage gain is reduced to $1/\sqrt{2}$ times the low frequency value.

Common Mode Rejection Ratio: The ratio of the input voltage range to the peak-to-peak change in input offset voltage over this range.

Harmonic Distortion: That percentage of harmonic distortion being defined as one-hundred times the ratio of the root-mean-square (rms) sum of the harmonics to the fundamental. % harmonic distortion =

$$\frac{(V_2^2 + V_3^2 + V_4^2 + \ldots)^{1/2}\ (100\%)}{V_1}$$

where V_1 is the rms amplitude of the fundamental and $V_2, V_3, V_4, \ldots$ are the rms amplitudes of the individual harmonics.

Input Bias Current: The average of the two input currents.

Input Impedance: The ratio of input voltage to input current under the stated conditions for source resistance (R_S) and load resistance (R_L).

Input Offset Current: The difference in the currents into the two input terminals when the output is at zero.

Input Offset Voltage: That voltage which must be applied between the input terminals through two equal resistances to obtain zero output voltage.

Input Resistance: The ratio of the change in input voltage to the change in input current on either input with the other grounded.

Input Voltage Range: The range of voltages on the input terminals for which the amplifier operates within specifications.

operational amplifiers (con't)

Large-Signal Voltage Gain: The ratio of the output voltage swing to the change in input voltage required to drive the output from zero to this voltage.

Output Impedance: The ratio of output voltage to output current under the stated conditions for source resistance (R_S) and load resistance (R_L).

Output Resistance: The small signal resistance seen at the output with the output voltage near zero.

Output Voltage Swing: The peak output voltage swing, referred to zero, that can be obtained without clipping.

Offset Voltage Temperature Drift: The average drift rate of offset voltage for a thermal variation from room temperature to the indicated temperature extreme.

Power Supply Rejection: The ratio of the change in input offset voltage to the change in power supply voltages producing it.

Settling Time: The time between the initiation of the input step function and the time when the output voltage has settled to within a specified error band of the final output voltage.

Slew Rate: The internally-limited rate of change in output voltage with a large-amplitude step function applied to the input.

Supply Current: The current required from the power supply to operate the amplifier with no load and the output at zero.

Transient Response: The closed-loop step-function response of the amplifier under small-signal conditions.

Unity Gain Bandwidth: The frequency range from DC to the frequency where the amplifier open loop gain rolls off to one.

Voltage Gain: The ratio of output voltage to input voltage under the stated conditions for source resistance (R_S) and load resistance (R_L).

voltage comparators/buffers

Input Bias Current: The average of the two input currents.

Input Offset Current: The absolute value of the difference between the two input currents for which the output will be driven higher than or lower than specified voltages.

Input Offset Voltage: The absolute value of the voltage between the input terminals required to make the output voltage greater than or less than specified voltages.

Input Voltage Range: The range of voltage on the input terminals (common mode) over which the offset specifications apply.

Logic Threshold Voltage: The voltage at the output of the comparator at which the loading logic circuitry changes its digital state.

Negative Output Level: The negative DC output voltage with the comparator saturated by a differential input equal to or greater than a specified voltage.

Output Leakage Current: The current into the output terminal with the output voltage within a given range and the input drive equal to or greater than a given value.

Output Resistance: The resistance seen looking into the output terminal with the DC output level at the logic threshold voltage.

Output Sink Current: The maximum negative current that can be delivered by the comparator.

Positive Output Level: The high output voltage level with a given load and the input drive equal to or greater than a specified value.

Power Consumption: The power required to operate the comparator with no output load. The power will vary with signal level, but is specified as a maximum for the entire range of input signal conditions.

Response Time: The interval between the application of an input step function and the time when the output crosses the logic threshold voltage. The input step drives the comparator from some initial, saturated input voltage to an input level just barely in excess of that required to bring the output from saturation to the logic threshold voltage. This excess is referred to as the voltage overdrive.

Saturation Voltage: The low-output voltage level with the input drive equal to or greater than a specified value.

Strobe Current: The current out of the strobe terminal when it is at the zero logic level.

Strobed Output Level: The DC output voltage, independent of input conditions, with the voltage on the strobe terminal equal to or less than the specified low state.

Strobe ON Voltage: The maximum voltage on either strobe terminal required to force the output to the specified high state independent of the input voltage.

voltage comparators/buffers (con't)

Strobe OFF Voltage: The minimum voltage on the strobe terminal that will guarantee that it does not interfere with the operation of the comparator.

Strobe Release Time: The time required for the output to rise to the logic threshold voltage after the strobe terminal has been driven from zero to the one logic level.

Supply Current: The current required from the positive or negative supply to operate the comparator with no output load. The power will vary with input voltage, but is specified as a maximum for the entire range of input voltage conditions.

Voltage Gain: The ratio of the change in output voltage to the change in voltage between the input terminals producing it.

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functional blocks

(LM122/LM222/LM322, LM2905/LM3905 only)

Maximum Power Dissipation: The maximum total device dissipation for which the timer will operate within specifications.

Timing Ratio: The ratio of the firing voltage at the R/C pin to the reference voltage.

Comparator Input Current: The average current flowing from the R/C pin during the timing cycle.

Trigger Voltage: The voltage required at the trigger terminal to initiate a timing cycle, referenced to the ground pin.

Output Leakage Current: The maximum current flowing into the collector of the output transistor when the transistor is in the "off" state.

Reset Resistor: The equivalent resistor which may be used to calculate the discharge time of the timing capacitor. $t_{DISCHARGE} = (5)\ (C_t)\ (R_{RESET})$.

Collector Saturation Voltage: The collector to emitter voltage on the output transistor when it is in the "on" state with specified sink current flowing into the collector terminal.

Emitter Saturation Voltage: The voltage across the output transistor when the collector is tied to V^+, the transistor is in the "on" state, and the specified output current is flowing from the emitter terminal.

Capacitor Saturation Voltage: The offset voltage remaining on the timing capacitor after capacitor discharge current has dropped to zero.

Trigger Current: The current flowing into or out of the trigger terminal at the specified trigger voltage.

R_t: Timing resistor connected between V_{REF} and the R/C terminal.

C_t: Timing capacitor connected between the R/C terminal and the ground terminal.

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consumer circuits

AGC DC Output Shift: The shift of the quiescent IC output voltage of the AGC section for a given change in AGC central voltage.

AGC Figure of Merit (AGC Range): The widest possible range of input signal level required to make the output drop by a specified amount from the specified maximum output level.

AGC Input Current: The current required to bias the central voltage input of the AGC section.

AM Rejection Ratio: The ratio of the recovered audio output produced by a desired FM signal of specified level and duration to the recovered audio output produced by an unwanted AM signal of specified amplitude and modulating index.

Channel Separation: The level of output signal of an undriven amplifier with respect to the output level of an adjacent driven amplifier.

Detection Bandwidth: That frequency range about the free running frequency of the tone decoder/phase locked loop where a signal above a specified level will cause a detected signal condition at the output.

Detection Bandwidth Skew: The measure of how well the detection bandwidth is centered about the free running frequency. It is equal to the maximum detection bandwidth frequency plus the minimum detection bandwidth frequency minus twice the free running frequency.

Hold In Range: That range of frequencies about the free running frequency for which the phase locked loop will stay in lock if initially starting out in lock.

Input Bias Current: The average of the two input currents.

consumer circuits (con't)

Input Resistance: The ratio of the change in input voltage to the change in input current on either input with the other grounded.

Input Sensitivity: The minimum level of input signal at a specified frequency required to produce a specified signal-to-noise ratio at the recovered audio output.

Input Voltage Range: The range of voltages on the input terminals for which the amplifier operates within specifications.

Large-Signal Voltage Gain: The ratio of the output voltage swing to the change in input voltage required to drive the output from zero to this voltage.

Limiting Threshold: In FM the input signal level which causes the recovered audio output level to drop 3 dB from the output level with a specified large signal input.

Lock In Range: That range of frequencies about the free running frequency for which the phase locked loop will come into lock if initially starting out of lock.

Maximum Sweep Rate: The maximum rate that the VCO may be made to vary its oscillating frequency over its Sweep Range.

Output Resistance: The ratio of the change in output voltage to the change in output current with the output around zero.

Output Voltage Swing: The peak output voltage swing, referred to zero, that can be obtained without clipping.

Phase Detector Sensitivity: The change in the output voltage of the phase detector for a given change in phase between the two input signals to the phase detector.

Power Bandwidth: That frequency at which the voltage gain reduces to $1/\sqrt{2}$ with respect to the flat band voltage gain specified for a given load and output power.

Power Supply Rejection: The ratio of the change in input offset voltage to the change in power supply voltages producing it.

Slew Rate: The internally limited rate of change in output voltage with a large amplitude step function applied to the input.

Supply Current: The current required from the power supply to operate the amplifier with no load and the output at zero.

Sweep Range: That ratio of maximum oscillating frequency to minimum operating frequency produced by varying the central voltage of the VCO from its maximum value to its minimum value with fixed values of timing resistance and capacitance.

VCO Sensitivity: The change in operating frequency for a given change in VCO central voltage.

analog switches

Driver Leakage Current: The sum of the currents into the source and drain switch terminals, with both held at the same specified voltage.

Logic "1" Input Voltage: The voltage level which is guaranteed to be interpreted by the device as a logical "true" signal.

Logic "0" Input Voltage: The voltage level which is guaranteed to be interpreted by the device as a logical "false" signal.

Logic Input Slew Rate: The voltage difference between the logic "1" and logic "0" states divided by the transistion time.

Switch Leakage Current: The current seen when a specified voltage is applied between drain and source of a channel that is logically turned off.

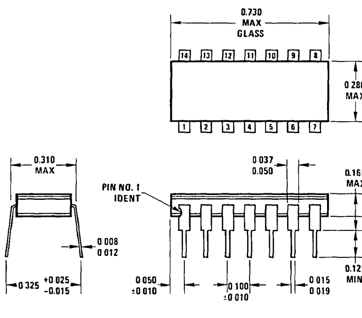
Switch On Resistance: The equivalent resistance from source to drain, tested by forcing a specified current and measuring the resultant voltage drop.

Switch Turn-Off Time: The interval between the time that the logic input passes through the threshold voltage and the time that the output goes to a specified voltage level in the test circuit.

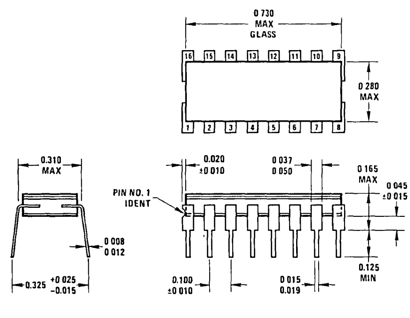
Switch Turn-On Time: The interval between the time that the logic input passes through the threshold voltage and the time that the output goes to 90% of its final value in the specified test circuit.

Physical Dimensions

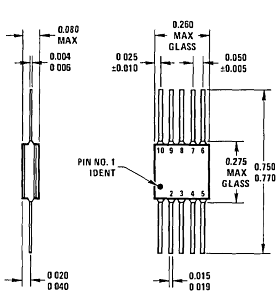
(All dimensions are in inches.)



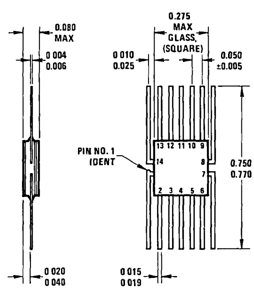
Package 1
14 Lead Cavity DIP (D)



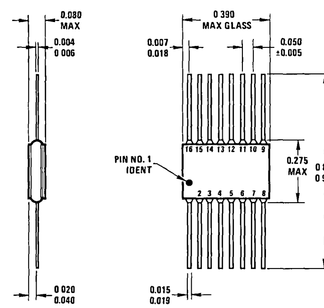
Package 2
16 Lead Cavity DIP (D)



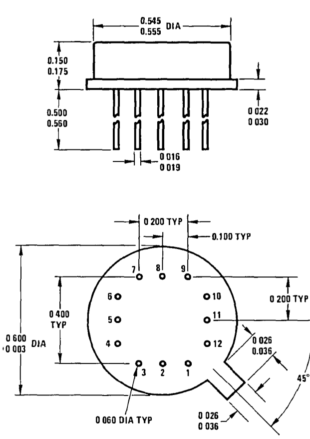
Package 3
10 Lead Flat Package (F)



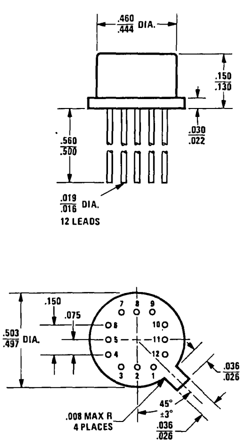
Package 4
14 Lead Flat Package (F)



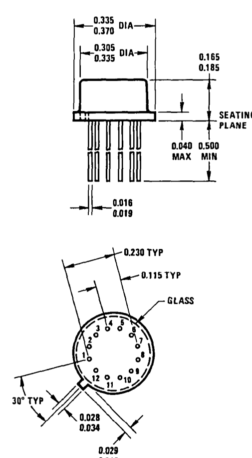
Package 5
16 Lead Flat Package (F)



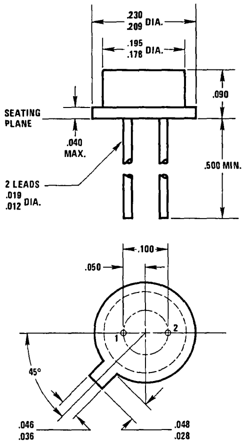
Package 6
12 Lead TO-8 Metal Can (G)



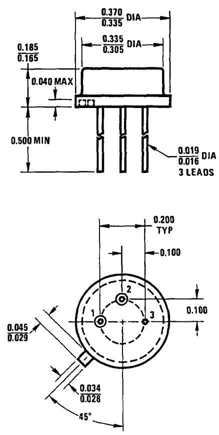
Package 6A
12 Lead TO-8 Metal Can (G)
(AH2114/AH2114C only)



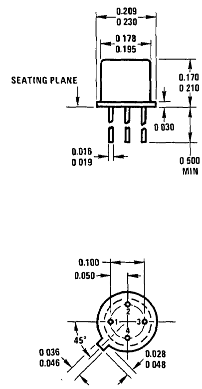
Package 7
12 Lead TO-8 Metal Can (H)



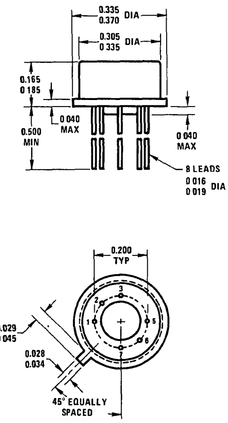
Package 8
2 Lead TO-46 Metal Can (H)



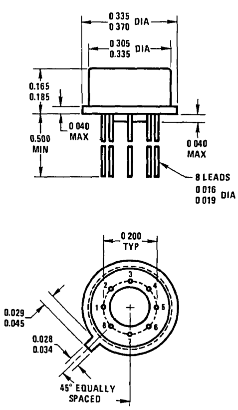
Package 9
3 Lead TO-39 Metal Can (H)



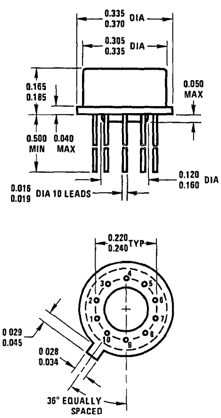
Package 9A
4 Lead TO-72 Metal Can (H)



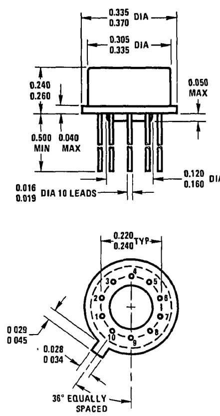
Package 10
6 Lead TO-5 Metal Can (H)



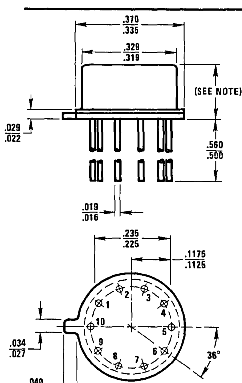
Package 11
8 Lead TO-5 Metal Can (H)



Package 12
10 Lead TO-5 Metal Can (H)
(Low Profile)

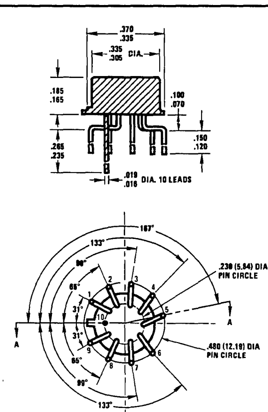


Package 13
10 Lead TO-5 Metal Can (H)
(High Profile)



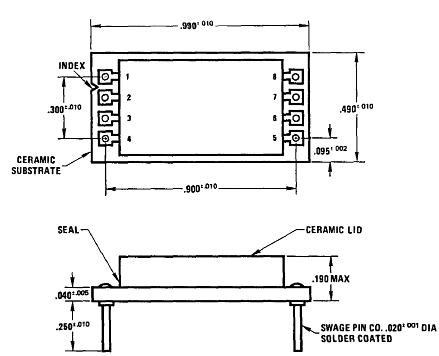
Dimension is 0.155/0.185 for all products except as follows: 0.260/0.290 for LH0001H/LH0001CH, LH0003/LH0003CH, and LH0004/LH0004CH; 0.240/0.260 for LH0005AH/LH0005H/LH0005CH; 0.180/0.210 for MH0007H/MH0007CH.

Package 14
10 Lead TO-5 Metal Can (H)

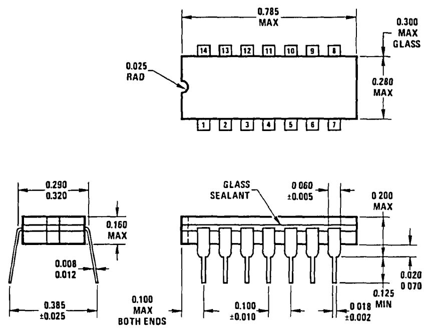


Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

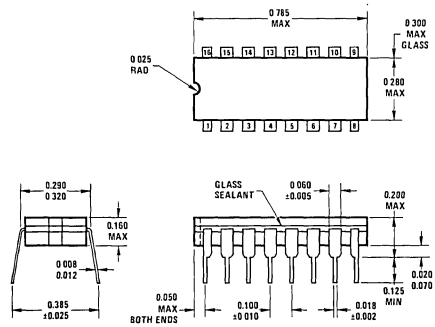
Package 14A
10 Lead Metal Can (H-03)



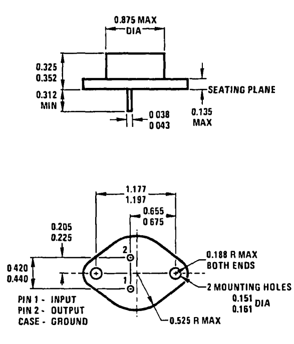
Package 15
8 Lead Cavity Package (J)



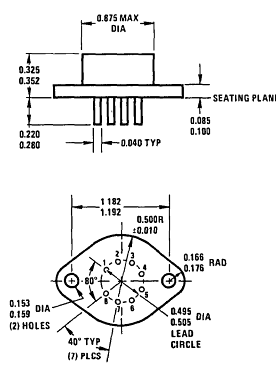
Package 16
14 Lead Cavity DIP (J)



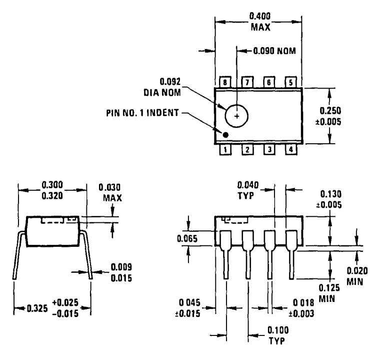
Package 17
16 Lead Cavity DIP (J)



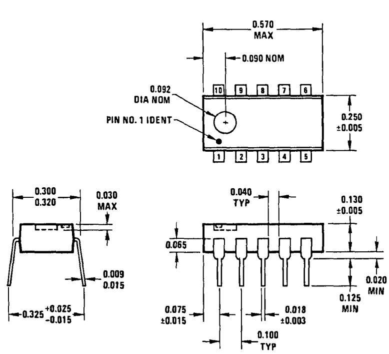
Package 18
2 Lead TO-3 Metal Can (K)



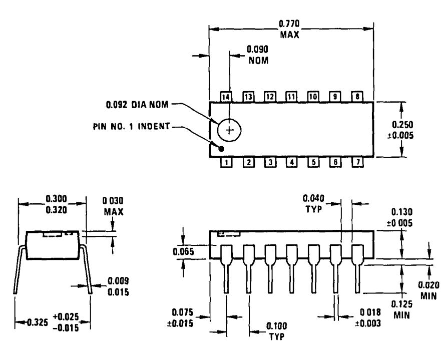
Package 19
8 Lead TO-3 Metal Can (K)



Package 20
8 Lead Molded Mini DIP (N)

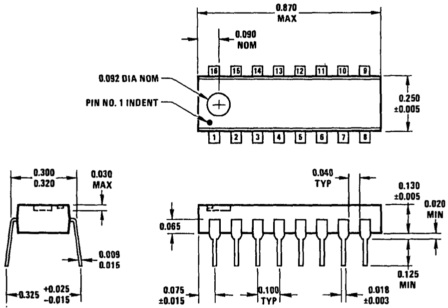


Package 21
10 Lead Molded DIP (N)

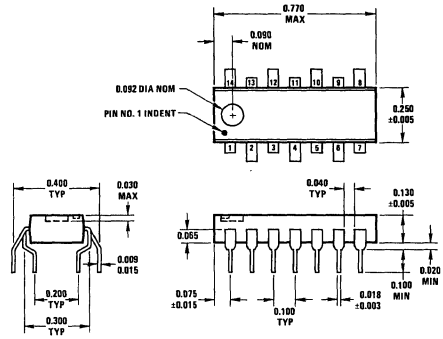


Package 22
14 Lead Molded DIP (N)

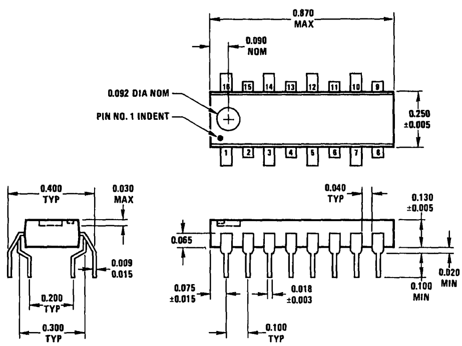
9



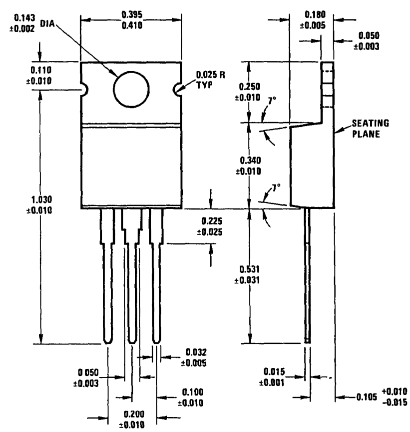
Package 23
16 Lead Molded DIP (N)



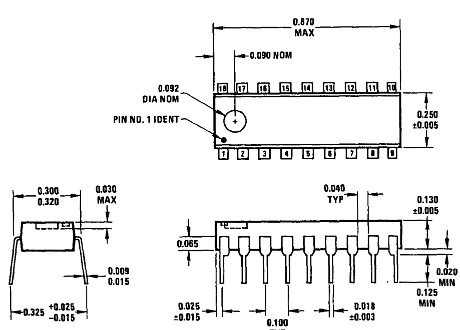
Package 24
14 Lead Molded DIP (N-01)
(Staggered Leads)



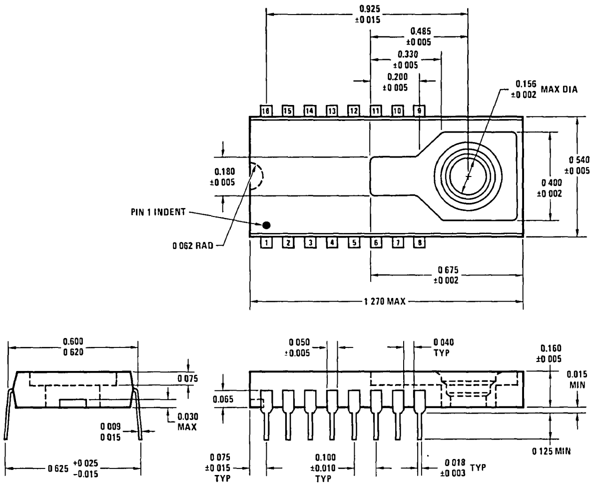
Package 25
16 Lead Molded DIP (N-01)
(Staggered Leads)



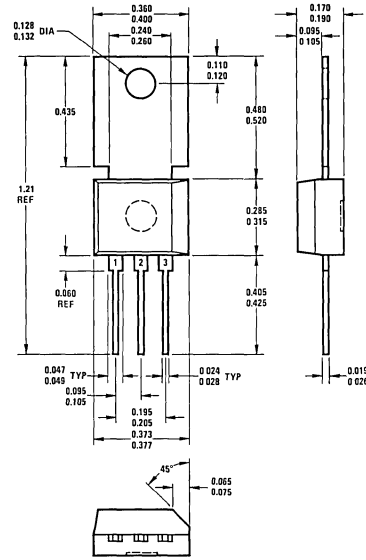
Package 26
3 Lead TO-220 Power Package (T)



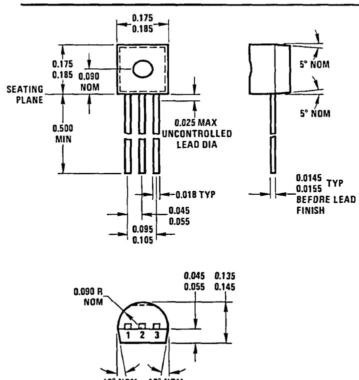
Package 29
18 Lead Molded DIP (N)



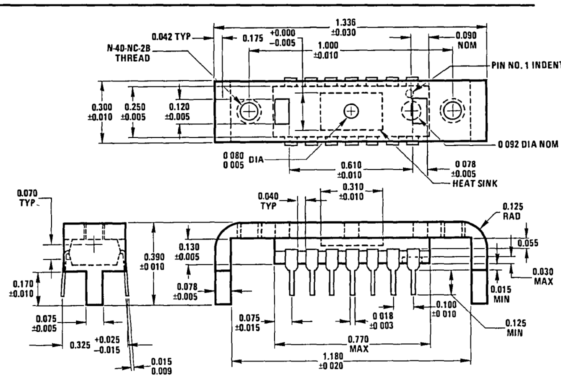
Package 36
16 Lead Wide Track Power Package (M)



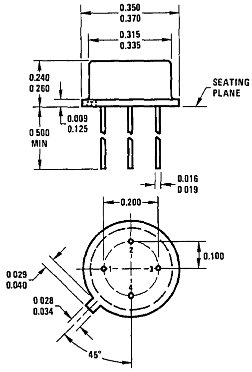
Package 37
3 Lead TO-202 (P)



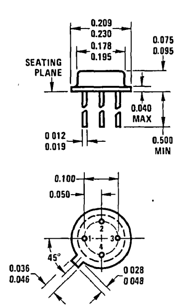
Package 38
3 Lead TO-92 Plastic Package (Z)



Package 39
14 Lead "SGS" Type Power DIP (S)



TX1
4 Lead TO-5 Metal Can Package



TX2
4 Lead TO-46 Metal Can Package

INCHES TO MILLIMETERS CONVERSION TABLE

INCHES	MM	INCHES	MM	INCHES	MM
0.001	0.0254	0.010	0.254	0.100	2.54
0.002	0.0508	0.020	0.508	0.200	5.08
0.003	0.0762	0.030	0.762	0.300	7.62
0.004	0.1016	0.040	1.016	0.400	10.16
0.005	0.1270	0.050	1.270	0.500	12.70
0.006	0.1524	0.060	1.524	0.600	15.24
0.007	0.1778	0.070	1.778	0.700	17.78
0.008	0.2032	0.080	2.032	0.800	20.32
0.009	0.2286	0.090	2.286	0.900	22.86

MIL-STD-883/MIL-M-38510

MIL-STD-883

Mil-Standard-883 is a Test Methods and Procedures Document for Microelectronic Circuits. It was derived from MIL-S-19500, MIL-STD-750, and MIL-STD-202C for transistors and diodes at about the time that National Semiconductor Corporation was entering the military microelectronics market. As a result, our standard quality control operations are written around MIL-STD-883. The bonding control, visual inspections, and post seal screening requirements set forth by 883 (as well as added control procedures beyond the requirements of 883) have been part of National's quality control procedures almost from the start. Our Quality Assurance Procedures Manual is available upon request.

We offer a complete line of linear/883 (Class B) products as standard, off-the-shelf items. Special Linear/883 data sheets have been prepared to reflect this capability. They show process flow, electrical parameters, end of test criteria, and test circuits. We save you the problem of specifying test and inspection procedures, and offer significant cost savings by having an off-the-shelf, "to the letter" 883 program. In addition, we will test any of our integrated circuits to any class of MIL-STD-883.

The detailed information concerning MIL-STD-883 screening is contained in National's specification NSC10002.

MIL-M-38510

MIL-M-38510 specifies the general requirements for supplying microcircuits. These are; product assurance, which includes screening and quality conformance inspection; design and construction; marking; and workmanship. The screening and quality conformance inspection are conducted in accordance with MIL-STD-883.

Screening

All microcircuits delivered in accordance with MIL-M-38510 must have been subjected to, and passed all the screening tests detailed in Method 5004 of MIL-STD-883 for the type of microcircuit and product assurance level.

The device electrical and package requirements of MIL-M-38510 are detailed by a device specification referred to as a slash sheet. Each slash sheet defines the microcircuit electrical performance and mechanical requirements. Each device listed on a slash sheet is referred to as a slash number and the group of the microcircuits contained on a slash sheet is defined as a family of devices. The device may be Class B or C as defined by MIL-STD-883, Method 5004 and 5005. Three lead finishes are allowed by the slash sheet, pot solder dip, bright tin plate, and gold plate.

The MIL-M-38510 specs for standard linear devices require 100% DC testing at 25°C, −55°C and +125°C. AC testing is performed at +25°C. The electrical parameters specified are tighter than the normal data sheet guaranteed limits. Additionally, MIL-M-38510 requires device traceability, extensive documentation and closely matched maintenance.

Quality Conformance

Quality conformance inspection is conducted in accordance with the applicable requirements of Group A, (electrical test), Group B and C, (environmental test) of Method 5005, MIL-STD-883. These tests are conducted on a sample basis with Group A performed on each sublot, Group B on each lot, and Group C as specified (usually every three months).

To supply devices to MIL-M-38510, the IC manufacturer must quality the devices he plans to supply to the detail specifications. Qualification consists of notifying the qualifying activity of one's intent to qualify to MIL-M-38510. After passing comprehensive audits of facilities and documentation systems, the IC manufacturer will subject the device to and demonstrate that they satisfy all of the Group A, B, and C requirements of Method 5005 of MIL-STD-883 for the specified classes and types of IC. The qualification tests shall be monitored by the qualifying agency. Finally the IC manufacturer shall prepare and submit qualification test data to the qualifying agency. Groups A, B, and C inspections then shall be performed at intervals no greater than three months.

The purpose of qualification testing is to assure that the device and lot quality conform to certain standard limits. In effect, lot qualification tests tend to ensure that once a particular device type is demonstrated to be acceptable, it's production, including materials, processing, and testing will continue to be acceptable. These limits are specified in MIL-STD-883 in terms of LTPD's (Lot Tolerance Percent Defective) for the various qualification test sub-groups. Qualification testing is performed on a sample of devices which are chosen at random from a lot of devices that has satisfactorily completed the screening of Method 5004 must be performed on each device, i.e. on a 100% basis as opposed to qualification testing (Method 5005) which occurs on a random sample basis.

In summary, the entire purpose of MIL-M-38510 and MIL-STD-883 is to provide the military, through its contractors with standard devices.

We at National Semiconductor have supplied and are supplying devices to the MIL-M-38510 specifications. To order a MIL-M-38510 microcircuit, specify the following:

For example; to specify an LM741 in a DIP processed to the requirements of MIL-M-38510, Class B, with gold plated leads, specify M-38510/10101BCC.

MM38510/	XXX	XX	X	X	X
Specifies the General Requirements of MIL-M-38510	Slash Sheet No.	Device Type	Device Class	Case Outline	Lead Finish

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2900 Semiconductor Drive
Santa Clara, California 95051
(408) 732-5000
TWX: 910-339-9240

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